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Flood Management Enhancement Using Remotely Sensed Data

Final Project Report

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FLOOD MANAGEMENT ENHANCEMENT USING REMOTELY SENSED DATA

FINAL PROJECT REPORT

INTRODUCTION

Background. SENTAR, Inc., entered into a cooperative agreement with NASA Goddard Space Flight Center (GSFC) in December 1994. The intent of the NASA Cooperative Agreement was to stimulate broad public use, via the Internet, of the very large remote sensing databases maintained by NASA and other agencies, thus stimulating U.S. economic growth, improving the quality of life, and contributing to the implementation of a National Information Infrastructure. SENTAR headed a team of collaborating organizations in meeting the goals of this project. SENTAR's teammates were the NASA Marshall Space Flight Center (MSFC) Global Hydrology and Climate Center (GHCC), the U.S. Army Space and Strategic Defense Command (USASSDC), and the Alabama Emergency Management Agency (EMA).

For this cooperative agreement, SENTAR and its teammates accessed remotely sensed data in the Distributed Active Archive Centers, and other available sources, for use in enhancing the present capabilities for flood disaster management by the Alabama EMA. The project developed a prototype software system for addressing prediction, warning, and damage assessment for floods, though it currently focuses on assessment. The objectives of the prototype system were to demonstrate the added value of remote sensing data for emergency management operations during floods and the ability of the Internet to provide the primary communications medium for the system. To help achieve these objectives, SENTAR developed an integrated interface for the emergency operations staff to simplify acquiring and manipulating source data and data products for use in generating new data products. The prototype system establishes a systems infrastructure designed to expand to include future flood-related data and models or to include other disasters with their associated remote sensing data requirements and distributed data sources.

Scope. This report covers the specific work performed during the seventh, and final, milestone period of the project, which began on 1 October 1996 and ended on 31 January 1997. In addition, it provides a summary of the entire project.

Purpose. The purpose of this report is to: 1) document the successful completion of all the seventh period milestones and 2) to provide a status of the significant accomplishments, problems encountered, and overall project results. The document presents the results of the prototype demonstrations in the SUMMARY OF ACTIVITIES section. This is followed by a FUTURE ACTIVITIES section. In addition, there is a summary of the entire project presented in Appendix A. This information is intended to provide project insight to NASA and others in applying NASA remote sensing data to disaster management.

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SUMMARY OF MILESTONE PERIOD ACTIVITIES

Significant Accomplishments. SENTAR had two products for the seventh milestone period. These were:

1. Completion of the final project report
2. Successful completion of the prototype demonstrations.

These two products have been successfully completed. This report constitutes the completion of the first product. The second milestone was achieved with the completion of the prototype demonstrations in December, with follow up interviews of the demonstration participants in January and February. Details of the demonstrations are described in the following paragraphs.

Prototype System Development Status. The prototype system consists of four major geographically-separated components. The major system components are a Data Processing Center (DPC) (located in Huntsville, AL), the Alabama EMA Emergency Operations Center (EOC) (in Clanton, AL), the remote sensing data providers (various locations in the world), and the remote or county users (at various locations within the state of Alabama). For the prototype system, the DPC is split between two facilities: the NASA GHCC for remote sensing data processing and the USASSDC for the Geographic Information System (GIS) and ARC/INFO conversion processing.

During the sixth milestone period, there were upgrades to the hardware and software at both DPC facilities. In addition, Alabama EMA completed a major upgrade of their computer resources. A new Sun server was installed and new, more capable PCs were provided for the emergency management staff. These improvements were specifically provided to support the Federal EMA's (FEMA's) Emergency Management Information System for the chemical stockpile incineration program, however they are also supporting this effort. These replacement PCs provide the computing and storage capacities necessary to run ArcView adequately with the large data files that will be used. Prior to the prototype experimentation and demonstrations, the remote sensing and GIS data file processing were completed and the files were installed on the Sun server and some of the PCs. In addition, the revised version of the Emergency Management Operations Tool (see following subsection for details) was loaded onto the PCs and configured for their local area network.

Software Module Development. The prototype system consists of a set of commercial-off-the-shelf applications integrated under a common user interface, called the Emergency Management Operations (EMO) Tool. The system makes extensive use of existing software products at the Alabama EMA to provide system functionality wherever possible. Where these software packages did not meet the functional needs of the prototype system, SENTAR developed software applications and utilities. Three software components were developed for this project:

1. The EMO Tool
2. The Vector/Raster Data Formatter
3. Data Retrieval Scripts.

The EMO Tool resides on the PCs of the EOC operations center, the Vector/Raster Data Formatter operates on PCs at the DPC, and the Data Retrieval Scripts operate on the Sun server at the EOC. (Refer to Figure 1.) These three software components were developed and tested during previous milestone periods. During the seventh milestone period the only change to these products was the addition of on-line help to the EMO Tool. This was set up like a standard Windows help utility with topic selection from search or contents options. Figure 2 illustrates a portion of the Windows help display that was added to the EMO Tool.

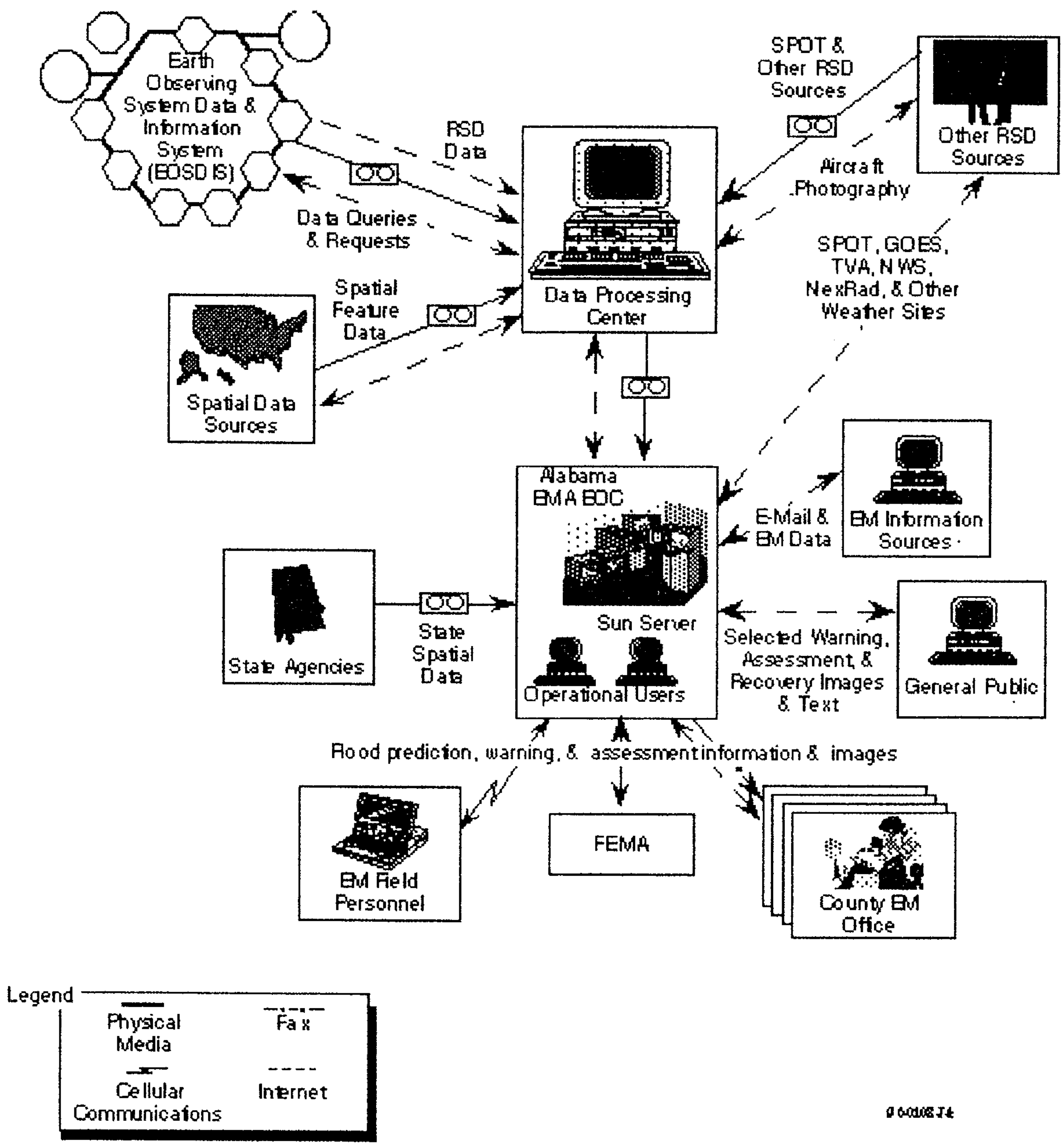

Figure 1. Prototype system concept.

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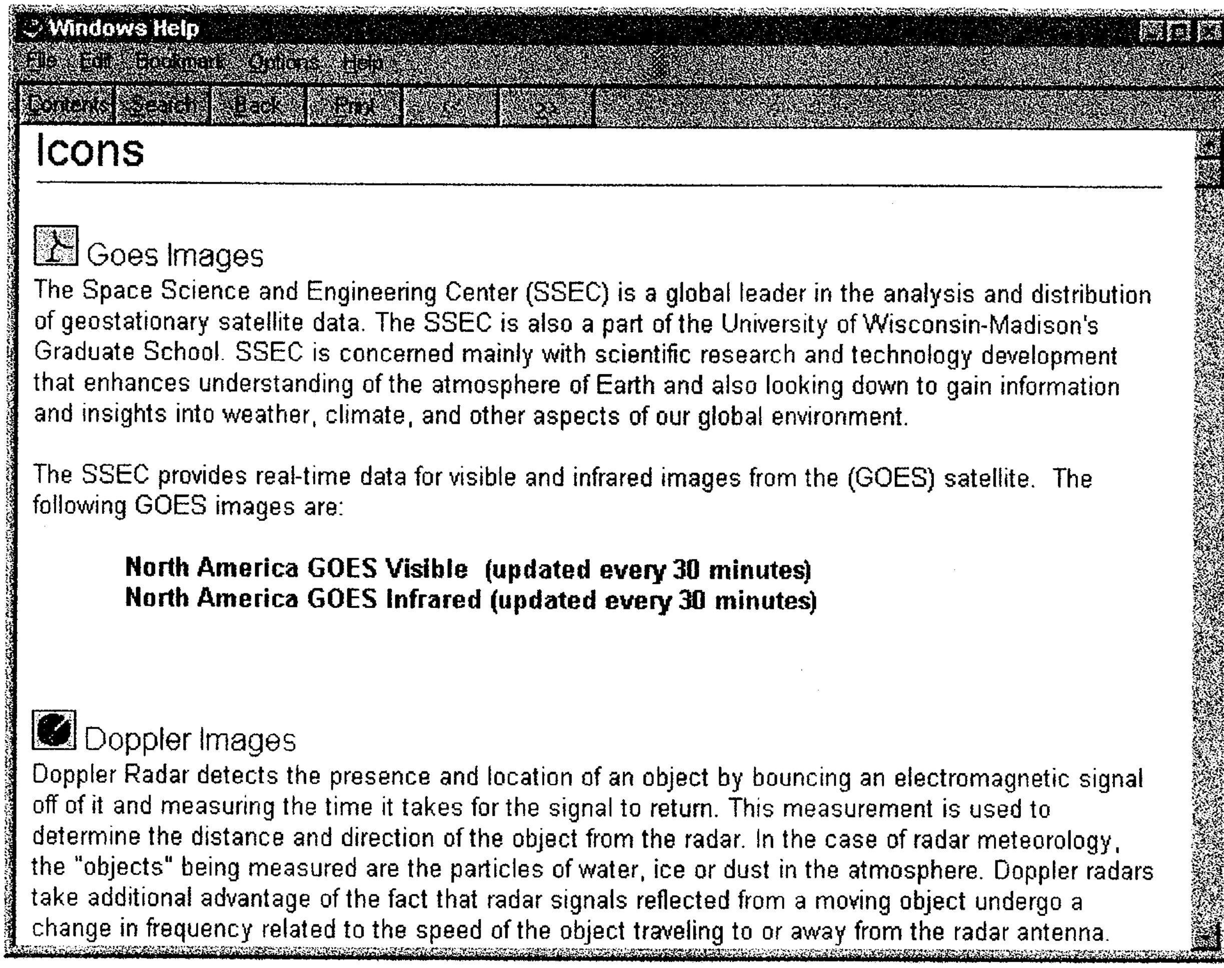

Figure 2. Sample display from the EMO Tool help topics.

Two of the three software components, the EMO Tool and the Vector/Raster Data Formatter, were installed and demonstrated on the appropriate platforms. The Data Retrieval Scripts were not installed on the Alabama EMA server for the exercises/demonstrations, as direct Internet access was not available for the demonstrations. Instead, these were run from SENTAR's ISP computers and downloaded to the Alabama EMA via their dial up connection.

Remote Sensing Data Acquisition and Processing. During the seventh milestone period, SENTAR finalized processing of the Landsat TM imagery that is the primary imagery backdrop for the prototype system and produced the data on CDs. The satellite data cover all of northern Alabama and the southeast portion of the state. (See Figure 3.) The data were reformatted for importing into the Map-X remote sensing software where the individual bands were combined into a single file and then converted into the BIL file format for exporting to ArcView. The composite band file is a large file (~300 Mbytes) that is cumbersome for the emergency managers to work with when not all six bands are needed. Therefore, SENTAR also produced three-band composite files. For these, three of the Landsat TM bands were combined into a single-band, color composite file. A Map-X algorithm was applied to enhance the colors of the composite file. This algorithm generates a simulated true color image by analyzing the range of pixel values used in the bands, then spreads out the color values across the 256 bits of each pixel of the composite file. Figure 4 shows an example of the effect of the simulated true color image processing. The resulting file was also converted into a BIL format for exporting to ArcView. The color composites were generated by assigning Landsat TM bands 4, 3, and 2 to the colors red, green, and blue, respectively.

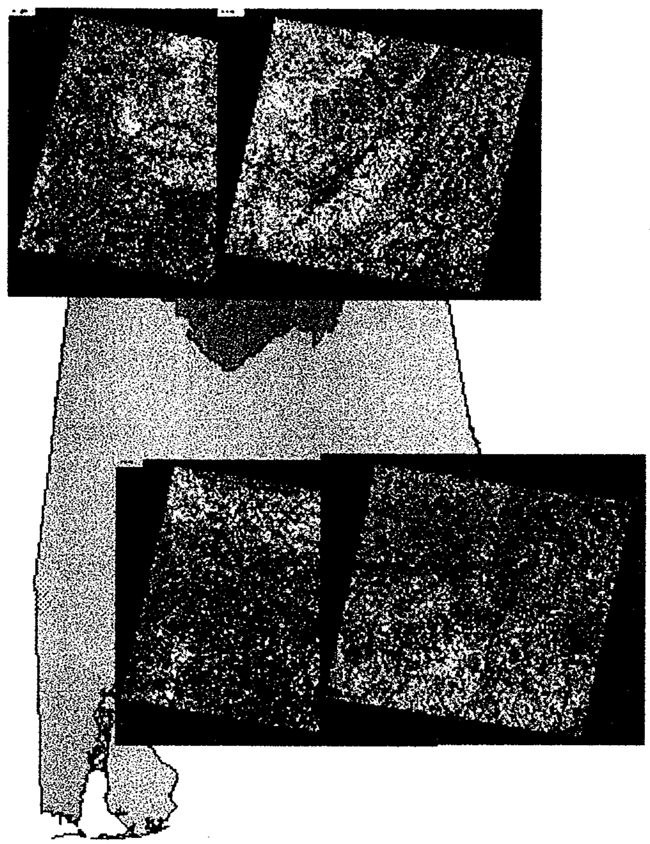

Figure 3. Area covered by the processed Landsat TM data.

Finally, water classification raster files were produced from the Landsat image using the tools within Map-X. (See Figure 5.) A median filter was applied to the resulting image file to eliminate solitary pixels identified as water. Although these may, in fact, be water, the desired output is for significant bodies of water and not every small pond. The boundaries for the water classified areas were then converted into a vector representation from the raster image. The vector file was converted into CAD format (.dxf) for exporting to ARC/INFO. Once in ARC/INFO, the vector file was again converted, this time to the ARC/INFO .e00 file format and ArcView .shp file formats. It is these last formats that were exported to Alabama EMA along with the original raster band images and the simulated true color image.

Landsat TM image bands 4 (red), 3 (green), and 2 (blue)

Map-X Simulated True Color Image of above Landsat TM image

Figure 4. Example of the Map-X simulated true color image processing.

Finally, water classification raster files were produced from the Landsat image using the tools within Map-X. (See Figure 5.) A median filter was applied to the resulting image file to eliminate solitary pixels identified as water. Although these may, in fact, be water, the desired output is for significant bodies of water and not every small pond. The boundaries for the water classified areas were then converted into a vector representation from the raster image. The vector file was converted into CAD format (.dxf) for exporting to ARC/INFO. Once in ARC/INFO, the vector file was again converted, this time to the ARC/INFO .e00 file format and ArcView .shp file formats. It is these last formats that were exported to Alabama EMA along with the original raster band images and the simulated true color image.

These various image and vector files were grouped by the Landsat TM image from which they were derived and were burned onto a writeable CD. A readme file was also added to describe the contents of the CD and a Process.txt file was added to describe the processing performed on the original data to produce the data sets on the CD. Appendix B presents a sample of a readme file and the Readme file. This format for the files on CD represented a prototype of what production CDs consist of.

Also during this milestone period, SENTAR purchased U.S. Geological Survey (USGS) National Aerial Photography Program (NAPP) and National High-Altitude Photography (NHAP) program photographs. These are hardcopy images that were then scanned into a digital format for processing. Several black-and-white and color images were processed into BIL files for exporting to ArcView. The photographs acquired cover areas of southern Alabama that have experienced major floods in recent years. These images cover ground areas of 5x5 miles or 8x8 miles. To date, individual photographs have been digitized, georeferenced, and converted to BIL format for export to Alabama EMA. Figure 6 shows a sample of two of these images with some TIGER GIS data.

