Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 136299
UNCLASSIFIED	

TITLE

DATA FUSION AND CORRELATION TECHNIQUES TESTBED DEVELOPMENT MAP STUDY

AN: 94-00147

System Number:

Patron Number:

Requester:

Notes:

DSIS Use only:

Deliver to: RL

DATA FUSION AND CORRELATION TECHNIQUES

TESTBED DEVELOPMENT

MAP STUDY

Contract No. W7714-9-9367/01-QD

31 January 1991

Prepared for:

Defence Research Establishment Ottawa
Electronic Warfare Division
Ottawa, Ontario

Prepared by:

Software Kinetics Ltd.
65 Iber Road,
Stittsville, Ontario Canada
K2S 1E7

Software Kinetics Document No. 1600-73-019 *Version* 01

Document Approval Sheet

Document No.: 1600-73-019 *Version* 01

Document Name: Data Fusion and Correlation Techniques Testbed Development Map Study

Approvals	**Signature**	**Date**
Prepared By:	I. Graham	15 Feb 91
Project Engineer:	J. Perrin	15 Feb 91
Project Manager:	R. T. Moore	19 Feb 1991

Document Revision History

Revision	**Description of Changes**	**Origin Date**
01	New Document Issued	31 January 1991

Table Of Contents

1. INTRODUCTION

1.1 Purpose

The purpose of this study is to evaluate the map display requirements for the Analyst Workstation of the Data Fusion And Correlation Techniques Testbed (DFACTT). The DFACTT system is currently being developed in Embedded Smalltalk, which is based on Smalltalk V/286. The study begins with a description of the mapping requirements for DFACTT, followed by a general comparison of the map types under consideration, examining the differences in availability, display performance, and system requirements. Finally, recommendations are presented which address the mapping requirements both for the DFACTT prototype and for longer term development.

1.2 Background

The Data Fusion And Correlation Techniques Testbed was conceived to investigate tools and algorithms for the correlation and analysis of intelligence gathered during army field operations. At the core of the current system of intelligence gathering is the Analyst, who must organize large quantities of data to develop an understanding of the enemy situation. The Analyst receives information from many sources: some of this information is acquired by reconnaissance, but most is acquired by the interception of enemy radio transmissions. These transmissions may be intercepted either by radio operators listening to the vocal content, or by DF sensors gathering directional information; the recorded data will include signal characteristics along with either text data or transmitter location data.

Knowledge of the enemy's location is essential to the success of field operations. Consequently, it is necessary for all location data to be organized and presented in a form that provides the Analyst with *maximum* comprehension of the enemy situation. To achieve this, maps with overlaid location data are the single most valuable tool. At present, paper maps are used: enemy units' locations are indicated either with pins or with markings on transparent overlay sheets. DFACTT will extend the benefits of overlaid maps by providing a full graphical user-interface, including a map display which allows the Analyst to access information about enemy units simply by clicking on the overlaid icons.

The DFACTT platform is a multi-processor VME-based system: the platform includes a TMS34010 based graphics processor card capable of displaying 256 colours at a resolution of 1280 by 1024 pixels. The graphics card provides the fast display performance required to support DFACTT's window-based graphical user-interface.

2. DFACTT MAP REQUIREMENTS

The DFACTT Analyst Workstation provides a graphic display of a Universal Transverse Mercator (UTM) grid along with icons showing the known or suspected locations of enemy elements. This display is updated as new information is entered into the DFACTT Tactical Database. The displayed information consists of emitter locations provided by external sensors, and of relationships between the emitters resulting from data correlation activities. In the near term, analysts will also continue to utilize paper maps as backup in the event of system failure; therefore, it is essential that the Analyst be able to relate with ease the displayed graphical data to the paper maps.

One of the main problems with displaying maps on a video screen is the narrow view provided to the Analyst. A paper map sheet is usually much larger than the display area of a typical computer monitor; when the area covered by map is displayed at the same scale it subsequently shows a smaller area. To circumvent this problem it must be possible for the analyst to quickly zoom in and out between different map scales to view the area of interest.

These general issues lead to the following essential functional requirements:

1. The Analyst Workstation graphic display must include a map background which has graphic content similar to that of the paper maps in use. The level of detail in the displayed map must be equivalent to that provided by 1:100,000 (preferably 1:50,000) scale maps.