GIS Data Layer Development. The development of the GIS data layers for the prototype system were completed during this milestone period. SENTAR acquired the necessary source data to support the data layers for the Alabama counties to be included in the prototype system. The desired data layers previously defined with Alabama EMA for the prototype system were divided into three categories: those that can be produced from the U.S. Census Bureau's TIGER data, those that can be obtained from other federal agencies, and those that will be obtained from state sources. TABLE 1 lists the data coverages that were produced for the prototype system from the desired data coverages for these three categories.

SENTAR contracted out for new sets of these data layers using the most current version of TIGER data. These data layers were supplemented with data layers that were provided by the U.S. Army from the Integrated Disaster Planning Package (e.g., the Redstone Arsenal boundary). TIGER data for the counties of northern Alabama and southeast Alabama were combined and the composite vectors were processed to correct for proper edge matching at the county boundaries, dangling vectors, and open polygons. The completed data coverages were completed and provided to SENTAR last milestone period. This milestone period SENTAR performed a quality check of the data and installed the data coverages onto the Alabama EMA server. Figure 7 shows a state view with the northern and southeast counties of Alabama for which TIGER data coverages were provided. Figure 8 illustrates the level of detail in the GIS vector files by displaying a small portion of south Madison County in northern Alabama. This figure presents six of the data coverages, featuring the hydrology and road coverages.

Figure 5. Portion of a water classification image file generated from Map-X.

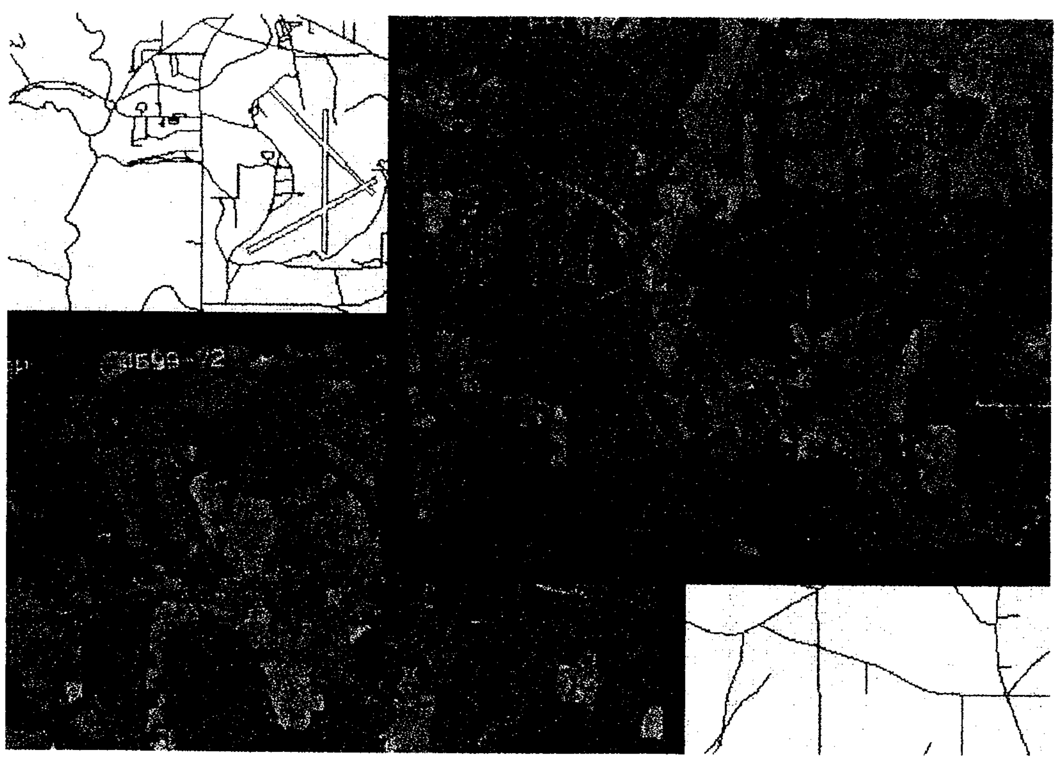

Figure 6. Example of the USGS NAPP photographs with some TIGER GIS data.

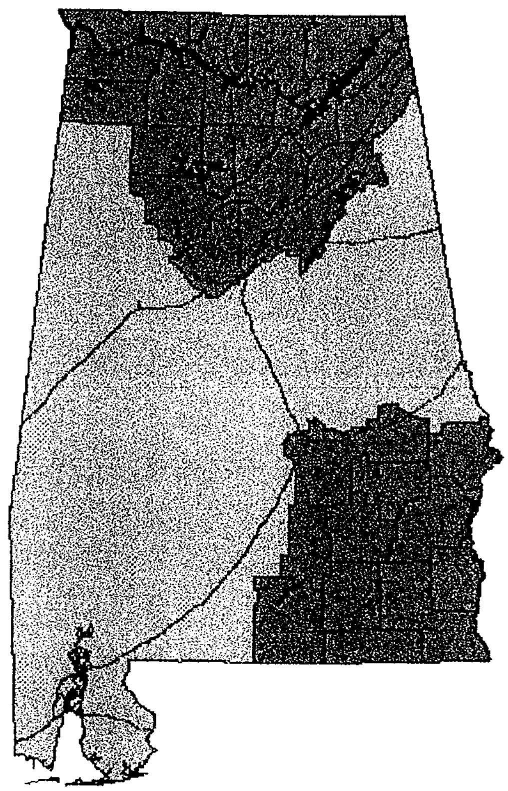

Figure 7. Alabama counties in the prototype system.

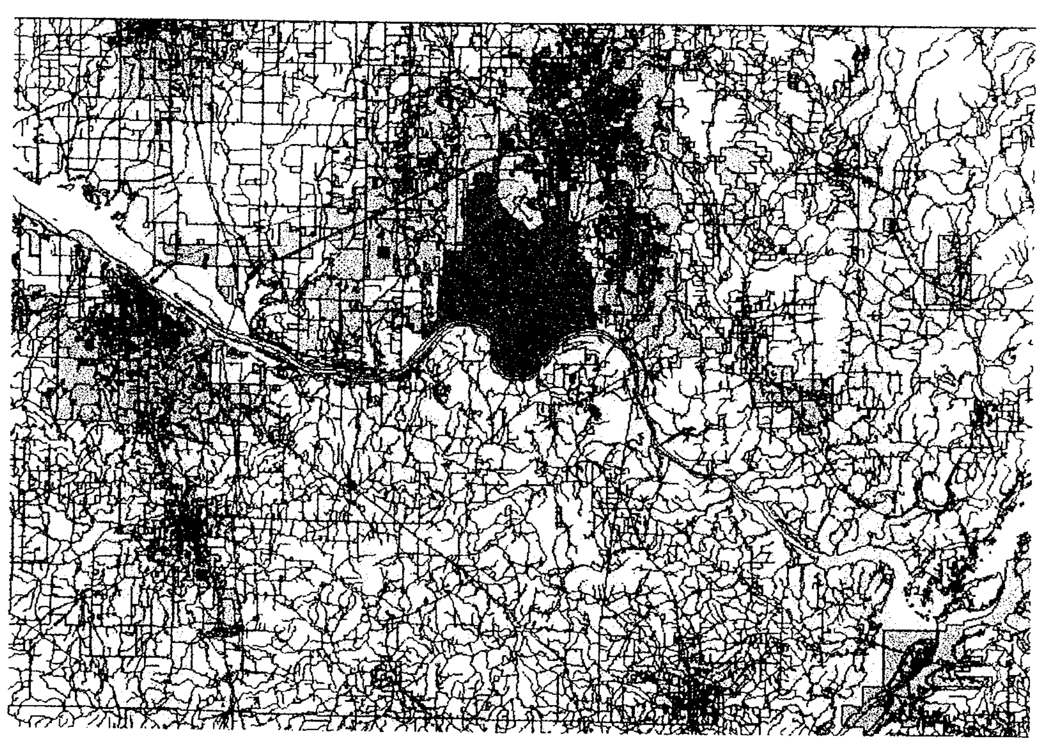

Figure 8. Sample of the TIGER derived data coverages for northern Alabama.

The next category was other federal agencies. For this data layer, the newly digitized data of the Flood Insurance Rate Maps (FIRM) were obtained. FEMA developed digital FIRMS for 19 counties in Alabama, which are part of the Digital Q3 Flood Data. These data were purchased and received from the FEMA Map Center during the sixth milestone period. All 19 counties were reprocessed to convert the projection datum to North American datum 1983 (NAD83) versus the NAD27 datum used in the source data. This conversion was necessary for these data to be compatible with the Landsat raster imagery, which was provided to Alabama EMA in the Universal Transverse Mercator projection, NAD83 datum. This processing was performed at the USASSDC facilities using ARC/INFO. This processing was essential because ArcView does not have the ability to perform the projection and datum conversions as can be done using ARC/INFO.

For the state agency data, Alabama EMA sent out formal letters requesting the desired data and these were followed up with telephone contacts by SENTAR personnel to discuss the details of the proposed data transfers. Data were provided by the Alabama Power Commission and a power plant data coverage was generated. No other state agencies provided data to be developed into data coverages prior to the exercises/demonstrations, however some are currently developing GIS data coverage of their data and have agreed in principle to provide these data to Alabama EMA when available.

TABLE 1
DATA LAYERS PROVIDED FOR PROTOTYPE SYSTEM

Data Source	Data Layer
TIGER	Hydrology, boundaries (local, county, state, military, and international), urban areas, block group, voting district, school district, demographics (census tract), interstate highways, roads and streets, railroads, airports, runways, shopping centers, trailer parks, apartment complexes
Other Federal Agencies	Flood Insurance Rate Maps
State Agencies	Power plants

Prototype Demonstrations. An experiment/demonstration plan was developed during the last milestone period. This plan was designed to conduct a series of two simulated flood events in which the overall prototype system is demonstrated. The activities of the plan exercise the developed and integrated components of the system to show overall functionality and examine how the prototype system works with the existing plans and procedures at the Alabama EMA EOC. Each experiment/demonstration focuses on one of the geographical areas of the GIS data coverages developed for this project. In addition, each experiment/demonstration exercises particular aspects of the prototype system. There was one experiment/demonstration involving a hurricane that makes landfall on the Florida panhandle and heads north through the southeast counties of Alabama, causing flooding along several rivers and streams. The other experiment/demonstration consisted of flooding in northern Alabama resulting from severe and prolonged spring thunderstorms. In both cases, Landsat TM images were used as the backdrop imagery in the GIS for the normal, or non-flooded, view. Then for the visualization of the flood, Landsat TM imagery was used as a water derived classification to locate and assess the flood regions in one case and aerial photography was used in the other.

The experiments/demonstrations were developed in separable portions since the complete demonstrations were designed to take several days working on a part-time basis. The schedule had to be easily modifiable since Alabama EMA's actual mission always had priority over these activities and, thus, there might have been interruptions in the execution of the experiments/ demonstrations.

The plans for the experiments/demonstrations were developed during the sixth milestone period except for details of the integration of Alabama EMA specific operating procedures, which were to be added during the first part of the final milestone period. However, Alabama EMA was only beginning the process of determining who in the EOC should run the GIS and remote sensing applications and how to utilize the resulting data and data products in their mission. Thus, they were not ready to provide the detail SENTAR was looking for in the exercise/demonstration plan. These exercises/demonstrations were then changed into two parts. The first part was a training program to produce hands-on usage of the tools and data by operations staff at the EOC. This was done to make sure they really understood what data was being provided to them, and to get them working with the data to start the process of determining how to integrate these data products into their specific missions. The second part consisted of SENTAR and NASA GHCC personnel executing the exercise/demonstration plan instead of the EOC staff. This resulted in the successful data processing and transmission steps of the plan, but produced no data on the utilization of the data products in actual EOC operations.

A second limitation of the exercises/demonstrations was that very little of the state GIS data were produced during the project. It is these data sets that represent the most important GIS information to be used by the emergency managers during actual emergencies. Although many of the data sets are in development within state agencies, only the power plant information was available for the exercises/demonstrations. The lack of additional state data coverages only impacted the evaluation of disaster impact and recovery utilization of state infrastructure.

Scenario 1: Southeast Alabama Flood. This first scenario simulated a hurricane hitting the southeast portion of the state and causing flooding on certain rivers in Alabama that tend to be very flood prone. The scenario began with the monitoring of the storm off shore through the GOES imagery that was downloaded regularly and viewed through the image viewer. GOES has the resolution to accurately monitor the progress of major storms such as hurricanes. Since an actual hurricane was not threatening Alabama, the GOES imagery was used to track major cloud activity through the southern portion of the state and to track hurricanes in other areas of the hemisphere. Similarly, the Internet links to the National Weather Service (NWS) were regularly checked to get storm forecasts, warnings, and watches.

After monitoring the imaginary hurricane for several hours, landfall was declared and a run of the inland winds generated. It plotted a path of the hurricane through the southeast portion of the state. (See Figure 9.) An ArcView project file was then built with the available TIGER, power plant, FEMA floodplain, and water classification (nonflooded condition) GIS data. In addition, the Landsat TM and USGS aerial photography for this region are added to the project file.

Based on NWS flood warnings, radar imagery, and NWS river reports retrieved from the Internet, it was determined that there was possible flooding on the Pea River near Elba. The USGS aerial photographs that had been processed for that area were now used to access the nonflooded region along the river to begin planning route into and out of the area using the TIGER road data.

Also, the data providers were contacted to determine if there was a satellite image that could be used to ascertain the extent of the flood. An available Landsat image was used as if it were an actually procured image of the flood. It was processed at the DPC (currently at the NASA GHCC). There the image was processed into a BIL formatted file for all six bands, the simulated true color image, and water extent. The latter was also produced into a vector file and converted into the ArcView format. All the files, except the six-band file can be transmitted over the Internet to Alabama EMA even though they only have a 28.8 kbps dial up Internet connection. The simulated true color image would take about four hours to transmit, however the reliability of the connection for that long is questionable. One technique that can be used is to not export the entire image, since the Landsat image covers a wider area than is typically needed except for very major events. In addition, a CD would also be made to provide all files in a format that is easily transportable and easily stored for archival purposes.

With the new image imported into ArcView, the capabilities of the ArcView tool were then used to generate outputs of the original view of the river as a raster image and the new view as a vector representation using the water classification vector file from the new image. The FEMA floodplain data was also used to show where the 100 and 500 flood zones were in the area of concern. Figure 10 shows a sample of the products produced. Since the images were not of an actual flood, there were no areas where the water classification had encroached on homes and businesses.

Scenario 2: Northern Alabama Flood. This second scenario simulated flooding on the Tennessee River near Decatur, Alabama, resulting form severe and prolonged spring thunderstorms. The scenario began with the monitoring of the storms through the radar imagery that was downloaded from the Internet and viewed through the image viewer. Doppler and NEXRAD radars provided highly accurate monitoring of the progress of the thunderstorms. In addition, flood potential was also monitored via the Internet with FloodCast predictions and NWS warnings and watches. Also, TVA Lake Information (stream flow rates and heights) was retrieved to access the flood potential on the Tennessee River.

When it was determined that the Tennessee was exceeding its banks, data providers were contacted to determine if there was a satellite image that could be used to ascertain the extent of the flood. It was determined that there were none, but a local TV helicopter crew took some still photography of the river. This was simulated through the use of aerial photography previously taken by SENTAR personnel. These images were taken at oblique angles to the ground which increases the difficulty of georectification. The images were developed and taken to the DPC where they were scanned, imported into Map-X, and georectified. Next, the images were

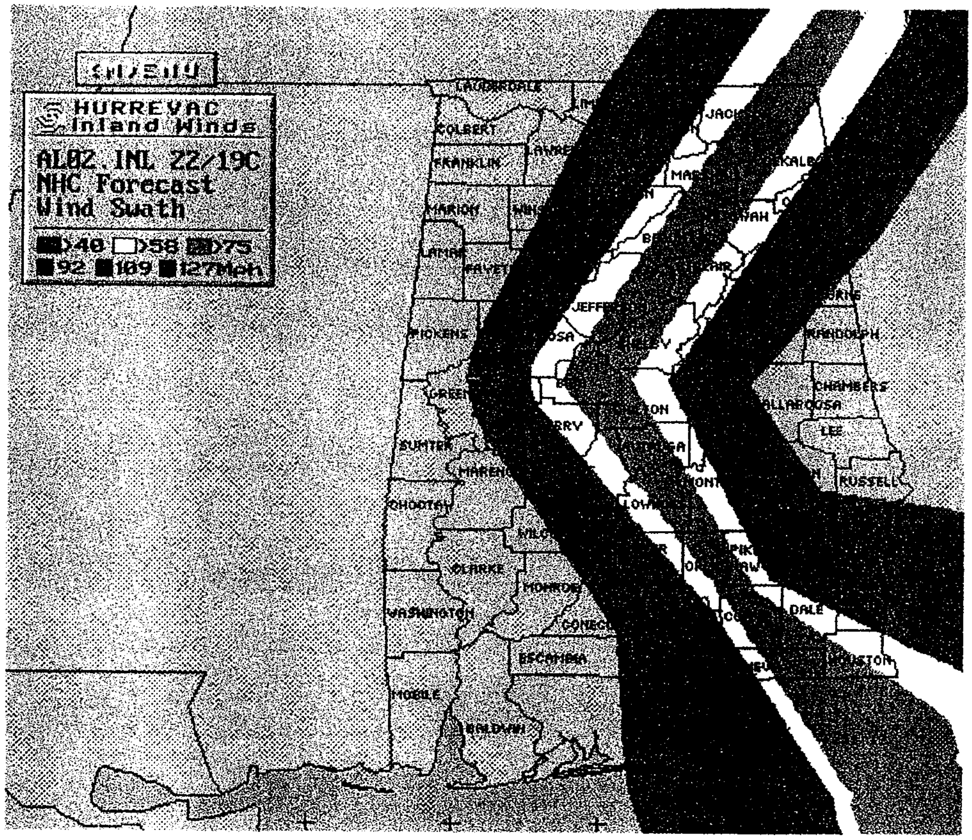

Figure 9. In-land wind output for scenario.