2. The smaller displayed map scales must closely approximate the paper map scales (1:25,000 and 1:50,000). Larger scale displays must be provided for broader views.

3. The overlayed icons must stand out clearly from the map background.

4. Sources for maps must be readily accessible.

5. Display of the map information must not have a significant impact on system performance.

The first two items do not mean that the displayed map must look identical to the paper map. They do, however, require that major features be displayed and that they be easily recognisable.

3. MAP TYPE COMPARISON

3.1 Types of Maps

There are three basic types of map data sources which have been considered for use with the DFACTT system - vector, raster, and video maps. The characteristics of each type of map data are described in the following subsections.

3.1.1 Vector Maps

A vector map is a map which has been digitized as a collection of map features in the form of points, vectors, and polygons. Each feature, in addition to this spatial information, may contain additional attributes which describe its full characteristics. A point feature may represent a feature such as a building, a 70m radio antenna, or a channel marker. Vectors represent features such as roads, rivers, or political boundaries. Polygons represent features such as lakes, cities, or regions of radioactivity.

The most significant aspect of vector maps is that they can provide more than just a single visual representation of the world. A vector map is a model of the real world which may be displayed in many different ways to suit the requirements of the user. A map display may show only features of the map which have certain characteristics; additionally, the visual representation of those characteristics may be modified. These capabilities yield the added advantage that a single vector map may contain much more information than can be displayed at one time without undue clutter.

Vector maps are usually constructed using the labour-intensive process of manually entering features of a paper map using a device such as a graphics tablet. Automated vectorization of scanned raster maps is becoming more common as image processing technology improves, but still requires manual editing to check for and correct inconsistencies.

3.1.2 Raster Maps

A raster map is a map which has been digitized as a matrix of equal-sized rectangular cells each of which has an associated intensity or colour. Such a map usually consists of a very large matrix, or *image*, of very small cells, known as *pixels*, and is constructed by scanning a paper map at resolutions as high as 1000 dots per inch or more. Raster maps can also be constructed from aerial and satellite photographs or images using image processing techniques.

Raster maps are used almost exclusively for their visual effect, and do not generally provide a useful model of the real world. They can provide highly detailed map displays which look very much like the paper maps from which they originated. However, each pixel of a raster map can contain very little actual information about the underlying real world location, especially if the map includes symbolic and textual information and grid lines. There are two other limitations of raster maps: a single map can contain no more data than can be viewed at once without unduly cluttering the display, and the choice of display scale is limited in practical terms by the scanned map scale and scan resolution. Rescaling is possible but is processing-intensive and not convenient during operation.

3.1.3 Video Maps

A video map is a recording of a paper map on videodisc; this recording can be played back as a raster image in the form of a video signal. Unlike vector and raster maps, which are recorded as digital data, video map data is recorded as an analog signal. To read this analog data into a computer, the image must be captured using a frame grabber. After a digital raster image has been captured it can be treated in the same way as a raster map and is subject to the same limitations.

3.2 Map Availability

3.2.1 Vector Map Availability

Substantial labour is required to produce a digital vector map; thus, vector maps of a small enough scale for use in DFACTT are not readily available. Even when the maps are available they are not all stored in the same standard format, requiring that significant effort be spent on conversion.

The Directorate of Geographic Operations at NDHQ is currently participating in an international effort to develop a single standard Vector Product Format (VPF), and to produce the Digital Chart of the World (DCW). The DCW, which is scheduled to be completed by February 1992, will be a set of seven CD-ROMs containing VPF vector maps of the entire world in detail equivalent to 1:1,000,000 scale paper maps. Though this will not include enough detail to be very useful for DFACTT, it lays the groundwork for the VPF standard, and maps of greater detail should gradually become available.

3.2.2 Raster Map Availability

The US Defense Mapping Agency (DMA) is currently in the process of building a library of raster maps on CD-ROM. By 1993 it is expected to have scanned at least 10,000 maps at a scale of 1:50,000. These maps are being scanned at a resolution of 254 dots per inch, with 24 bits per pixel (8 red, 8 green, 8 blue).

Raster maps create a special problem in that display performance is only reasonable if the map is stored in the resolution to be displayed. Image processing algorithms could be implemented to convert the DMA maps to resolutions appropriate for DFACTT.