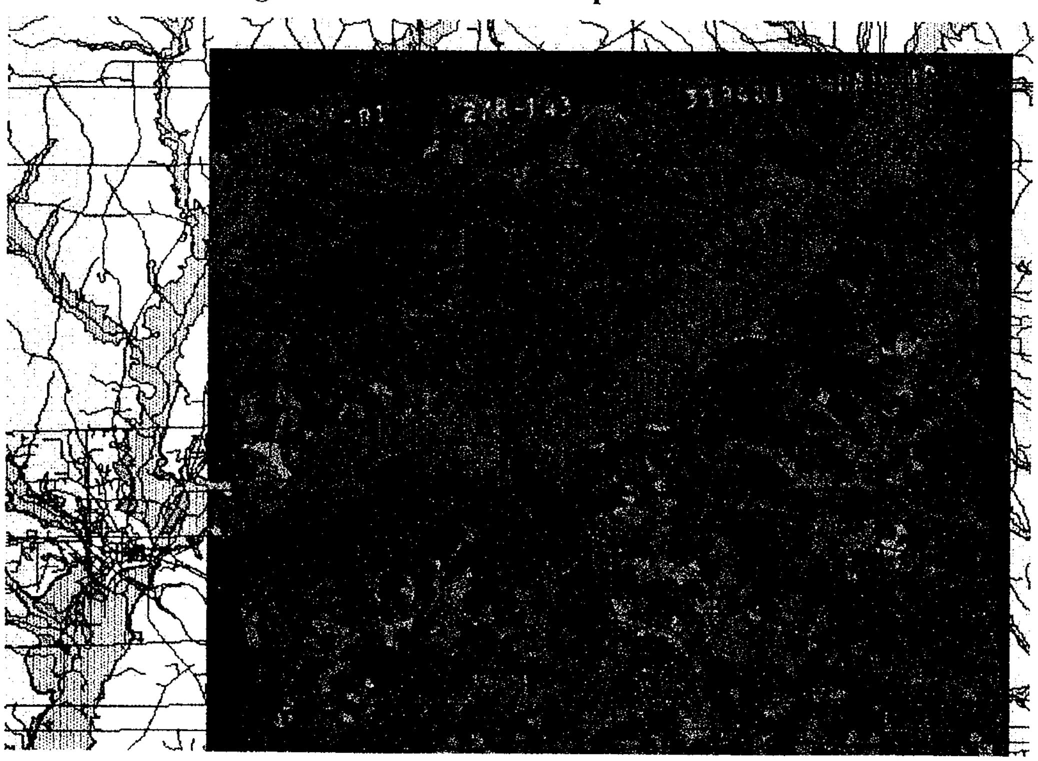

Figure 10: Sample of the products produced for Scenario 1.

processed into BIL formatted files for the three color bands and a single-band simulated true color image. Due to the smaller areas of the photographs (generally under 5-10 Mbytes), there was no problem transferring then via the Internet.

With the new images imported into ArcView, the capabilities of the ArcView tool were again used to generate outputs. In this case, the original view of the river was represented using the water classification vector from the pre-flooded Landsat image and the new view of the river was represented by the aerial photographs as raster images. Water classification vectors were not generated from the aerial photographs since the oblique angle to the ground was an unknown, as were the characteristics of the atmosphere. These factors were beyond our capabilities to make the necessary corrections to account for the color variation across the image for a common ground feature.

The FEMA floodplain data was again used to show where the 100 and 500 flood zones are in the area of concern. Figure 11 shows a sample of the nonflooded Landsat TM data with selected TIGER data for the affected area. Figure 12 shows the same area with one of the aerial photos added. Finally, in Figure 13 the water classification vector file for the nonflooded situation is displayed over one of the aerial photos.

Figure 11. Landsat TM band 7 and TIGER road, hydrology, and railroad data.

Figure 12. Landsat TM and TIGER data with aerial photograph.

Figure 13. Figure 12 image with Landsat derived water classification vectors.

Other Activities

Home Page. During this milestone period, some further work on the redesign of the project home page that was started last milestone period was continued.

Principal Investigator Conference. The Principal Investigator (PI) represented the project at the NASA/FEMA Conference on GIS and Applications of Remote Sensing to Disaster Management in Washington, DC, January 14-16, 1997. Appendix C presents the slides that were used at that conference.

Civil Air Patrol. As a result of contacts made at the September 1996 PI conference, SENTAR established contact with the Director of Communications of the Civil Air Patrol regarding integration of their system for near real-time aerial photograph capturing and downloading with our system for georectification of those photos and integration with the GIS. We met with representatives of the Alabama wing of the CAP in an attempt to work out a plan for testing this as part of the prototype exercises/demonstrations, but the aligning of schedules and the availability of the necessary equipment and personnel did not come together to make this happen.

Problems Encountered

The following were significant problems encountered during the course of the project that had impact on the overall project results or outputs.

Data Acquisition. There was confusion at the start of the project about whether project funds or NASA would pay for the remote sensing data used on the project. The original budgeting for the project assumed that NASA would supply the necessary data, as the data were coming from NASA archives. When it was determined that project funds would be required, there were further delays in determining whether the project could purchase data as a NASA affiliated user. The result was that actual Landsat TM data were not acquired until well into the second year of the project.

Internet Connectivity. Alabama EMA was unable to establish dedicated Internet access through the Alabama Supercomputer Network operated by the Alabama Supercomputer Authority for the exercises/demonstrations. Internet access was provided through the MSFC GHCC using their 800 dial-up service. Current plans have delayed the start of Internet connectivity through Alabama Supercomputer Authority until early 1997.

Clarification of Collaborative Agreements. Some of the details of the required support from USASSDC were not explicitly defined in the articles of collaboration. This involved equipment or personnel that were available at USASSDC where SENTAR would operate from and, thus, were not always identified in the articles of collaboration. When later USASSDC needed to move the SENTAR office, it was not clear what we needed and we were set up in an area that did not fully meet our needs. The result was a period of time where there were misunderstandings as to what was needed to support the project and what could be provided.

User Identification. The final planning and execution of the exercises/demonstrations were hampered by the fact that Alabama EMA is currently in the process of deciding who should use the GIS related software tools and how they should be integrated into their operations. It will take some time before this gets resolved, and until it does it limits the potential use of the tools and data provided as part of this prototype system. It will probably take approximately one year of close consultation with the appropriate staff and working actual disasters with them to fully address how best to fit these tools and data into their operations.

Milestones. The project was created as a series of sequential milestones that were put in place to ensure that there was regular progress across the project. At times during the project, particular milestones proved difficult to meet at the preplanned times. Where the completion of these particular milestones at those specific times was not hampering the progress of the project, it would have been useful to reschedule the milestones rather than spend excessive project manpower resources completing a milestone that did not need to be completed at that time.

Requests for Assistance from NASA

No technical assistance requested from NASA GSFC was requested during this milestone period.

FUTURE ACTIVITIES

The future activities for SENTAR related to the NASA CAN are:

1. ***Solicit Follow-on Funding from Alabama EMA.*** SENTAR is pursuing Alabama EMA to fund a continuation of the effort. The primary goal is to complete the effort to work the GIS and remote sensing products into their specific operational procedures.
2. ***Take the Prototype System Concept to Other State EMAs.*** SENTAR is refining what are the specific tools and data that are required to adapt this prototype system to other state EMA offices.
3. ***Explore Off-Shoot Efforts Using Remote Sensing Data.*** SENTAR is pursuing off-shoots from this project that involve the use of remote sensing imagery. These include other government research solicitations to extend the specific remote sensing data usage, potential commercialization with a company producing weather radar with storm tracking software, and the start of a new corporation from SENTAR to pursue the development of a new type of Internet-based mapping service that incorporates remote sensing data.

APPENDIX A
PROJECT SUMMARY

Flood Management Enhancement Using Remotely Sensed Data

Project Summary

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Background. SENTAR, Inc., entered into a cooperative agreement with NASA Goddard Space Flight Center (GSFC) in December 1994. The intent of the NASA Cooperative Agreement was to stimulate broad public use, via the Internet, of the very large remote sensing databases maintained by NASA and other agencies, thus stimulating U.S. economic growth, improving the quality of life, and contributing to the implementation of a National Information Infrastructure. SENTAR headed a team of collaborating organizations in meeting the goals of this project. SENTAR's teammates were the NASA Marshall Space Flight Center (MSFC) Global Hydrology and Climate Center (GHCC), the U.S. Army Space and Strategic Defense Command, and the Alabama Emergency Management Agency (EMA).

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Purpose. The purpose of this report is to: 1) provide a summary of the accomplishments of the project and 2) provide some thoughts the future of this work. This information is intended to provide project insight to NASA and others in applying NASA remote sensing data to disaster management.

PROJECT SUMMARY

Project Goals. The project goals were to develop a GIS-based, prototype system for enhanced emergency management of floods that: 1) utilizes Remote Sensing Data (RSD), the Internet, and existing software products and 2) is readily expandable into an all-hazards tool for use throughout Alabama or anywhere the necessary source data is available.

The specific objectives were to:

1. Identify RSD, particularly from NASA's DAACs, that have the potential to enhance flood management
2. Develop and demonstrate a prototype system for utilizing RSD for flood management by Alabama EMA staff
3. Demonstrate the value added of RSD for emergency management operations
4. Demonstrate the feasibility of using the Internet as the communication network from the DAACs to end user.

The system concept developed uses remote sensing data sets from the NASA DAACs, or other data providers, that are integrated into a commercial Geographical Information System (GIS). When used with the geographical, infrastructure, and demographic data in the GIS, the remote sensing data provide the Alabama EMA with additional capabilities for addressing flood related disasters.

The second element of the system concept is the use of the Internet as a communication path for transferring remote sensing data and data products from the data providers to the processing center, and then to the Alabama EMA and its staff in the field. The project showed that much of the communications can be achieved via the Internet.

Project Status. At the conclusion of the NASA sponsored phase of this research project, a prototype system has been developed consisting of four major geographically-separated components. The major system components are a Data Processing Center (DPC) (located in Huntsville, AL), the Alabama EMA Emergency Operations Center (EOC) (in Clanton, AL), the remote sensing data providers (various locations in the world), and the remote or county users (at various locations within the state of Alabama). For the prototype system, the DPC is split between two facilities: the NASA GHCC for remote sensing data processing and the USASSDC for the Geographic Information System (GIS) and ARC/INFO conversion processing. The specific elements that have been installed and demonstrated are the:

- DPC for remote sensing processing using the commercial software package MapX, a SENTAR produced data reformatted for importing the files into ArcView, and the commercial package ARC/INFO
- The Emergency Management Operations (EMO) Tool developed by SENTAR to provide a single user interface for the COTS applications to be used by the emergency mangers on their PCs
- ArcView 3.0 for data viewing, manipulation, and spatial analyses by the emergency managers
- Sample data files for the EMO Tool
- TIGER GIS vector data consisting 16 data coverages for 17 northern and 13 southeastern Alabama counties (see Figure 1 and TABLE 1), plus Redstone Arsenal boundary, all provided on CD
- FEMA Q3 Flood data for 19 counties in Alabama (see TABLE 2), provided on CD
- One state spatial data coverage for power plants

- Landsat TM imagery for the areas covered by the TIGER GIS data – these images are provided as multiband images, a three-band composite, and a water classification in vector and raster formats, provided on a CD for each of the Landsat source images (Figure 2)
- Sample USGS National High Altitude Aerial Photography in color and black and white images for selected high flood areas.

TABLE 1
TIGER DATA COVERAGES

Census block groups	Railroads	Voting districts
Roads and state highways	State boundaries	Apartment complexes
Interstate highways	Counties boundaries	Trailer parks
Streams and rivers	Urban area boundaries	Shopping centers
Lakes	School districts	
Airports and airfields	104th Congressional districts	

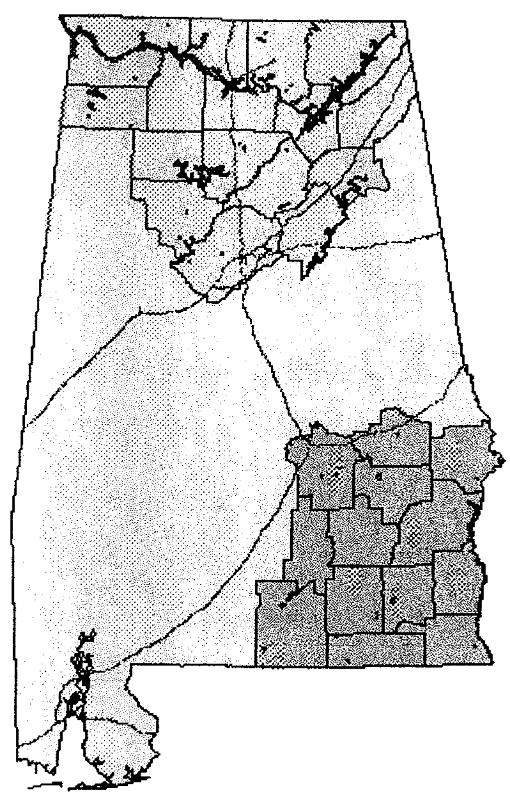


Figure 1. TIGER data for Alabama counties in the prototype system

TABLE 2
ALABAMA COUNTIES WITH FEMA Q3 FLOOD DATA

Baldwin	Covington	Houston	Morgan
Barbour	Dale	Jefferson	Randolph
Calhoun	Dallas	Madison	Russell
Coffee	Geneva	Mobile	Tuscaloosa
Conecuh	Henry	Montgomery	

The components of the prototype system that shall be implemented post the NASA sponsored research project are:

- Loading and configuring the Internet retrieval scripts on the AEMA server once they have dedicated Internet access
- Integration of the GIS spatial analysis products into the EOC's standard operating procedures
- Expansion of the GIS database with the additional State Agency spatial data
- Consolidation of the DPC into a single facilities.

There was a demonstration of the system capabilities and the databases that have been provided to EOC staff. This was supplemented with a training session on how the use the data to produce the data views and spatial analyses needed during and after a disaster.

From here, the system will be supplemented with additional satellite or aerial photography as it becomes available or is specifically acquired and additional state spatial data will be added as it becomes available until all the desired data coverages are included.

REMOTE SENSING DATA ANALYSIS AND PROCESSING

DAAC Data Research and Processing. SENTAR initially investigated the use of several data types from NASA's archives. Specifically these include the Advanced Very High Resolution Radiometer (AVHRR), Special Sensor Microwave/Imager (SSM/I), Geostationary Operational Environmental Satellite (GOES), and Landsat Thematic Mapper (TM)and Multispectral Scanner System (MSS). The results of that investigation was that only Landsat TM was desirable for use in the GIS for water delineation visually and through classification analysis. GOES was determined to be useful in the product oriented version on the Worldwide Web. Landsat MSS could be useful if no other data were available, but generally the resolution was too coarse for emergency management operations.

SENTAR performed a review of the current research in the application of remote sensing data for predicting, assessing, or monitoring floods. The objective was to determine if there were other uses of or types of remote sensing data for floods that we had not considered. The relevant journals, periodicals, conference proceedings, and NASA technical archives were searched for papers and reports. Listed below are some of the more significant papers and reports that we reviewed. Generally, there were no surprises that were uncovered in terms of sensors that could be used. Some interesting work has been done on using AVHRR data for some special flood events, but the conditions where the AVHRR data would be useful was atypical for Alabama.

Thus, the satellite data to be used was limited to Landsat TM for incorporation into the GIS for integration with the GIS data and GOES data for use as weather information in the image format available on the Worldwide Web.

SENTAR processed Landsat TM imagery as the primary imagery backdrop for the prototype system and produced the data on CDs. The satellite data cover all of northern Alabama and the southeast portion of the state (see Figure 3). The data were reformatted for importing into the Map-X remote sensing software were the individual bands were combined into single file and then converted into a BIL formatted file for exporting to ArcView. The composite band file is a large file (~300 Mbytes) that is cumbersome for the emergency managers to work since all six bands are needed. Therefore, SENTAR also produced simulated true color single-band files. For these files, three of the Landsat TM bands were combined into a color composite image and then converted into a single-band file. A Map-X algorithm was applied to enhance the colors of the composite file. This algorithm generate a simulated true color image by analyzing the range of pixels values used in and then spreads out the color values across the 256 bits of each pixel of the composite file. Figure 4 shows an example of the effect of the simulated true color image processing. The resulting file was also converted into a BIL format for exporting to ArcView.

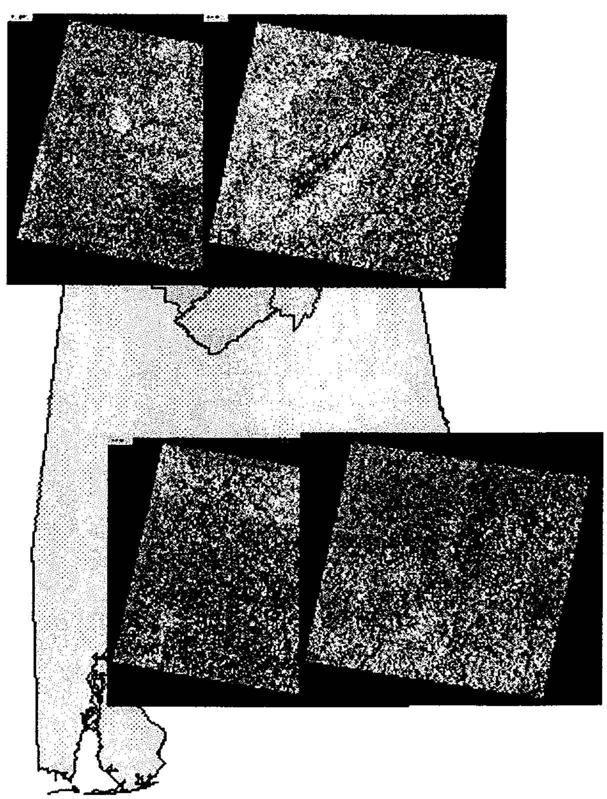
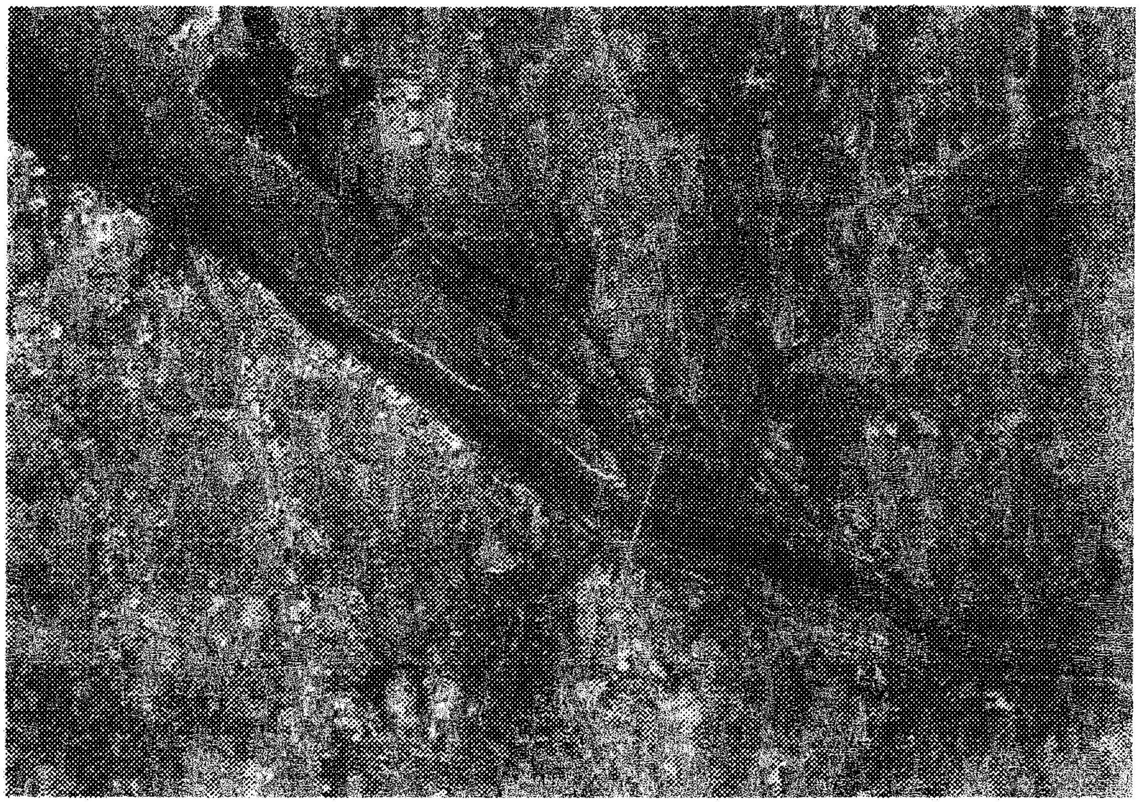


Figure 3. Area covered by the processed Landsat TM data.

Finally, water classification raster files were produced from the Landsat image using the tools within Map-X. A median filter was applied to the resulting image file to eliminate solitary pixels identified as water. Although these may, in fact, be water, the desired output is for significant bodies of water and not every small pond. The boundaries for the water classified areas were then converted into a vector representation from the raster image. The vector file was converted into CAD format (.dxf) for exporting to ARC/INFO. Once in ARC/INFO, the vector file was again converted, this time to the ARC/INFO .e00 file format and ArcView .shp file formats. It is these last formats that were exported to Alabama EMA along with the original raster band images and the simulated true color image.

These various image and vector files were grouped by the Landsat TM image from which they were derived and were burned onto a writeable CD. A readme file was also added to describe the contents of the CD and a Process.txt file was added to describe the processing performed on the original data to produce the data sets on the CD. In addition, an image file was added to show the area extent of the four Landsat TM images and which specific one is on the CD (see Figure 5). This format for the files on CD represented a prototype of what production CDs consist of. As other satellite images become available for a disaster they will be similarly processed and packaged on a CD. This same procedure would apply to SPOT images and those of the new US commercial satellites that will becoming operational in late 1997 or 1998.



Landsat TM image bands 4 (red), 3 (green), and 2 (blue)

Map-X Simulated True Color Image of above Landsat TM image

Figure 4. Example of the Map-X simulated true color image processing.

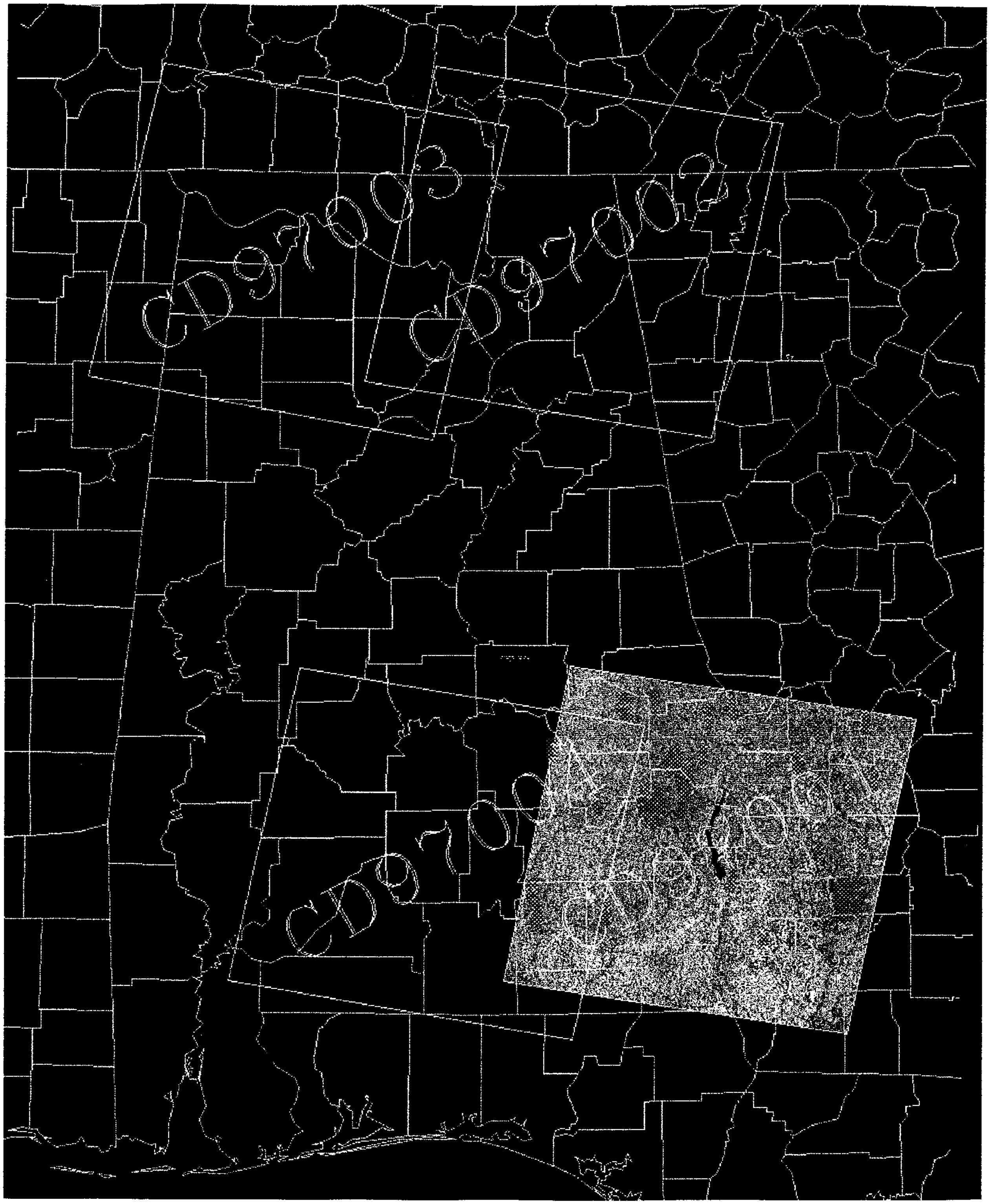


Figure 5. Image on CDs to visualize the areas of the Landsat TM images.

SENTAR also processed some selected U.S. Geological Survey (USGS) National Aerial Photography Program (NAPP) and National High-Altitude Photography (NHAP) program photographs to use as base map images for narrowed waterways that regularly flood to provide higher resolution than the Landsat TM images. These are hardcopy images that were scanned into a digital format for processing. Some black-and-white and color images were processed into BIL files for exporting to ArcView. The photographs acquired cover areas of southern Alabama that have experienced major floods in recent years. These images cover ground areas of 5x5 miles or 8x8 miles. Figure 6 shows a sample of two of these images with some TIGER GIS data.

Figure 6. Example of the USGS NAPP photographs with some TIGER GIS data

Georeferencing Oblique Aerial Photography. Because of the limitations on the availability of satellite images when they are needed, SENTAR researched the use of non-professional aerial photography. The limitations of the available satellite imagery is most notably the availability of the satellite over the site of interest at the time of interest, lack of visibility due to cloud cover, the processing and delivery time from the satellite data producers, the resolution of the imagery, and the cost of the imagery. The use of aerial photography has the potential of eliminating most of these limitations, although professional quality aerial photography is equally expensive as the satellite imagery. An alternative is the use of non-professional photography, for example would be photography taken by the Air National Guard which already supports the Alabama Emergency Management Agency, or even amateur photography taken by anyone with access to an aircraft and a camera. A critical question with this approach was the ability to georeference photographs taken at oblique depression angles for integration into the GIS.

To address this question, SENTAR performed a short parametric analysis on a series of aerial photographs taken aboard a small aircraft using a standard 35 mm camera. The analysis looked at aerial photography at altitudes of 1000 to 9,000 feet above the local terrain, at a series of depression angles, and at four geographical positions relative to a fixed ground location. These photographs were then scanned into a digital format, enhanced for visibility, and then georeferenced. As the depression angle increased, particularly for the higher aircraft altitudes, the distortion of the georeferenced image increased. While this was expected, the more interesting conclusion was that there was sufficient accuracy in the georeferencing to meet the needs of emergency management operations. Figure 7 show the original and georeferenced image photographs at a depression angle of about 40°. The before image is as seen in the original photograph and the after is the processed image with overlaid road and hydrology vector files.. The distortion in Figure 7 is clearly evident as the distance from the camera to the ground increases and the ground area per pixel increases. In addition, the accuracy of the georeferencing in these portions of the image is reduced. The overlaid road and hydrology vector files are clearly less accurate in the lower portion of the georectified image. Note that the matching of the vector files and the image is not exact, but is clearly close enough to perform a graphical analysis of the effect of flooding, as depicted in the image, to the various vector data layers.

One limitation of the aerial photography versus the satellite images is the reduced areas of coverage. This was particularly true for the test photographs taken by SENTAR. We were using a light aircraft with a ceiling of 10,000 feet above sea level (or 9000 feet above the local terrain for the area photographed). To compensate for this and also to remove some of the heavily distorted areas of an image, multiple georeferenced images can be combined in a mosaic, as shown in Figure 8. Here three images of the same area have been combined to produce a composite that provides a wider area of coverage. The three images used for this composite image were taken at altitudes of 3000 and 9000 feet above the local terrain; aircraft bank angle of 0°, 20°, and 45°; aircraft headings of south, north, and east; and a camera depression angle of approximately 40°. Figure 9 presents a slide that was developed for briefings that summarizes the methodology used to create the image of Figure 8. A similar approach can be taken to create a mosaic image that covers a length of a river or an extended area.

The intent is to export these images to the EOC where they will be used within the GIS with the feature data layers. They can also be combined with other images, such as hardcopy maps to produce static maps for distribution to those without the GIS software. Figure 10 provides an example of this for one of the aerial photographs with vector data for the roads and hydrology and the USGC hardcopy map for those areas beyond the limits of the photographic image.

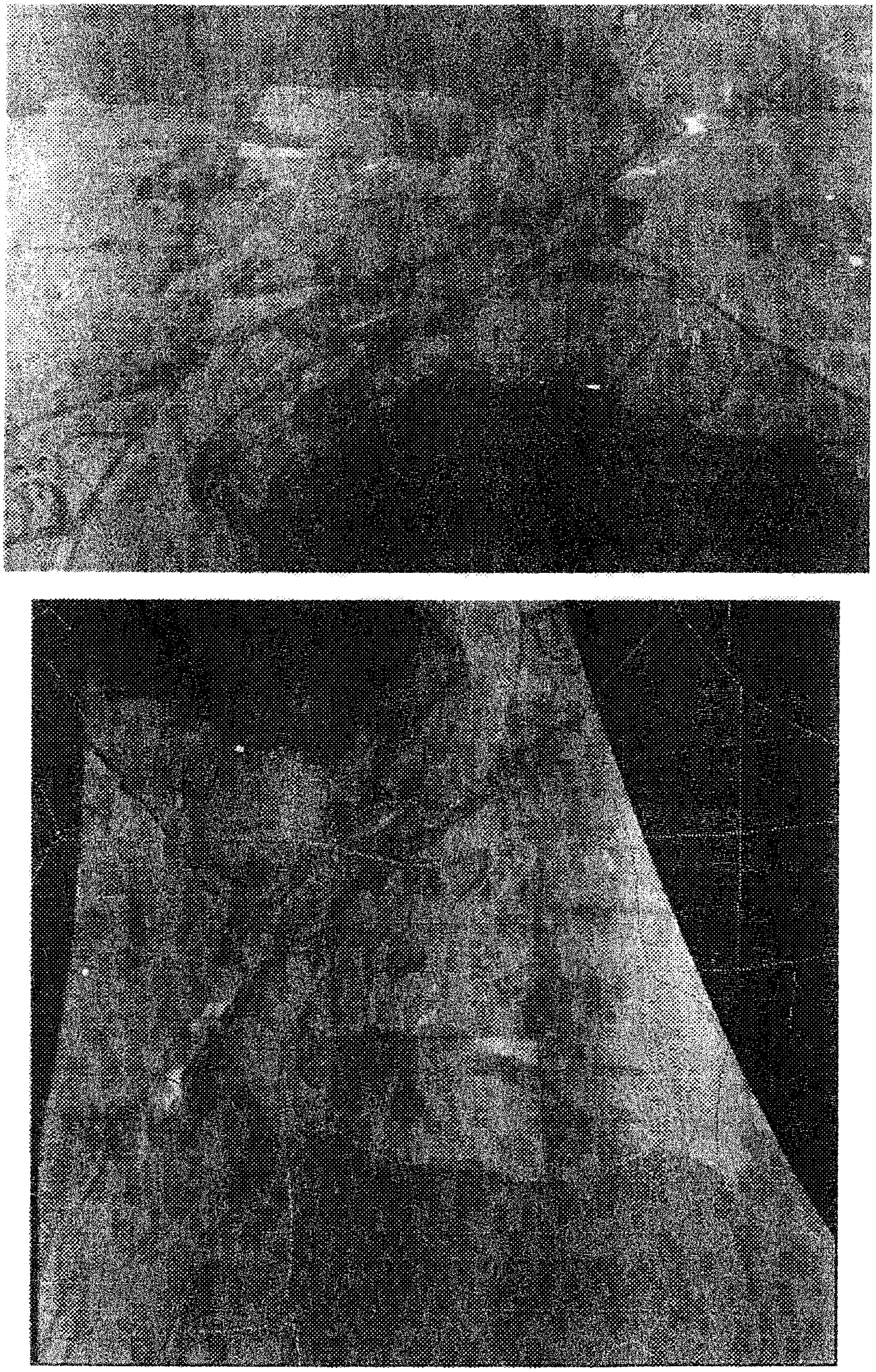


Figure 7. Original and georeferenced aerial image of a portion of the Flint River (taken at an altitude of 10,000 feet above sea level and at an aircraft bank angle of 0°)

Figure 8. Mosaic image of three aerial photographs taken at different aircraft altitudes, headings, and bank angles.

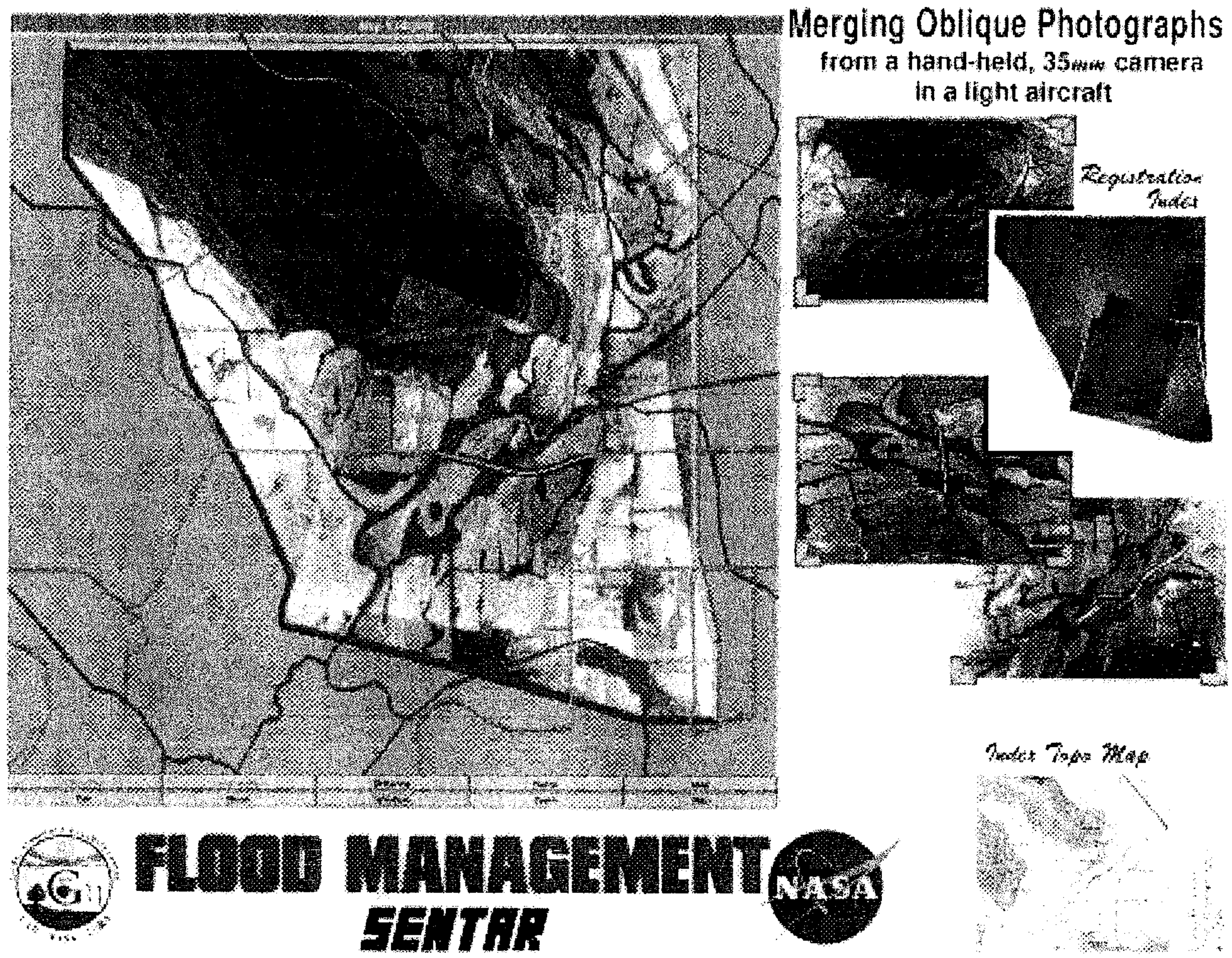


Figure 9. Slide summarizing the process of mosaicing three images to create a composite of the aerial photograph images.

A side benefit of the aerial photographs it that provides current information on some of the feature data of the GIS data layers as well as providing information on the effect of the disaster. Specifically, in the test images along the Flint River, we were able to see how roads have been changed or added. Similarly, changes in streams were noted, primarily due to manmade changes for road construction or agricultural reasons. This side benefit is significant because it can provide emergency management staff with more accurate representations of the area than in the feature data layer and because it can provide those familiar with the area with greater confidence in the GIS-based system. When the GIS data layers do not accurately reflect the spatial feature as the user knows it, the user loses confidence in the entire data layer and eventually the system itself.

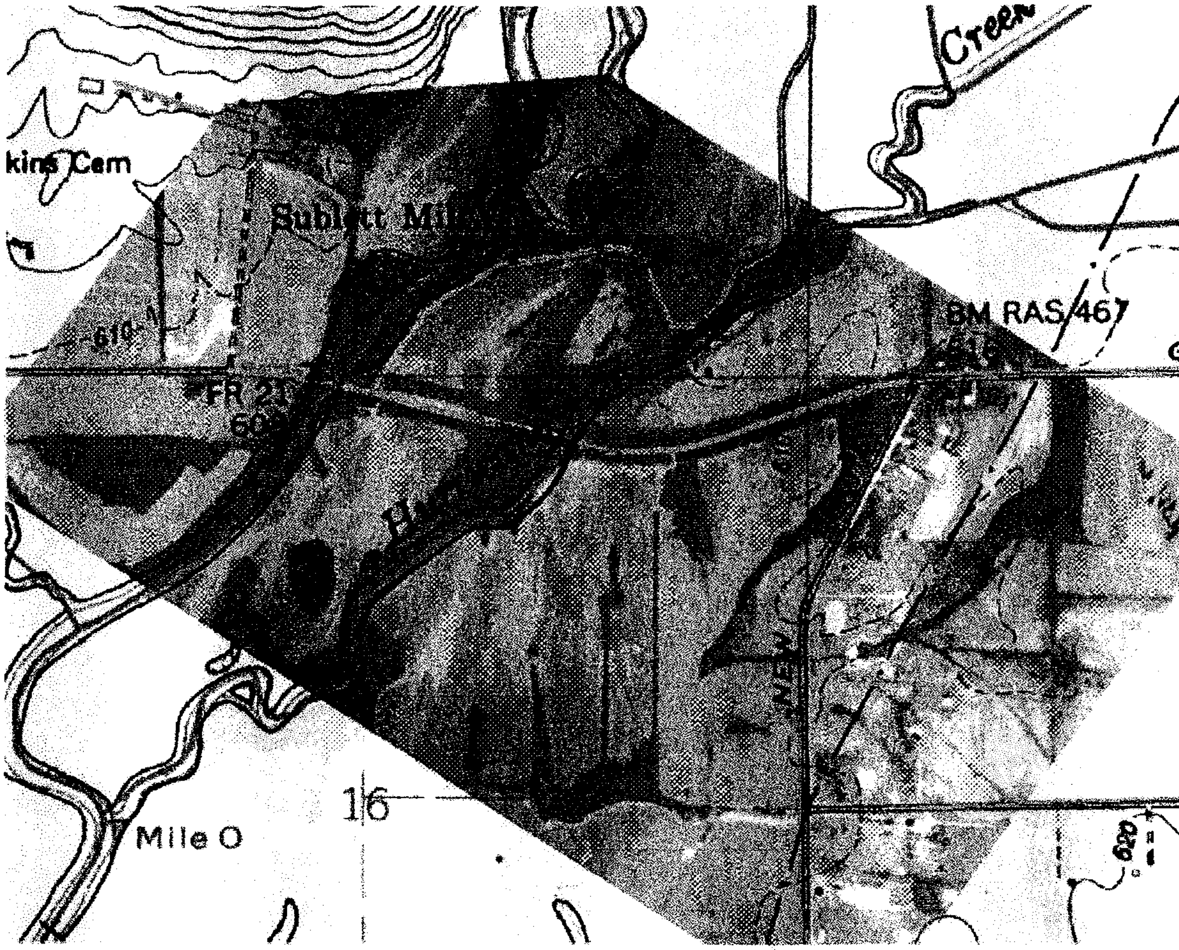


Figure 10. Example of a static map composed of an aerial photograph, USGS hardcopy map image, and vector feature data for roads and hydrology.

The use of satellite and professional imagery will always be a primary source of remote sensing data where available, however this effort has also shown that the use of non-professional, oblique-angle aerial photography also can be of value to emergency managers.

PROTOTYPE SYSTEM

Overview. The prototype system developed by SENTAR and its collaborators for integrating remote sensing data into a GIS for emergency management operations is illustrated in the Figure 11. The central components of this system are the Emergency Operations Center (EOC) and the Data Processing Center. These two centers are supported by various data sources and the EOC is itself a data provider to the County Emergency Management offices, remote filed personnel, FEMA, and even the general public. The Data Processing Center produced a baseline set of GIS data coverages from US Government agencies and state sources and a set of Landsat TM images from the EROS Data Center (one of the EOSDIS DAACs) for the regions of the state covered by the prototype system. These data sets will be supplemented with other remote sensing data products as disasters are encountered. Additional data sets for actual floods may come again from the EOSDIS or from other satellite data providers or from aerial photography. These data that are to be georectified will be processed and reformatted at the Data Processing Center and then sent to the EOC for usage by the emergency managers. Remote sensing data not requiring georectification or reformat processing will go directly to the EOC for usage.

At the EOC, the database of the baseline GIS and remote sensing data is supplemented with additional GIS data coverages generated from spatial data provided by other state agencies. The emergency managers use the baseline and current data sets within their GIS software and other viewing tools to generate image analyses of the potential flood area, the actual flood area, or flood damage assessment. By combining the GIS and remote sensing data, they are able to obtain information not possible with only one data type. The views of the combined data sets they create can be captured and sent to County Emergency Management offices, remote field_personnel, and FEMA, as appropriate. In the future, it is planned to also provided selective information directly to the public via a Web site and via the state television broadcasters.

The primary tool the EOC staff will use is ArcView, a commercial GIS software package. In addition, they will access various Internet sources for Web-based information, FTP and Gopher sites, and contact with other emergency management professionals. SENTAR has developed a graphical user interface to facilitate the accessing of the various applications for ArcView, the Internet retrieved data, and other PC-based tools that they currently use through a single interface. This interface application is called the Emergency Management Operations (EMO) Tool.

Software Modules. The prototype system consists of a set of commercial-off-the-shelf (COTS) applications integrated under a common user interface, called the Emergency Management Operations Tool. The system makes extensive use of existing software products at the Alabama EMA to provide system functionality wherever possible. Where these software packages did not meet the functional needs of the prototype system, SENTAR developed software applications and utilities. Three software components were developed for this project, they are:

1. Emergency Management Operations (EMO) Tool
2. Vector/Raster Data Formatter
3. Data Retrieval Scripts.

The EMO Tool resides on the PCs of the EOC staff, the vector/raster data formatter operates on PCs at the Data Processing Center, and the data retrieval scripts operate on the Sun server at the EOC; refer to Figure 11.

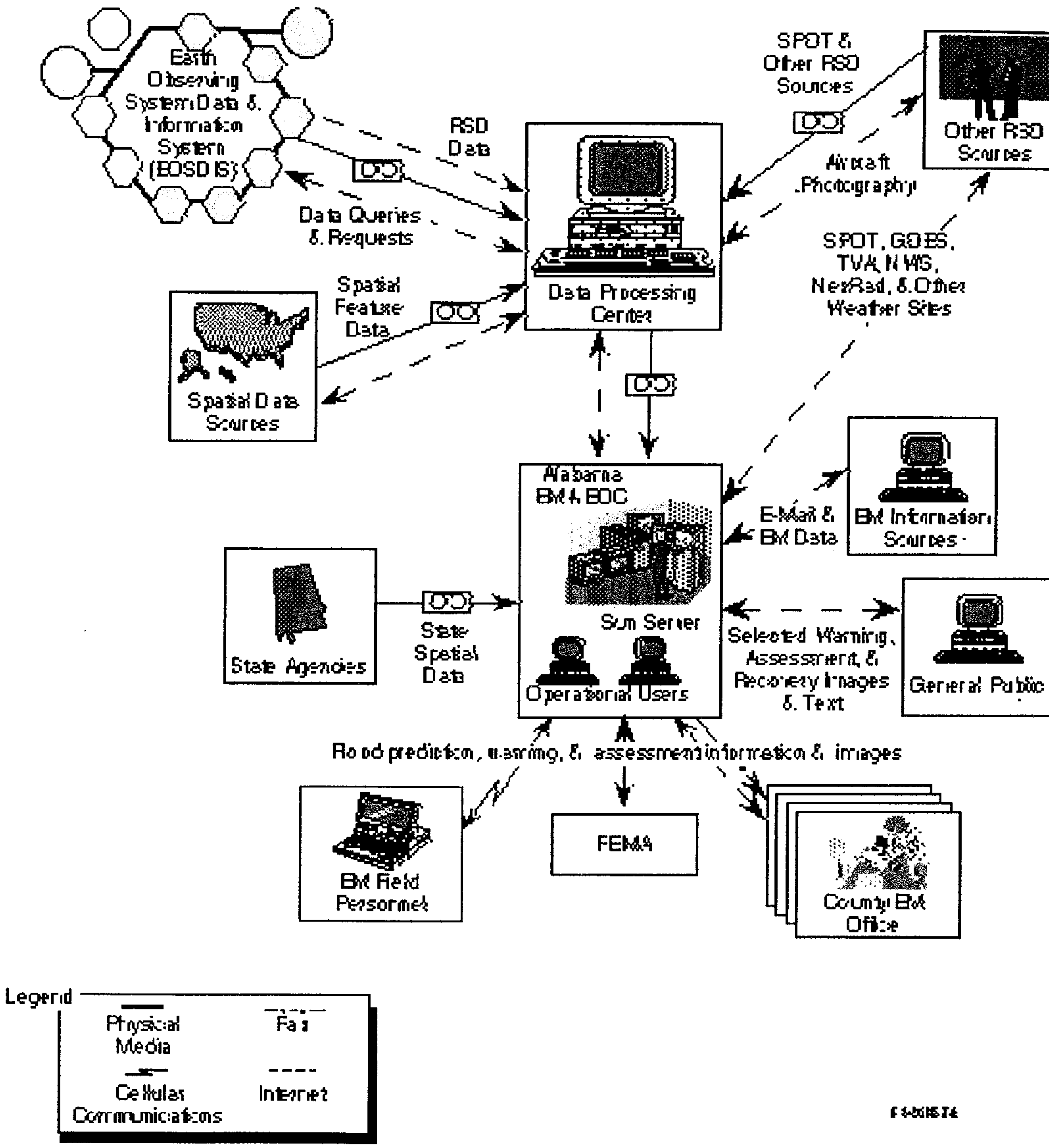


Figure 11. Prototype system concept.

Two of the three software components were installed on the appropriate platforms. These consist of the EMO Tool and the Vector /Raster Data Formatter. The Data Retrieval Scripts were not actually installed on the Alabama EMA server for testing as they did not have direct Internet access for the demonstrations. Instead, these were run form SENTAR's ISPs computers.

EMO Tool. The EMO Tool provides the EOC staff with a single user interface for the COTS applications integrated into the prototype system for access by the operations staff from their PC's, thus allowing separate COTS applications to be integrated into one package. The interface to the EMO Tool easily allows the EOC staff to acquire and view data downloaded off the

Internet (such as GOES, and radar images along with NWS forecasts and warning bulletins). The tool also executes and spawns external applications at the touch of a button, most notably the ArcView GIS software, without having to locate icons within program groups or search in directory paths.

The prototype tool was developed in Visual Basic 4.0 as a 16-bit application and runs under the Window 3.1 and Windows 95 operating systems. The tool has been composed with pre-developed drop and drag components, making future enhancements easy to add on. Figure 12 shows the EMO Tool display with samples of retrieved image and text files.

The tool has been broken down into 4 modules with the first being the graphical user interface (GUI) (see Figure 12). The GUI is composed of a variety of push buttons and pull down menus. These buttons and menus give choices to the staff as to what area they might be interested in within the state of Alabama for viewing radar or weather bulletins from that location.

The second module is an internal viewer for the tool. Although the tool supports an external web and resource browser such as Netscape or Mosaic, development called for the operation of a

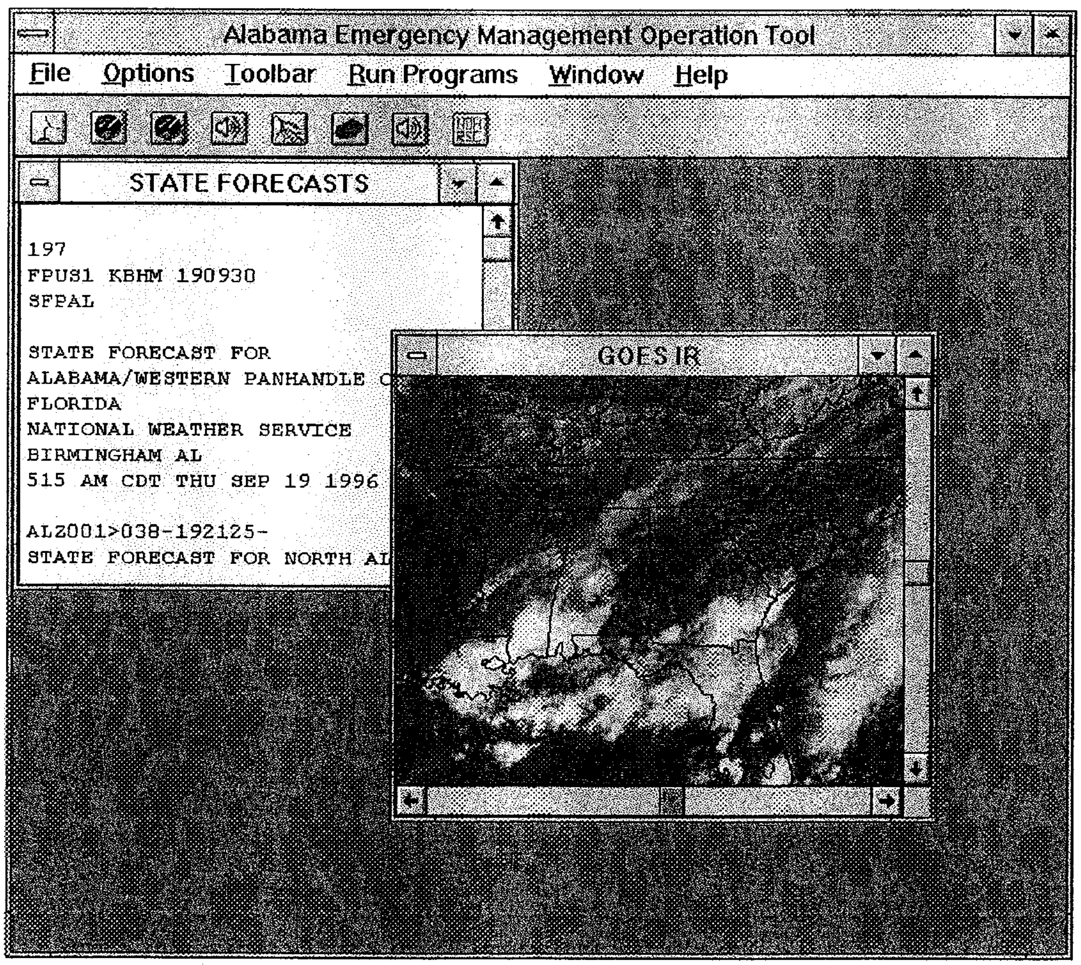


Figure 12. Prototype of Emergency Management Operations Tool

hands-off internal viewer. The internal viewer supports image formats in the form of GIF, JPEG, and TIFF and ASCII text file formats from both PC and UNIX computers. The tool allows the user to bring in multiple images/ASCII text files each having its own scrollable window. This multi-image/text ability allows the user to view several files at the same time.

The third module is the internal source code for the image and text file retrievals and routine pop, pull and refresh code for the windows functions. The source data file retrievals are performed outside the tool application on the SUN server, utilizing the data retrieval scripts which are described later. The EMO Tool instead takes images and text files from designated storage locations on the server and load them into the internal viewer. The reason for extracting these files from the server rather than directly from the remote computers, is to conserve the bandwidth of the EOC's Internet connection and to insure that common versions of the files are used by all emergency managers.

The fourth and final module is the help utility. As with many commercial packages, help files come with separate help documents separate from the application itself. Though the use of the file menu system in the EMO Tool, internal on-line help information is supported. These files provide instructions for each button and menu and provide the user with pictures of how to operate the tool. The software for the help file functionality is provided by the VB HelpWriter utility. Figure 13 shows a sample of the help utility display for the icon buttons.

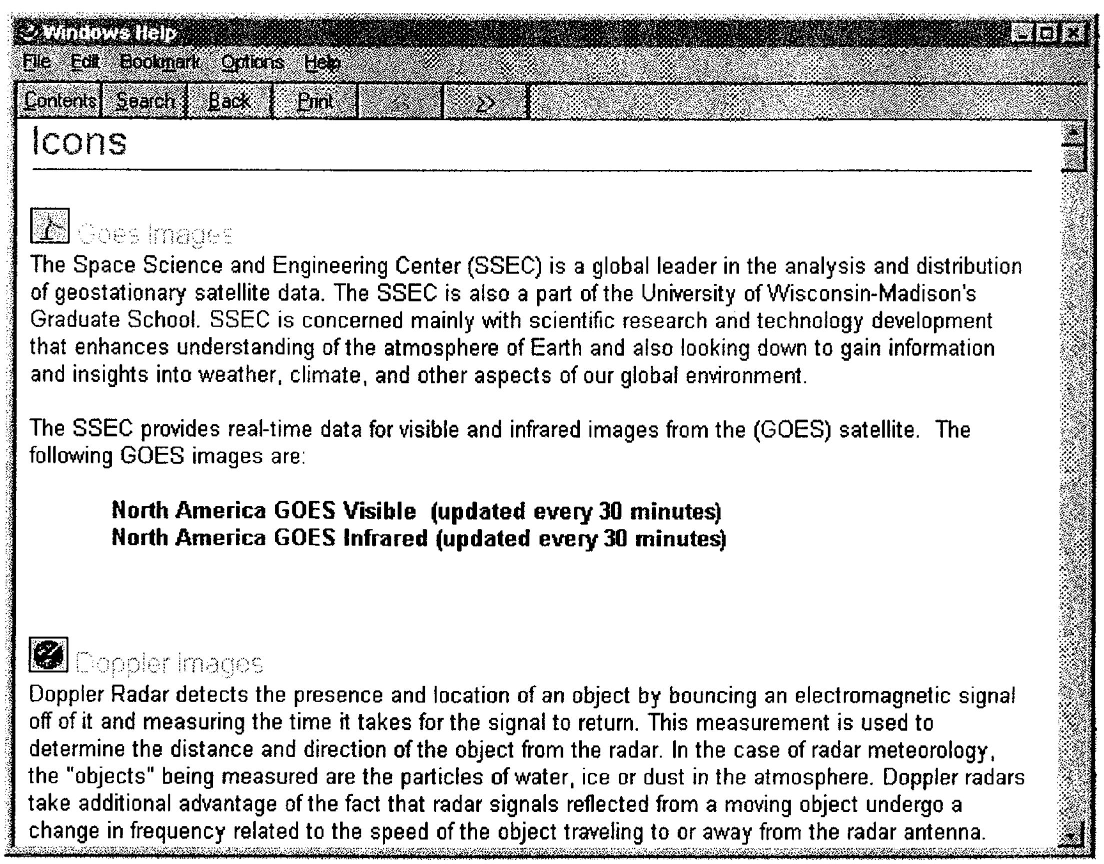


Figure 13. Sample display from the EMO Tool help utility.

Vector/Raster Data Formatter. SENTAR is using of the Map-X remote sensing software to perform the image processing functions of georeferencing and feature classification. Map-X's ability to perform 3rd-order georectification provides the SENTAR team with the ability to work with imagery from high-end satellite data down to low quality 35m aerial photography on a standard PC platform. The limitation to using Map-X was the inability to export processed images into the ARC/INFO and ArcView packages while retaining the georeferencing information because of proprietary file formats. With help from the Map-X developer, Delta Data Systems, in terms of providing the output file format information, SENTAR was able to develop the vector/raster formatter.

The vector/raster data formatter converts raster imagery from Map-X format to the common Band Interleaved by Line (BIL) raster file format for both single and multi-band images. The formatter creates various description files associated with the BIL file: a header file that describes the layout of the image pixel data, a color file that describes the image color map, a statistics file that describes image statistics for each band of the image, and two other text files that break down the internal components of the image file and also describe the format of the first channel.

The formatter was developed using the Visual C++ language. It takes full advantage of new input/output stream functions in C++ due to the size of the complex imagery. The utility itself goes by the name AIF2BIL because of its creation of a BIL file from Map-X's .AIF file.

Data Retrieval Scripts. SENTAR's design concept makes extensive reuse of existing software products to provide system components wherever possible. In the case of data retrieval scripts it was in the best interest of SENTAR to reuse pre-developed scripts and utilities from the University of Texas and RSPAC.

The data retrieval script developed by SENTAR is a UNIX-based script which will reside on the SUN server at the EOC. The script is composed of function calls to a small Perl utility called url_get. Url_get was written to retrieve documents specified by their Uniform Resource Locator (URL) on the World Wide Web. Through these calls, the script download radar and satellite GIF/JPG images, along with gopher NWS forecast ASCII text pages. Other portions of the script use the standard File Transfer Protocol (FTP) to download files from those sites that support direct anonymous FTP services. All of the ASCII text files and images will be stored on the EOC server. These files will then be retrieved from the server by the EOC staff via the EMO Tool.

The retrieval scripts primary purpose is to help in the automatic retrieval of specified files, while conserving bandwidth used by EOC staff during emergency management operations. The script will be placed in the EOC server's cron tab giving only the system administrator the proper permissions on how often it should be executed and which URLs are to be downloaded. This module is complete except for inclusion of the final set of URLs and final testing on the EOC server.

GIS Data Layer Development. The SENTAR staff worked closely with the Alabama EMA staff to determine the spatial data necessary to support emergency management operations for all disasters. TABLE 3 identifies these data categories, or layers, and groups them under 13 thematic areas. The data layers and the associated data attributes are listed in TABLE 4. The data layers and attributes per data layer were agreed upon by the appropriate staff at Alabama EMA. During the final review of the data layers, the Alabama EMA staff identified potential source departments and agencies for the data layers that consist of state controlled or generated data. SENTAR supported Alabama in attempting to acquire the data from the appropriate state agencies. Telephone contacts were made to verify that the state agency have the needed data and to begin the process of characterizing the data currency, format, and storage media. Most of the data are available, but the quality and currency varies significantly. In addition, most of the data are not in electronic format and almost none of it is in a spatial database. Several agencies stated that they are now in the process of designing a spatial database for the data, however, none was available during the duration of this project. Thus, what the data was aquired was manually incorporated into an ArcView data coverage.

TABLE 3
THEMATIC GROUPS OF DATA LAYERS

THEME	DATA LAYERS		
Hydrology	FEMA Flood Maps Hydrography Lake Levels Streamflows	Wetlands (D) USACE Flood plains	Snow & Rain Accumul. (D) Coastal Hydrology
Utilities	EAS Radio Coverage Doppler Radar (D) Burn Sites Sewer Systems	Fresh Water Systems Fuel Facilities Water/Sewer Treatment Plants	Transmission Lines (D) Electric Power grid (D) Solid Waste Sites
Geology	Surface Geology (D)	Elevation Contours	
Boundaries	Military Installations Built-Up Areas County Bound. International Bound.	Local Government Bound. State Administrative Bound. Federal Administrative Bound. Census Geography	Facility Bound. Military Leased Lands Restricted Areas
Socioeconomic	Demographics (population)	Demographics (over 55)	Economic (income) (D)
Geodetic	USGS Control Points		
Hazards/ Environmental	Hazardous/Toxic/ Radioactive Wastes	Medical Wastes Hazardous Materials	
Man-Made Features and Structures	Nuclear Plants Fire Departments EOCs Roads & Streets Maritime Ports	Bridges Airports Hospitals Police Departments Designated Shelters	Pipelines Railroads Power Plants Gov't Man-Made Structures
Photogrammetric	Photos and Imagery		
Cultural Resources	Historical Standing Sites and Graveyards		
Land Use/Land Cover	Land Cover/Land Use		
Emergency Planning Enhancements	Evacuation Routes	Disabled, Nursing Homes	
Remote Sensing	Water Classification TVA Lake & Streamflow Data	Flood Warnings Snow Cover	Surface Temperature

TABLE 4
PROTOTYPE SYSTEM GIS DATA LAYERS

Priority [see note]	Data Layer	Data Source		Attributes	
		Primary	Secondary	No.	Names
1. Hydrology					
1	Hydrography	TIGER	USGS DLG	2	Feature Name, Census Feature Class Code (CFCC)
1A	FEMA Flood Data	FEMA	Insurance Institute	6	Area, Map Parcel, Flood Way, Hazard Zone, Flood Elevations, FIPS Code
1A	USACE Flood Plain	USACE		4	Area, Hazard Zone, Flood Elevations, FIPS
2	Coastal Hydrology	SeaLAB of Dolphin Island			TBD based on source data
Deferred	Wet Lands	US Fish & Wildlife	USGS		
Deferred	Snow and Rain Accumulation.	DLG			
2. Utilities					
1	Fuel Facilities	ADEM	TIGER, Counties & Cities	6	Type (well, tank farm, storage), Capacity, Capacity Units, Contents, State (solid, liquid, gas), By-products
1	EAS Radio Coverage	State	NOAA	4	Transmitter Name, Address, POC, Telephone #
1A	Fresh Water Systems	ADEM	Counties & Cities	3	Type (other, water lines, aqueduct), Diameter, Facility Name
1A	Sewer Systems	ADEM	Counties & Cities	2	Diameter, Facility Name
1A	Water/Sewer Treatment Plants	ADEM	Counties & Cities	5	Name, Address, Type, Diameter, Owner
2	Solid Waste Disposal Sites	ADEM	Counties & Cities	4	Type (public, private) Waste Type (inert, tires, construc-tion debris, concrete & block), Facility Name, Address
2	Burn Sites	ADEM	Counties & Cities	6	Type (public, private), Waste Type (medical, POL, other), Facility Name, Address
Deferred	Transmission Lines	FEMA	DLG		
Deferred	Electrical Power Grids				
Deferred	Doppler Radar				
3. Geology					
1	Elevation Contours	USGS DEM	DMA DTED	2	Type, Elevation
Deferred	Surface Geology	State, USGS Maps			

4. Boundaries					
1	County Boundaries	TIGER	USGS DLG	2	State, County (FIPS)
1	State Admin. Boundaries	TIGER		3	State, Type, CFCC
1	International Boundaries	TIGER	USGS DLG	2	Type, ID Code
1	Local Boundaries (cities, etc.)	TIGER		3	Local Name, County, State
1	Federal Boundaries (parks, etc.)	AL Conservation Department			TBD based on source data
1A	Military Installation	Military Installations	USASSDC, USGS, Maps	2	Type, ID Code
2	Built-Up Areas	TIGER		1	Name
2	Census Geography	TIGER			TBD
3	Restricted Areas	State, Military Installations	Counties & Cities	4	Area Name, Managing Agency, Type
3A	Facility Boundaries	Gov/Military Installations		2	Name, Type
3A	Military Leased Land	Military Installation	None	2	Type, ID Code
5. Socioeconomic					
2	Demographics (population)	TIGER	USGS DLG	5	State & County Names, Block & Group, Number, Housing Units
2	Demographics (over 55)	TIGER	USGS DLG	5	State & County Names, Block & Group, Housing Units
Deferred	Economics (income)				Income and House Values
6. Geodetic					
2	USGS Control Points	USGS		1	ID Number
7. Hazards/Environmental					
1A	Hazardous/Toxic/Radioactive Waste	ADEM	Counties, Cities & Military Installations	3	EPA Number, Facility Name, Address
1A	Hazardous Materials (also private incinerators, medical waste)	ADEM	Counties, Cities & Military Installations	3	EPA Number, Facility Name, Address
2	Medical Waste	ADEM			
8. Man-Made Features and Structures					
1	Roads and Streets	TIGER	USGS DLG	5	CFCC, Feature Name, Feature Type, Alt. Feature Names
1	Airports	DMA DAFAF	USGS DLG	2	Feature Name, No-Fly Zone
1	Railroads	TIGER	USGS DLG	3	CFCC, Feature Name, Feature Type
1	Nuclear Plants	State	EIS, FEMA	5	Site Name, Category, Type (technology), Buffer Dist., Operations Phone #, Street Address
1	EOCs	AEMA		3	EOC Name, Address, Phone #

1	Hospitals	AL Dept. of Public Health	FEMA, TIGER	4	Name, Operations Phone #, Address, Number of Beds
1	Designated Shelters	AEMA		4	Shelter Name, Hazard Type, Address, Phone #
1A	Bridges	AL DOT		3	Load Capacity, Overhead Clearance, Elevation
2	Pipelines	County, City, State, Military Installations	Corps of Engineers	4	Owner, Type, Diameter, Contents
2	Power Plants	State, TVA, APC, Co-Ops, Military Installations	Counties & Cities	5	Facility Name, Category, Owner, (classification), Address, Phone #
2	Government Man-Made Structures	State, Military Installations	Counties & Cities	5	Description, Owner, Type (city, county eng office, county courthouse, Gov level, etc.) Address, Phone #
3	Maritime Ports	SWSA		1	Name
3	Police Departments	State, Counties & Cities		3	Dept. Name, Operations Phone #, Address
3	Fire Departments	AL Fire College	Counties & Cities	4	Type (public, volunteer, private, commercial), Name, Operations Phone #, Capabilities (bomb, HAZMAT)
9. Photogrammetric					
1	Photos and Imagery	EDC, Aircraft Photos	SPOT	6	Source, Image type (picture, satellite, movie, TV), Registration Lat./Long., Resolution, Tile #, Image Date
10. Cultural Resources					
3	Historic Standing Sites and Graveyards	Historical Commission	National Historic Registry	4	Facility Name, Owner, Phone #, Type (including maritime sites, prehistoric archeological sites, Native American sites)
11. Land Use/Land Cover					
3	Land Use/Land Cover	USGS DLG	Counties & Cities	1	Type
12. Emergency Planning Enhancements					
1	Evacuation Routes	AEMA	County EMAs	1	Route Type
1	Disables, Nursing Homes	AL Commission for the Aging		3	Facility Name, Owner, Phone #, Number of Beds, Address
13. Remote Sensing					
1	Land/Water Classification	EDC, Aircraft Photos	SPOT	5	Class Type, Location, Source, Projection, Date

1	TVA Lake & Stream Flow Data	TVA		5	Sensor Type, Name, Location, Sensor Value, Date, Time
1	Flood Warnings	NWS	Floodwatch	4	Source, Type, Start Time/ Date, End Time/Date
2	Surface Temperature	NOHRSC			Temperature
2	Snow Cover	NOHRSC			Cover Type

Note: Priority definitions

1	Top priority, must be included in initial version
2	Desirable for initial version if data availability and resources permit
3	Lowest priority, deferred to a follow-on effort
A	If available
Deferred	Lesser priority data layer; deferred to another effort
Dropped	Determined not to be needed at the installation EOC

The desired data layers of TABLE 3 were divided into three categories: Those that can be produced from the U.S. Census Bureau's TIGER data, those that can be obtained form other federal agencies, and those that will be obtained from state sources. TABLE 5 lists the data coverages that were produced for the prototype system from the desired data coverages for these three categories.

SENTAR contracted out for new sets of these data layers using the most current version of TIGER data. These data layers were supplemented with data layers that were provided by the U.S. Army from the Integrated Disaster Planning Package (e.g., the Redstone Arsenal boundary). TIGER data for the counties of northern Alabama and southeast Alabama were combined and the composite vectors were processed to correct for proper edge matching at the county boundaries, dangling vectors, and open polygons. The completed data coverages were delivered to SENTAR and a quality check of the data was performed prior to installing the data coverages onto the Alabama EMA server.

The TIGER-derived data layers are essentially the data layers that were provided by the US Army from the Integrated Disaster Planning Package (IDPP) which used as a starting point for the data coverages on this project.. SENTAR contracted out for new sets of these data layers using the most current version of TIGER data. The TIGER data for the counties of northern Alabama and southeast Alabama were combined and the composite vectors were processed to correct for proper edge matching at the county boundaries, dangling vectors, and open polygons. The completed data coverages have been competed and provided to SENTAR.

The next category are the other federal agencies. For these data layers the desired data are either already on-line or available via electronic media with the except of the Flood Insurance Rate Maps (FIRM). FEMA developed digital FIRMS for 19 counties in Alabama, which are part of the Digital Q3 Flood Data. These data were purchased and received from the FEMA Map Center during the sixth milestone period. All 19 counties will be installed on the Alabama EMA server during the coming milestone.

TABLE 5
DATA LAYERS BY BROAD DATA SOURCES

Data Source	Data Layer
TIGER	Hydrology, boundaries (local, county, state, military, and international), urban areas, block group, voting district, school district, demographics (census tract), interstate highways, roads and streets, railroads, airports, runways,
Other Federal Agencies	Flood Insurance Rate Maps, elevation contours, surface geology, USGC control points, land use/land cover, surface temperature, snow cover, flood warnings
State Agencies	Fuel facilities, EAS radio coverage, fresh water systems, sewer systems, water/sewer treatment plants , solid waste disposal sites, burn sites, federal boundaries, hazardous/toxic/radioactive waste, hazardous materials, medical waste, nuclear plants, EOCs, hospitals, designated shelters, bridges, pipelines, power plants, police and fire departments, historic standing sites and graveyards, evacuation routes, nursing homes

For the state agency data, Alabama EMA sent out formal letters requesting the desired data. Responses from some of the agencies have been received. These were followed up with contact by SENTAR to discuss the details of the proposed data transfers. Data has been provided by Alabama Power commission and the construction of the power plant and nuclear power plants has begun. Additionally, the Alabama Historical Commission is collecting the requested data for the historical standing sites and will release data to the Alabama EMA when compiled. The Alabama Department of Environmental Management (ADEM) has agreed to the release of their data, which will provide data for most of the state data coverages. They are, however, now in the process of putting all their data into a GIS, so the delivery of the requested data will be delayed until the new ADEM GIS is built.

FUTURE ACTIVITIES

The primary goal for future activities is to turn this prototype system into an actual operational system at Alabama EMA, and then at other state or county EMA offices. The specific activities to be performed are:

1. Work with the EMA operational staff to define specific outputs from the integration of the remote sensing data and GIS data in ArcView based on their standard operation procedures for floods or other disasters.
2. Expansion of the data coverages for those data categories that are controlled by the state agencies.
3. Build an archive of processed satellite and aerial, photography.
4. Refine the satellite image files that are packaged on a CD to meet the specific usage needs of the EMA staff; this may mean providing single band files or subsetting the Landsat image into two or four images for easier handling.
5. Pursue the initial efforts to support more predictive tools by combining of soil moisture, precipitation data, and river or lake levels; with particular attention to the use of the greater detail digital elevation model data now becoming available.

APPENDIX B

CD README AND PROCESSING DESCRIPTION FILES

CD Contents Listing in Readme.txt file:

SENTAR CD97-001 April 1997

Landsat TM Image Data
Path 19/Row 38, Acquisition date: April 10,1993

This file should be viewed using a non-proportional font, such as Courier.

This CD contains raster and vector data products derived from Landsat TM imagery for southeast Alabama. These products are formatted for use in ArcView 3.0 or compatible software. Files specific to the software which was used to do the data processing (MapX by Delta Data Systems, tel. 601-799-1813) are in the MAPXFILE folder.

This is one of a series of 4 CDs. INDEX.GIF shows the location of this data set and the other satellite imagery in the series with respect to the state and county boundaries.

The data processing was done by SENTAR, Inc. with the assistance of the Global Hydrology and Climate Center, which is part of NASA's Marshall Space Flight Center (MSFC). This work was sponsored by a NASA Goddard Space Flight Center (GSFC) Cooperative Agreement and is intended to support the Alabama Emegerncy Management Agency.

For a discussion of the data processing see the file PROCESS.TXT

Points of Contact:

Greg Romanowski and Greg Hodges, SENTAR, Inc.

4910 Corporate Drive, Suite C, Huntsville, AL 35805
205-430-0860, sentar@iquest.com
Doug Rickman, Global Hydrology and Climate Center
977 Explorer Blvd.
Huntsville, AL 35806
205-922-5889, doug@hotrocks.msfc.nasa.gov

CD TABLE OF CONTENTS

INDEX.GIF	TM image (band 5) with state and county boundaries.
PROCESS.TXT	Description of data processing used.
README.TXT	This file.

ALLBANDS Folder

TM019038.BIL	
TM019038.CH1	Six band image of TM bands 1-5 and 7 with raster data
TM019038.CLR	(bil), color table (clr), channel 1 (ch1), header (hdr),
TM019038.HDR	and text (txt) files
TM019038.TXT	Projection is UTM and Datum is NAD 1983

ARC_FILE Folder	Water Classification folder of ARC/INFO vector files
TM019ARC.DBF	Water classification files for bands 1 and 6 in
TM019ARC.SHP	ARC/INFO export format (.e00) and
TM019ARC.SHX	ArcView shape file formats for arcs and
TM019PLY.DBF	polygons(*arc.* and *ply.*, respecitively)
TM019PLY.SHP	Projection is UTM and Datum is NAD 1983
TM019PLY.SHX	
TM019038.E00	

IMAGES Folder

STCI1938.TIF	Simulated True Color Image for bands 7-5-1, R,G,B
STCI1938.JPG	in TIFF and JPEG image formats

MAPXFILE Folder

empty

STCI Folder

STCI1938.BIL	
STCI1938.CH1	Simulated True Color Image, bands 4, 3, and 2 for red,
STCI1938.CLR	green, blue with raster data (bil),color table (clr),
STCI1938.HDR	channel 1 (ch1), header (hdr), and text (txt) files
STCI1938.TXT	

WATER_CL Folder

SCT_1938.BIL	Water classification generated from scattergram from
SCT_1938.CH1	Bands 1 and 6,
SCT_1938.CLR	with raster data (bil), color table (clr),
SCT_1938.HDR	channel 1 (ch1), header (hdr), and text (txt) files
SCT_1938.TXT	

Landsat TM Data Processing Description in Process.txt file:

April 1997

Landsat TM Image Data Processing

SENTAR purchased and processed Landsat TM imagery for use by the Alabama Emergency Management Agency. The processed Landsat TM imagery is intended to be used as backdrop images within a vector GIS by showing ground vs. water during non-disaster (flood) conditions. The imagery has also been processed using a two-band scattergram to produce for water classification and vector representations.

The satellite data processed consist of four Landsat TM images. These cover potions of northern Alabama and the southeast and south central portions of the state. The raster image processing and conversion from raster to vector was done using the Map-X remote sensing software, made by Delta Data Systems, tel 601-799-1813.

1. The source data were reformatted into Map-X format. This consisted of reformatting the individual satellite bands and combined them into single file of all six bands. This file was subsequently converted into BIL format for exporting to ArcView and is contained on this CD in the ALLBAND folder.

2. Three of the six bands were combined in Map-X to make a color composite. A Map-X algorithm was applied to generate a single band (8 bit) image that simulated a true color (24 bit) image. This was also exported into a BIL format. This file is contained in the STCI folder.

3. A water classification was produced on the Landsat image using a two-band scattergram within Map-X. The basis for this step is the fact

that water is darker in the two TM bands used than other land covers. For some images, this raster classification file was further processed using a median filter to eliminate single water pixels (presumably ponds and/or image noise) throughout the image. The final raster file containing the water classification was converted to a BIL format and is in the WATER_CL folder.

4. The boundary for the water classification was then converted into a vector representation from the raster image. The vector file is converted into the CAD format .dxf for exporting to ARC/INFO. The vector files of the water classification in Map-X and CAD formats are contained in the MAPXFILE folder.

5. Once in ARC/INFO, the vector file is again converted. This time to the ARC/INFO.e00 format. It is this last format that can exported to ArcView. The ARC/INFO and ArcView formatted versions of the vector water classification are contained in the ARC_FOLE folder.

6. Images of the single band, multi-band Landsat TM data and the Map-X scattergrams are also provided in non-georeferenced TIF and in the JPEG format. These are in the IMAGE folder.

APPENDIX C

NASA/FEMA CONFERENCE ON GIS AND APPLICATIONS OF REMOTE SENSING

Marshall Space Flight Center

Application of Satellite and Aerial Imagery to Enhance Emergency Management Operations for Floods

Presentation to the

Conference on GIS and Applications of Remote Sensing to Disaster Management

January 15, 1997

S•E•N•T•A•R, Inc.

Information Technology Solutions for Complex Systems

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97-0133

Public Use of Earth and Space Science Data over the Internet

This project is a cooperative agreement with the **Information Infrastructure and Technology Applications (IITA)** component in NASA's high Performance Computing and Communications Program.

The goal of IITA is to:

"...accelerate the implementation of a National Information Infrastucture through NASA science, engineering, and technology contributions."

IITA Web Address: http://iita.ivv.nasa.gov/iita1.html

The NASA ***IITA Public Use of Earth and Space Science Data over the Interne program*** goal is:

"... to stimulate broad public use, via the Internet, of the very large remote sensing databases maintained by NASA and other agencies to stimulate U.S. economic growth, improve the quality of life, and contribute to the implementation of a National Information Infrastructure."

Program Web Address: http://rsd.gsfc.nasa/rsd
Public Access Center Web Address: http://www.rspac.ivv.nasa.gov

Concept For Enhanced Emergency Management for Floods

The system concept is to use remote sensing data sets from the NASA DAACs, or other data providers, to produce new data layers that are integrated into a commercial Geographical Information System (GIS). These new data layers, when incorporated with the geographical, infrastructure, and demographic data in the GIS, will provide the Alabama Emergency Management Agency with additional capabilities for addressing flood related disasters.

The second component of the system concept is to use the Internet as the primary communication path for transferring remote sensing data and data products from the data providers to the processing center, and then to the Alabama Emergency Management Agency and its staff in the field.

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Project Goal and Objectives

- Goal
  - To develop a GIS-based, prototype system for enhanced emergency management of floods that: 1) utilizes Remote Sensing Data (RSD), the Internet, and existing software products and 2) is readily expandable into an all-hazards tool for use throughout Alabama or anywhere the necessary source data is available.
- Objectives
  - 1. Identify RSD, particularly from NASA's DAACs, that have the potential to enhance flood management
  - 2. Develop and demonstrate a prototype system for utilizing RSD for flood management by Alabama EMA staff
  - 3. Demonstrate the value added of RSD for emergency management operations
  - 4. Demonstrate the feasibility of using the Internet as the communication network from the DAACs to end user.

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Available Data Sets

Vector Data

- TIGER -- 13 coverages from TIGER 94 data covering 30 Alabama counties
- FEMA Q3 Floodplains -- 1% and 0.2% flood zones for 19 Alabama counties
- Imagery derived water boundary -- aera coverages correspond to the Landsat TM image areas

Raster Data

- Four Landsat TM images covering the northern and south eastern portion of Alabama
- Images provided as multiband images including all visual bands, a simulated true color image, and a water classification image
- Sample aerial photography from USGS and SENTAR photos

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TIGER Data Coverages

Counties

Northern
- Blount
- Colbert
- Cullman
- DeKalb
- Etowah
- Franklin
- Jackson
- Jefferson
- Lauderdale
- Lawrence
- Limestone
- Madison
- Marshall
- Morgan
- St.Clair
- Walker
- Winston

Southeastern
- Barbour
- Bullock
- Coffee
- Covington
- Crenshaw
- Dale
- Geneva
- Henry
- Houston
- Macon
- Montgomery
- Pike
- Russell

Data Coverages

- Census Tract/Block Groups
- Streets, roads, highways
- Insterstates
- Waterways, rivers, other water features
- Airports and airfields
- Railroads
- State and county boundaries
- City and Township boundaries
- School districts
- 104th Congressional districts
- Voting districts
- Apartment complexes
- Trailor parks
- Shopping centers

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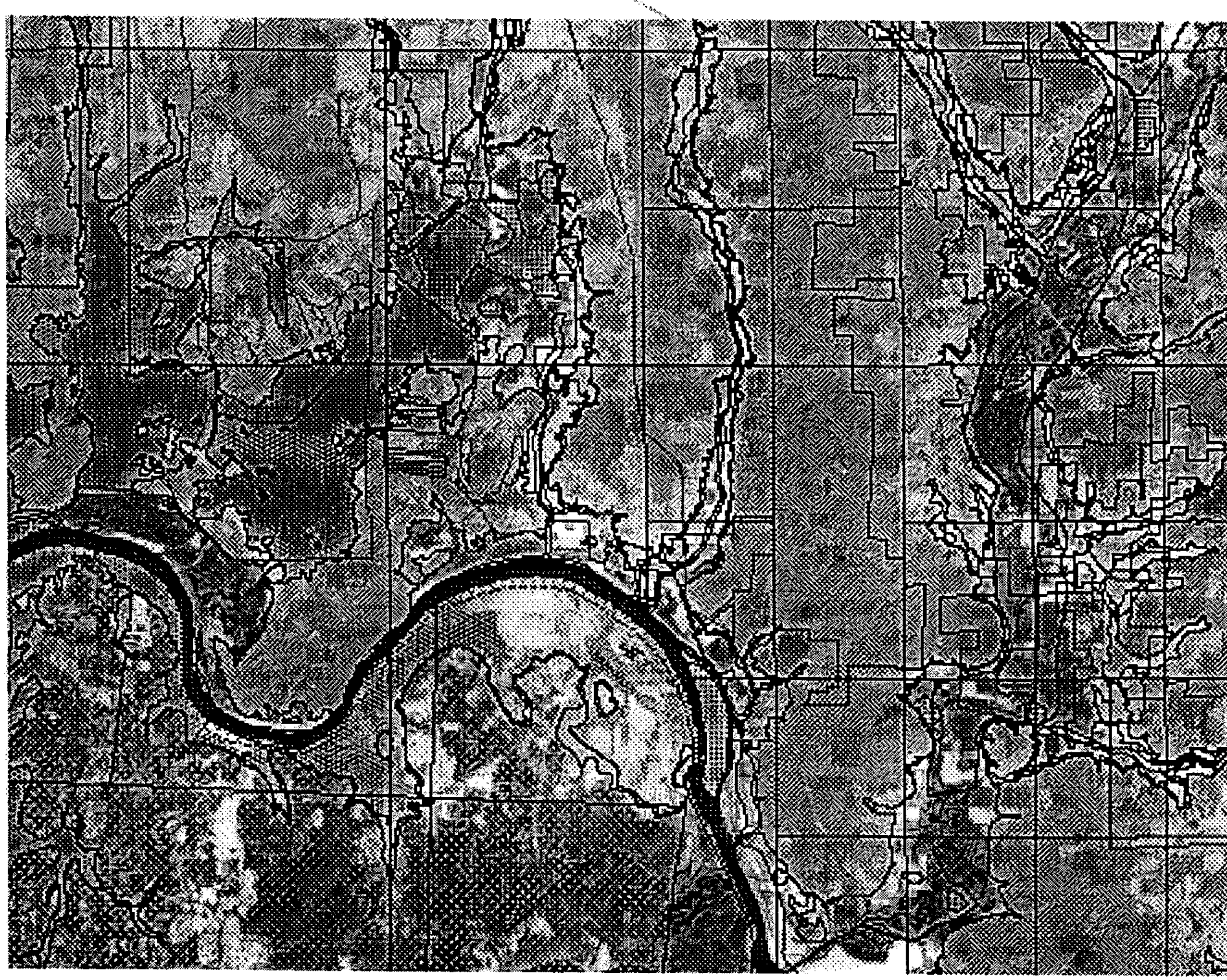
Combining Aerial, TIGER, and FEMA Q3 Data



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97-0133

GIS Data Coverages for the Alabama EMA

THEME	DATA LAYERS		
Hydrology	FEMA Flood Maps Hydrography Lake Levels	Wetlands (D) USACE Flood plains Streamflows	Snow & Rain Accumul. (D Coastal Hydrology
Utilities	EAS Radio Coverage Doppler Radar (D) Burn Sites Sewer Systems	Fresh Water Systems Fuel Facilities Water/Sewer Treatment Plants	Transmission Lines (D) Electric Power grid (D) Solid Waste Sites
Geology	Surface Geology (D)	Elevation Contours	
Boundaries	Military Installations Built-Up Areas County Bound International Bound	Local Government Bound State Administrative Bound Federal Administrative Bound Census Geography	Facility Bound Military Leased Lands Restricted Areas
Socioeconomic	Demographics (over 55)	Economic (income) (D)	Demographics (population)
Geodetic	USGS Control Points		
Hazards/ Environmental	Hazardous/Toxic/ Radioactive Waste	Medical Wastes Hazardous Materials	
Man-Made Features and Structures	Nuclear Plants Fire Departments EOCs Roads & Streets Maritime Ports	Bridges Airports Hospitals Police Departments Designated Shelters	Pipelines Railroads Power Plants Gov't Man-Made Structures
Photogrammetric	Photos and Imagery		
Cultural Resources	Historical Standing Sites/Graveyards		
Land Use/Cover	Land Cover/Land Use		
Emergency Planning Enhancements	Evacuation Routes	Disabled, Nursing Homes	

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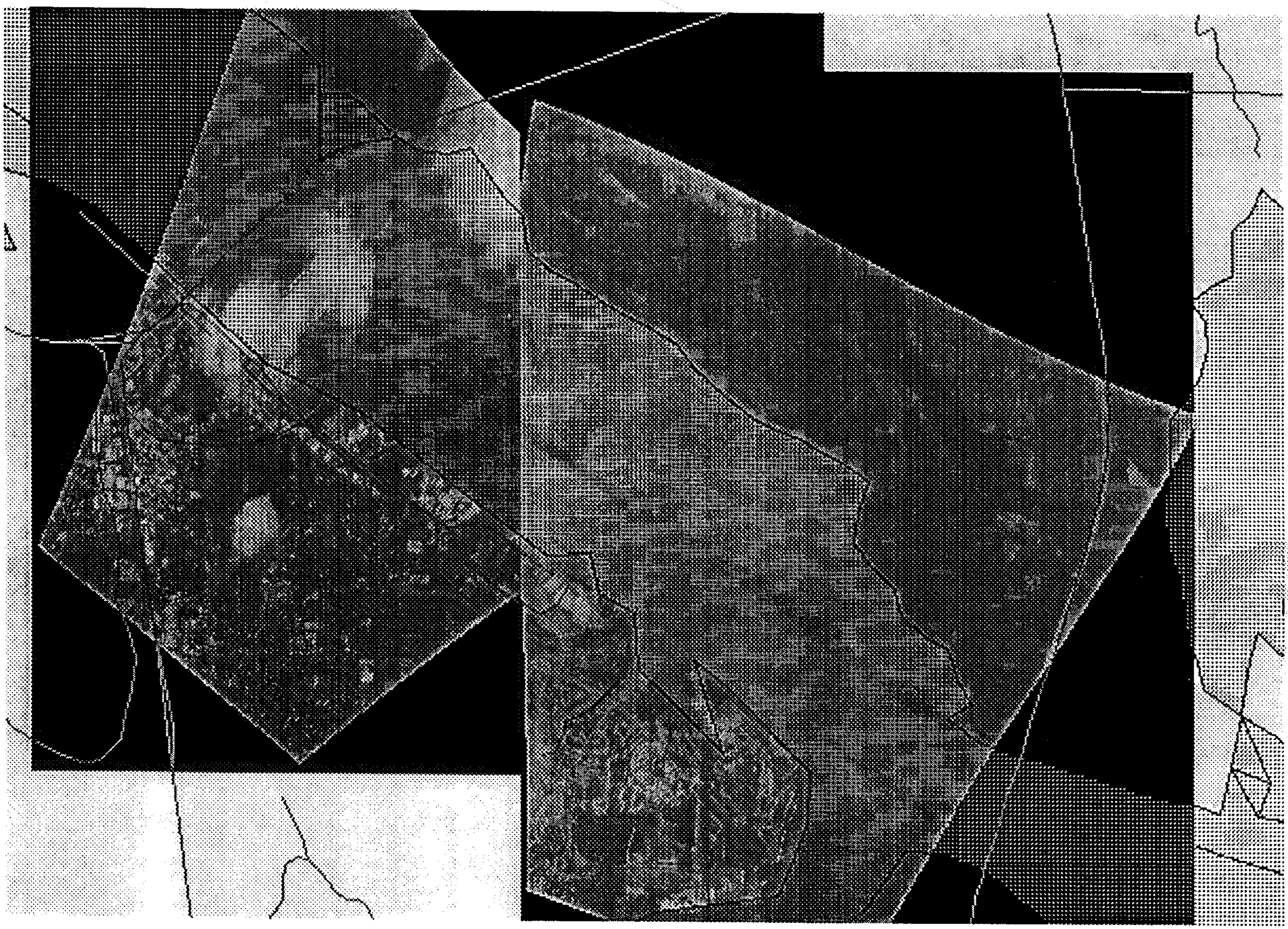
Combining Aerial, and TIGER Data



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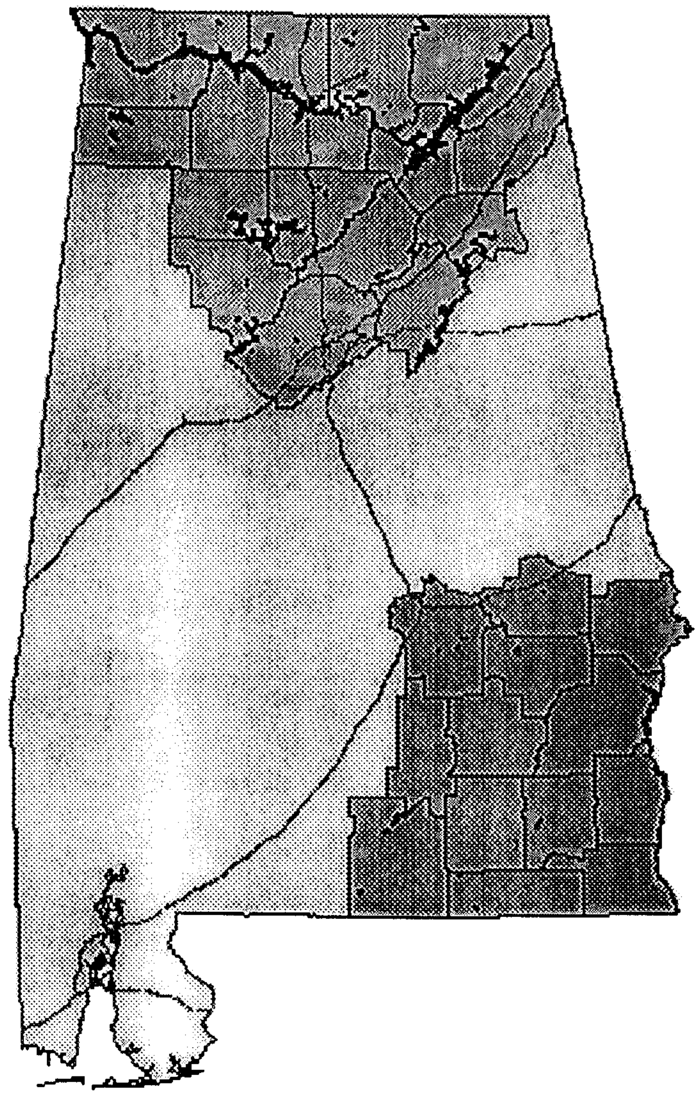
Alabama Counties in Prototype System



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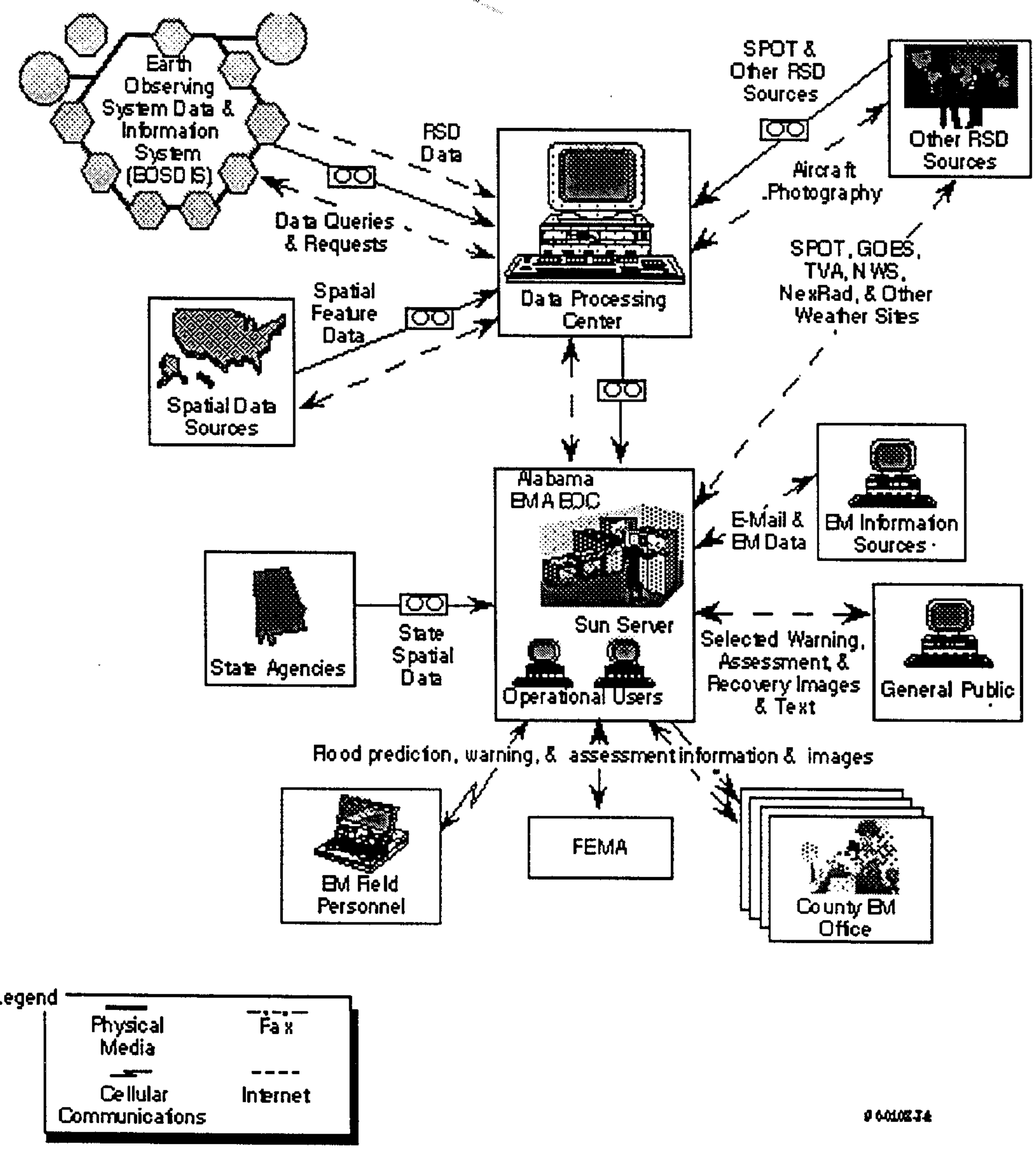
System Prototype Concept



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Completed Tools and Data

- GIS data coverages for 17 data coverages for 17 northern and 13 south eastern Alabama counties have been built; installed on AEMA computers and on CD media
- Four Landsat images processed and delivered on CD
- USGS aerial photography for sample areas in Alabama processed and delivered on CD
- EMO Tool user interface software program developed and installed on AEMA computers
- Internet server scripts developed for use on Sun server
- Tool and data assembled in Huntsville to process additional remote sensing data.

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What is Still to Be done?

- Continue to build achive of remote sensing data.
- Integrate data products and tools into SOPs
- Collect data and create data coverages for many of the state spatial data.
- Experiment with Civil Air Patrol images.
- Integrate the Internet portions of the system at the AEMA EOC (awaiting connection)
- Expand coverage to remaining counties.

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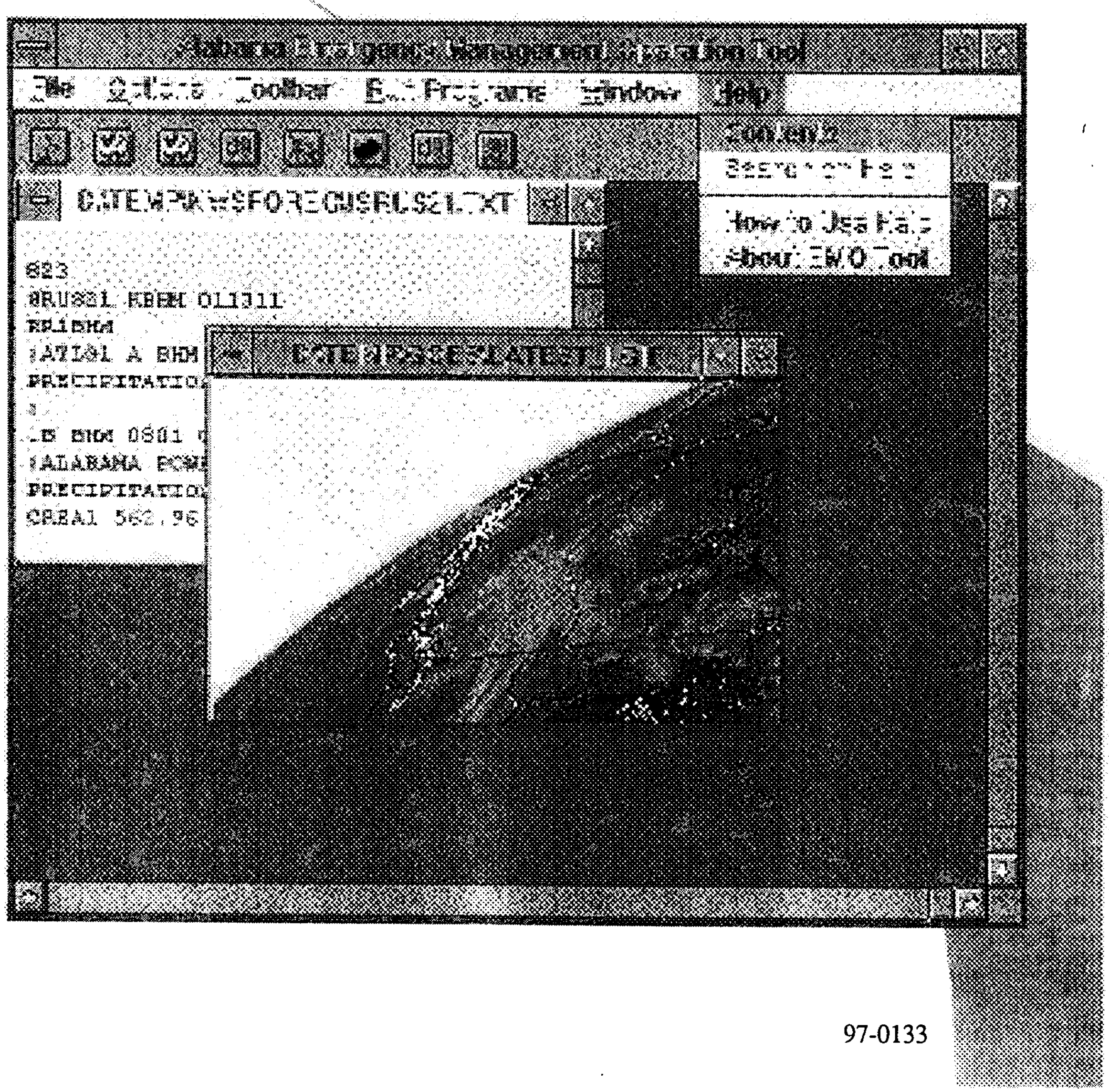
Emergency Management Operations (EMO) Tool

- Tool Purpose - simple user interface
- Tool Setup for Files and Programs
- Usage of Program Icons
- Usage of Menu Bar
- Usage of Windows in Viewing Area
- Usage of Linked Programs
- Tool Configuration Flexibility



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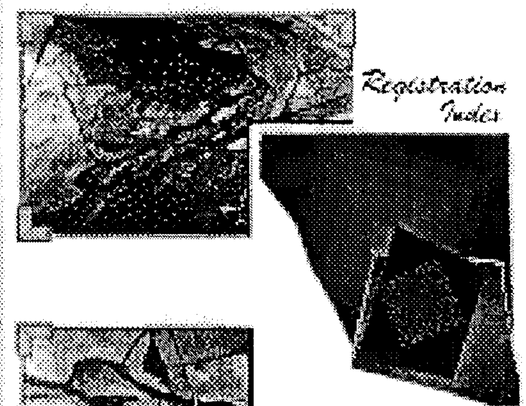
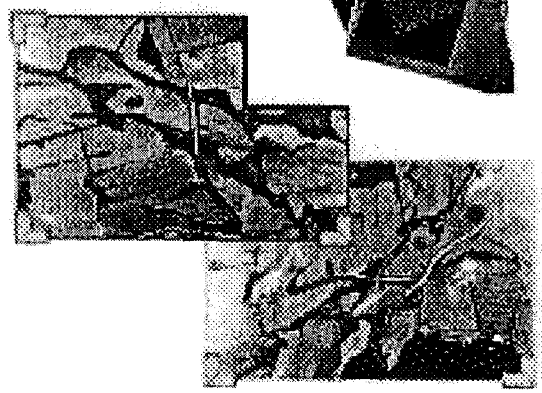
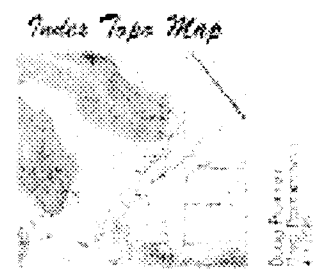
Merging Oblique Photographs

from a hand-held, 35mm camera
in a light aircraft







FLOOD MANAGEMENT

SENTAR

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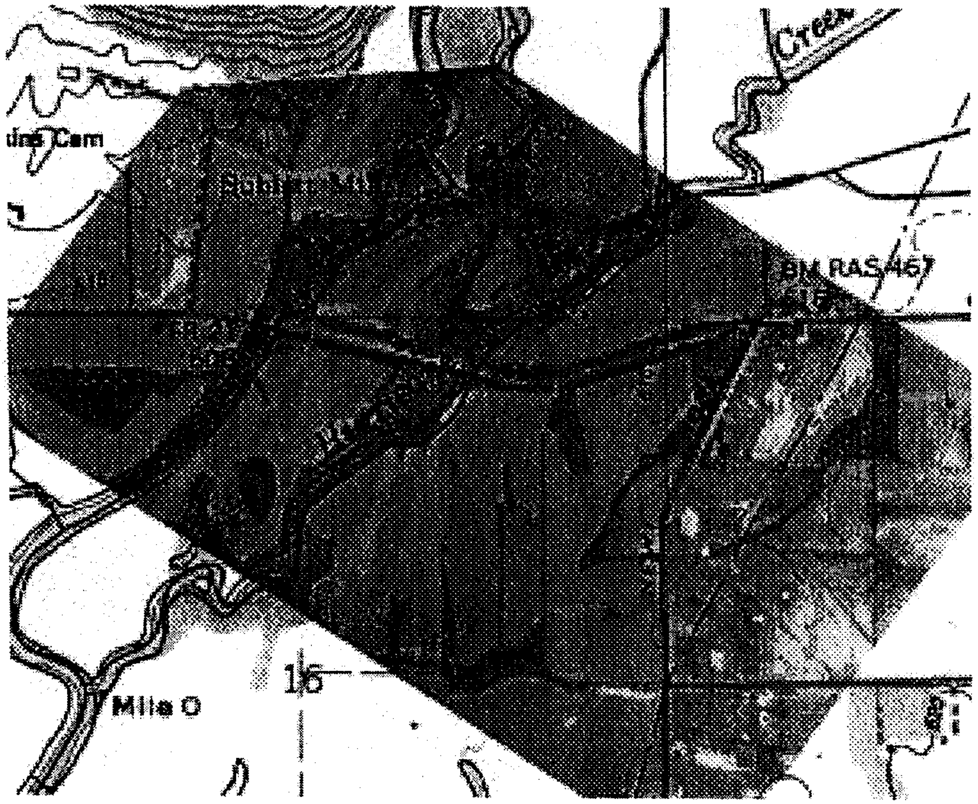
97-0133

Post the NASA CAN Project



- The Internet portion of the system will be finalized and tested.
- The state data coverages and the remaining of the counties for the TIGER data be completed.
- Remote sensing data from disasters will be processed when it comes available.
- A home page on the worldwide web will be established to export images and information to the public.

For project information on the Web:
http://iquest.com/~sentar/NASA/Flood_Management.html

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