An alternative is to construct the raster maps as needed using a scanner. The scanning process is simple, and requires little or no follow-up processing if done at the required resolution. This technique makes raster maps almost as readily available as paper maps and has already been demonstrated successfully for the DFACTT prototype.

3.2.3 Video Map Availability

The US Defense Mapping Agency currently has available over 60 videodiscs of maps at various scales, including 1:50,000 scale maps for some areas of major interest. Production of videodiscs for current unavailable areas is also possible using an imaging system such as that available from Interactive Television Company (ITC).

3.3 Map Display Performance and Limitations

3.3.1 Vector Map Performance

Vector maps have two major advantages over the other map types under consideration. First there is the potential to provide a great deal of flexibility in the display content and presentation for a given map--choice of scale, graphic representation, and inclusion/exclusion of particular types of features is inherent in the display software rather than being built into the map itself. Second, because of the logical breakdown of the map into feature objects, it is possible to use this information for analysis purposes as well as for display.

The biggest disadvantage to vector maps is their limited availability, which is due to the long production time required. Additionally, speed of display can be reasonably quick if there is not too much detail included, however, extensive display processing (eg. filled regions, double line roads, complicated feature selection) and/or large amounts of detail can result in extremely slow display times.

Memory and storage requirements vary greatly depending on the level of detail and breadth of information contained in the map. However, storage requirements outside cities can be orders of magnitude less than for raster maps, and are still significantly less within cities.

3.3.2 Raster Map Performance

Raster maps have two major advantages--availability and display speed. Using a large format scanner and relatively simple software a raster map with a high level of detail can be constructed with minimum effort from any available paper map. Access time from a database is only a few seconds (depending on the speed of the storage device), and subsequent display time is a mere fraction of a second if displayed directly at the scanned resolution.

The greatest disadvantages are very slow display update in scales other than the scanned scale, and very high storage demands. The scaling problem can be dealt with by making separate scans for each scale to be used, further increasing storage requirements. The storage and memory problems are more difficult to deal with; a standard 26" by 36" map sheet scanned at only 100 dpi (typical display resolution) and 256 colours requires almost 7 megabytes of storage. This can be reduced to less than 1 megabyte--at the cost of a significant amount of information--by scanning in two-tone monochrome (The resulting scanned image is called a binary image).

Another disadvantage to raster maps is that, unlike vector maps, the map data is of little use for analysis purposes; the map can be used primarily for visual presentation.

3.3.3 Video Map Performance

The main advantages to video map technology are that it is proven and that basic map retrieval is fast (typically 0.3 seconds). However, DFACTT requires the ability to overlay tactical information and has strict requirements as to the displayed scales. This means that the retrieved map images must be digitized as raster images with a frame grabber--in real time. At this point the issues are identical to those for raster maps, with the additional problem that frame grabbing resolution cannot be adjusted as precisely as scanning resolution. Without being able to grab the images in the desired resolution, display performance is seriously degraded because of the required rescaling.

3.4 Hardware and Software Requirements

3.4.1 Vector Map Requirements

Production of vector maps is a large enough task to place it beyond the scope of the DFACTT project. The hardware and software requirements identified here will therefore be geared towards the display of existing maps rather than the production of new maps.

To this end, there are no special hardware requirements. However, there is a need for display software which is accessible within the Smalltalk environment. Such display software could be developed fairly inexpensively if no flexibility were required and a simple vector display was acceptable. However, the advantages of vector maps lie in their potential display flexibility which can only be realized with much more complex display systems.

The Digital Chart of the World project includes the development of a C language prototype display tool--for which the source code is available--for displaying VPF maps. Unfortunately, this software cannot be effectively integrated with the DFACTT development environment because of the display software's extensive use of dynamic memory allocation. Though Smalltalk can make calls to C functions, all memory used by the C functions must be pre-allocated. Consequently, extensive software development would be necessary to make full use of vector maps.

3.4.2 Raster Map Requirements

The use of raster maps would require display software, a scanner, and scanning software. The display software is very simple to implement if the maps are scanned in the resolution in which they will be displayed. The complexity of the scanning software is dependent upon the capabilities of the scanning hardware; however, if a scanner is selected which allows continuously variable choice of resolution, the scanning software can also be very simple.

The use of raster map technology for the DFACTT project has already been demonstrated using prototyping techniques. The software has not been implemented fully; however, maps have been scanned and displayed as background for the Analyst Workstation graphic display. It was found that a single bit per pixel (monochrome, with no grey levels) provides an adequate display to allow the user to relate the displayed information to the corresponding map with ease. The use of colour scans requires that the colours be modified somewhat so that the displayed map does not distract from the overlayed icons, which must be clearly visible to the Analyst.

Storage requirements for raster maps are a significant concern. Because of the high storage demands for raster maps (almost 1 megabyte per map sheet assuming binary map-images scanned at 100 dpi), it is not feasible for an operable DFACTT system to have ready access to 1:25,000 maps of the whole world. A 300 megabyte hard disk would provide sufficient space for only about 340 1:25,000 scale maps covering an area of 90,000 square kilometres. The maps would need to be selected in advance of a given exercise.

Memory requirements are less of a concern than storage requirements. Assuming 1 megabyte map sheets it is desirable to have at least 1 megabyte of RAM free to use for mapping. If the user will be constantly changing scales and scrolling over large areas, performance could be improved by providing more memory, with the result that less disk access would be required.

3.4.3 Video Map Requirements

Using video map technology for DFACTT would require a videodisc player, a frame grabber, and display software which is integrated with the Smalltalk environment. The software must be capable of controlling both the videodisc player and the frame grabber, and must also handle rescaling and tiling of the grabbed images. These are fairly demanding requirements and would involve a relatively large development effort.

4. RECOMMENDATIONS

4.1 DFACTT Prototype Recommendations

For the DFACTT prototype, the most effective solution would be to use binary (two-tone monochrome) raster maps. The technology is inexpensive, the development effort is minimal, and the requirements described in Section 2 can be largely satisfied.

With raster maps, provision of multiple scales and corresponding levels of detail is possible by making the appropriate scans. For each of the required scales, separate scans must be made of paper maps with the desired levels of detail. Because of the relatively low resolution of video screens, it was found that the best results were obtained by scanning a paper map of twice the scale to be displayed, and doing so at double the resolution. For example, if a map is to be displayed at 1:25,000 on a screen with approximately 100 dpi, then a 1:50,000 scale paper map should be scanned at 200 dpi. Typical computer displays achieve a display resolution of approximately 100 dots per inch, and since exact scale is not required, a scan resolution of 200 dpi is appropriate.

Binary scans are recommended over grey-level or colour scans mainly to reduce storage requirements. Using only one bit per pixel instead of 4 or 8 bits means that there is less demand for memory. In addition, the maps can be scanned using a monochrome scanner instead of a more expensive colour scanner. As well as reducing cost, the smaller image size will significantly improve retrieval and display performance. In tests conducted to date, it has been found that the choice of one bit per pixel results in the loss of a significant amount of visual information; however, the remaining information still provides a good enough to display to allow the user to relate the displayed map to a paper map with ease.

To ensure that overlayed icons stand out, it was found that they must be displayed more brightly than the underlying map. Instead of using straight white on black for the map, using a 2/3 intensity grey-level proved to be ideal. This issue would be especially important if colour maps were displayed.

Scanned maps can be made available by purchasing a scanner. At present the DFACTT project team has access to an imprecise small-format scanner which is not well suited to the task of scanning maps. A large format scanner such as the FSS3012 available from Planon Systems Inc. combined with their CADImage scanner support software would be well suited to the task. The Planon scanner and software cost approximately $15,000. A less elaborate scanning system based on an Hewlett Packard desktop scanner can be purchased for approximately $2,200 complete with PC interface and image manipulation software (Maps would need to be scanned in 8.5" x 14" portions).

4.2 Long-term Recommendations

A fieldable DFACTT system may eventually require a map display sub-system which is less dependent on the use of paper maps. For the earlier versions of DFACTT it has been assumed that the map display need only provide enough visual information to allow the analyst to relate the display to a corresponding paper map. However, the benefits that can be obtained by extending the quantity and form of visual information may prove invaluable. The following sections provide some long-term recommendations to extend the prototype map display.

4.2.1 Colour Raster Map Experimentation

In conducting this study, very little research was carried out in the area of colour raster maps. Though colour scans can be performed with as high as 24 bits per pixel (8 red, 8 green, and 8 blue, yielding over 16 million possible colours), the paper maps themselves usually use only a small number of discrete colours. It should therefore be possible to process scanned colour images to reduce them to smaller images consisting of only 4 bits per pixel. One consideration, however, is that the required colour palette should remain consistent between maps. The reason for this is that adjacent maps can be displayed simultaneously. If the paper map sources are of varying styles this restriction to a single colour palette definition may not be adequate. It is recommended that additional research and experimentation be performed to investigate applicable image processing techniques, with the aim of reducing memory and storage requirements, as well as access and display times for colour raster maps.

4.2.2 Map Database Management Tool

It would be beneficial for the DFACTT system to be able to draw on numerous sources, several of which were pointed out in section 3.2, for existing maps. To this end, it is recommended that Map Database Manager software be developed. The software must provide database management functionality, including the capability to convert maps from various media into the form required for the DFACTT map database.

Capturing DMA raster maps requires a CD-ROM reader and software. The software must include an interface to the CD-ROM reader, as well as image processing algorithms which convert the 24-bit-per-pixel 254-dots-per-inch images into images more appropriate for the DFACTT database.

Capturing DMA (and other) videodisc maps requires a videodisc player, a frame grabber, and software. The software must include interfaces to the videodisc and frame grabber, as well as image processing capability to rescale the grabbed images.

Because the prototype map database will support raster maps only, an early version of the Map Database software need not provide for the conversion of existing vector maps. However, the ability to read and convert existing video maps and raster maps, available from the U.S. Defense Mapping Agency, should be considered.

4.2.3 VPF Support

As availability of VPF vector maps improves, it will become more and more worthwhile to provide vector map support for DFACTT. The VPF standard supports raster data as well as vector data, so a DFACTT implementation of VPF could provide the capability to display both types of maps. The DFACTT system could then take adantage of both the ready availability of raster maps (by scanning paper maps), and the display flexibility of vector maps.

The value of providing VPF support is, however, highly dependent on its success as a standard. Given that significant development effort would be required to achieve a reasonable level of performance, it would be best to leave this development until more VPF maps become available.

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)

SOFTWARE KINETICS LIMITED
65 IBER ROAD
STITTSVILLE, ONTARIO K2S 1E7

2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)

UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

DATA FUSION AND CORRELATION TECHNIQUES TESTBED DEVELOPMENT MAP STUDY (U)

4. AUTHORS (Last name, first name, middle initial)

GRAHAM, IAN G.

5. DATE OF PUBLICATION (month and year of publication of document)

JANUARY 1991

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

16

6b. NO. OF REFS (total cited in document)

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

CONTRACTOR'S REPORT (STUDY)

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

NATIONAL DEFENCE
DEFENCE RESEARCH ESTABLISHMENT OTTAWA
SHIRLEY BAY, OTTAWA, ONTARIO K1A 0K2 CANADA

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)

041LK11

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

W7714-9-9367/01-QD

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

1600-73-019 VERSION 01

10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availabilty (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

UNANNOUNCED

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

The purpose of this study is to evaluate the map display requirements for the Analyst Workstation of the Data Fusion And Correlation Techniques Testbed (DFACTT). The DFACTT system is currently being developed in Embedded Smalltalk, which is based on Smalltalk V/286. The study begins with a description of the mapping requirements for DFACTT, followed by a general comparison of the map types under consideration, examining the differences in availability, display performance, and system requirements. Finally, recommendations are presented which address the mapping requirements both for the DFACTT prototype and for longer term development.

The Data Fusion And Correlation Techniques Testbed was conceived to investigate tools and algorithms for the correlation and analysis of intelligence gathered during army field operations. At the core of the current system of intelligence gathering is the Analyst, who must organize large quantities of data to develop an understanding of the enemy situation. The Analyst receives information from many sources: some of this information is acquired by reconnaissance, but most is acquired by the interception of enemy radio transmissions. These transmissions may be intercepted either by radio operators listening to the vocal content, or by DF sensors gathering directional information; the recorded data will include signal characteristics along with either text data or transmitter location data.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

DIGITAL MAPPING
MAP GRAPHICS
DFACTT
COMMUNICATIONS ELECTRONIC WARFARE
DISPLAYS
ESM
SIGINT

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM