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**MAPPING ANALYSIS AND PLANNING SYSTEM  
FOR THE  
JOHN F. KENNEDY SPACE CENTER**

**C.R. Hall, M.J. Barkaszi, M.J. Provancha, N.A. Reddick, and C.R. Hinkle  
The Bionetics Corporations  
Kennedy Space Center, FL 32899**

**B.A. Engel  
Agricultural Engineering Department  
Purdue University  
West Lafayette, IN 47906**

**B.R. Summerfield  
Biomedical Operations and Research Office  
Kennedy Space Center, FL 32899**

**ABSTRACT**

Environmental management, impact assessment, research and monitoring are multidisciplinary activities which are ideally suited to incorporate a multi-media approach to environmental problem solving. Geographic information systems (GIS), simulation models, neural networks and expert-system software are some of the advancing technologies being used for data management, query, analysis and display. At the 140,000 acre John F. Kennedy Space Center, the Advanced Software Technology group has been supporting development and implementation of a program that integrates these and other rapidly evolving hardware and software capabilities into a comprehensive Mapping, Analysis and Planning System (MAPS) based in a workstation/local area network environment.

An expert-system shell is being developed to link the various databases to guide users through the numerous stages of a facility siting and environmental assessment. The expert-system shell approach is appealing for its ease of data access by management-level decision makers while maintaining the involvement of the data specialists. This, as well as increased efficiency and accuracy in data analysis and report preparation, can benefit any organization involved in natural resource management.

**INTRODUCTION**

This paper presents an overview of a decision support system being developed at the John F. Kennedy Space Center (KSC) for use in environmental compliance, management and research. Solutions to environmental problems often involve complex, interdisciplinary subjects. Decision making must meet the requirements of such fields as engineering, hydrology, geology, ecology, geography, political science, public health, planning, demography and sociology [1]. Also, environmental management issues are by nature complex spatial and temporal phenomena. Their distribution across the landscape, in terms of quantity and quality, vary through time in response to both natural and anthropogenic factors. The pattern of landscape development (rural, agricultural, urban, industrial) historically evolved independently from environmental concerns and did not address the need to manage conflicts with natural resource protection, pollution abatement, or the quality of the human environment [2], [3].

Management of both landscape development and natural resources now requires a more diverse approach to conflict abatement. Such a pro-active approach is enhanced by using advanced computer-based technologies for information analysis, decision support, and visual display. Examples of these computer applications include but are not limited to multi-media (video, hypertext, sound, etc.), geographic information systems (maps, overlays, spatially distributed data, etc.), simulation modeling (surface and ground water, air quality,) remote sensing, expert-systems, and user friendly machine interfaces [4], [5].

Mapping Analysis and Planning System

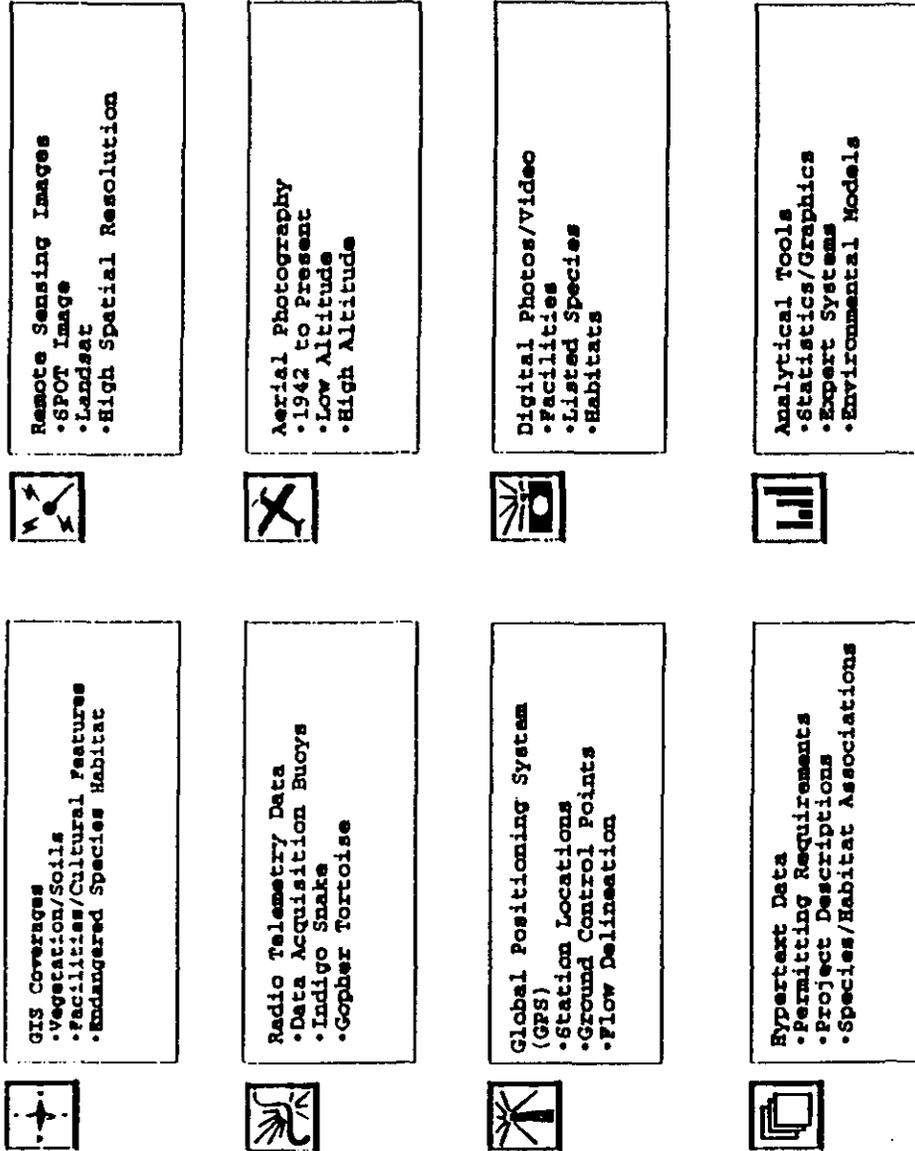


Figure 1. Schematic representation of the resources used in the development and implementation of the Mapping Analysis and Planning System.

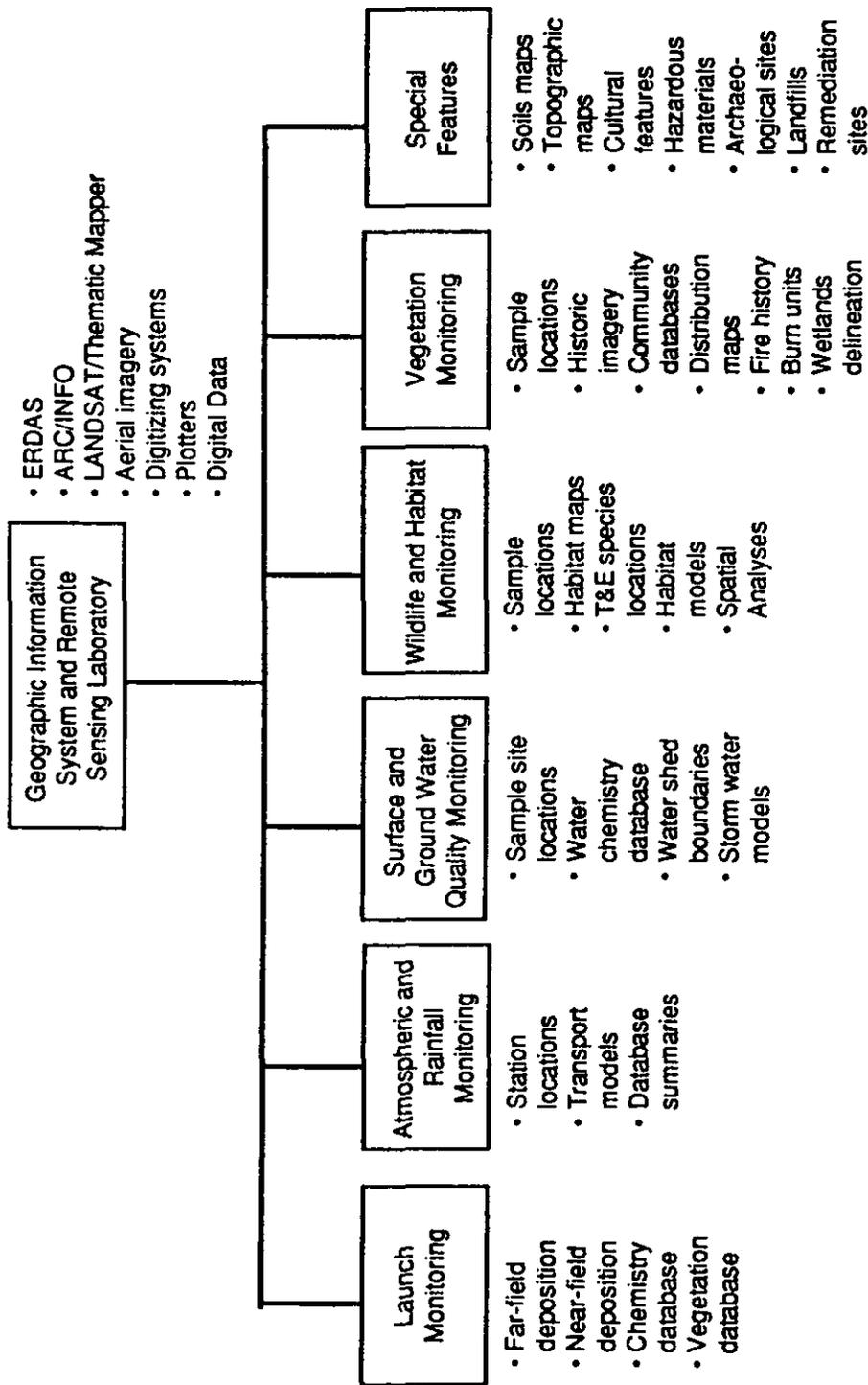


Figure 2. Long-term ecological data compiled in the GIS/Remote Sensing Laboratory

At the KSC, the Advanced Software Technology branch is working in conjunction with the Biomedical Operations and Research Office Pollution Control Officer to develop and implement a comprehensive, computer-based decision support system called the Mapping Analysis and Planning System (MAPS) which will be distributed across a network with the ultimate goal of making current information available to managers and planners at all levels. The MAPS will integrate the knowledge base from environmental research with policy, regulatory requirements, analytical tools and advanced display techniques (Figure 1).

Development of this concept and approach is currently a popular topic with many researchers and agencies exploring options in resource management. Results generally indicate that successful implementation of a comprehensive set of decision support tools requires that the users have available a large amount of high quality site specific data. Broad-spectrum data are needed regarding the site or landscape on which the system is directed as well as an understanding of the types of applications to which the system will be applied.

The primary database for the KSC MAPS consists of more than ten years of research involving field-collected and remotely sensed data covering a variety of subjects such as vegetation communities, wetlands, endangered species, habitats, soils, water quality, and cultural features [6] (Figure 2). Other site and project specific databases available within the MAPS include state and federal permits, permit monitoring data, identification of hazardous material storage areas, solid waste management units, landfills, space shuttle exhaust impacts, and facility siting constraints. Analytical capabilities include development of wildlife habitat association models, storm water and groundwater models and atmospheric diffusion models. Multi-media application include the ability to display digital imagery, captured video, audio, and hypertext to enhance the users understanding of environmental considerations, permit requirements, or regulatory constraints.

Both the environmental monitoring research database for KSC are in a continual state of collection and development. The KSC region is recognized as being biologically unique with more federally listed threatened and endangered species than any other protected area in the continental United States. The ongoing compilation of ecological data from such a diverse region make it some of the most current and reliable information available. In addition, the 140,000 acre facility is jointly managed by the U.S. Fish and Wildlife Service as the Merritt Island National Wildlife Refuge and the National Park Service as the Canaveral National Seashore.

In addition to the variety of sources providing an extensive monitoring and research database, environmental management responsibilities at KSC are also distributed across several NASA Offices and Contract organizations. Each has different responsibilities and information needs to meet requirements of state, and federal laws and regulations. Examples of laws and regulations that affect environmental management activities and generate various levels of information requirements include:

- Solid Waste Disposal Act
- Clear Air Act
- National Environmental Policy Act
- Resource Recovery Act
- Resource Conservation and Recovery Act
- Endangered Species Act
- Water Pollution Control Act
- National Energy Conservation Policy Act
- Pollution Prevention Act

Provisions of these laws are administered by a variety of Federal and State Agencies in Florida, including:

- Florida Department of Community Affairs
- Florida Department of Environmental Protection
- Management Districts
- Local Governments

United States Environmental Protection Agency  
United States Army Corp of Engineers  
United States Fish and Wildlife Service

Each of these organizations may require information or decision activities to design construction or operation of a facility for the purpose of minimizing economic or environmental risks and protecting human health. Stout and Streeter [7] state that the ultimate objective of laws and regulations is the minimization of potential risks associated with the activity of concern. Risk minimization is in turn best achieved by making informed decisions based on the best available data and information. The goal of the MAPS program is to coordinate the elements from all resources so that thoroughly informed decisions are more easily achieved.

#### APPROACH AND EXAMPLE

To combine regulatory requirements with other environmental information and data, the MAPS will link a variety of databases, digital imagery, GIS thematic layers, master planning files, video and legal information into a menu-driven decision support tool for KSC. A knowledge-based system shell is being developed to add expert site specific knowledge to the data fusion and query process. This will allow the users access to all available information, enhancing decision support and quality regarding environmental management. At present the system is being developed in a network environment utilizing UNIX-based work stations and DOS based personal computers. Software being incorporated into the system is a combination of commercially available packages. Basics of the system include:

- GIS software
- Image Processing software
- Video Capture and Editing
- Statistical Data Analysis
- 3-D Graphics
- Numerical Modeling
- Hypertext software
- Expert-systems/Neural Net Development packages

The system is currently being used for facility sitings where concerns must be addressed following requirements of the KSC environmental checklist [8]. The following paragraphs give a description of how the MAPS is used in the decision making processes for the siting of a new fuel storage facility.

The environmental checklist is the precursor to decision making for the siting of any facilities on KSC (Figure 3). Responses to questions on the checklist will either flag ancillary requirements, offer more detailed information on a topic, or prompt the user to input additional data. For example, a fuel storage facility will require a "yes" to the hazardous material storage question. The user is then prompted to supply the type of hazardous material as well as the amount. This system will then alert the user of any permits or official actions such as requirements for public meetings which need to be taken for that substance.

Depending on the question, there are currently different levels of maps, hypertext information, video and graphics to further the query by the user. At this time only some of these topics offer additional exploration; however, as the database size increases so will the extent of each checklist topic. Any topic in the checklist for which the user cannot provide a definitive answer must be checked "yes"; thus prompting the user to gather more information through the query process that will enable them to correctly respond. For the fuel storage facility example, the user may be unsure if the facility will be build in threatened or endangered species habitat; therefore, the user must check yes. The system then prompts the user to identify which habitats are present or, based on the location and surrounding area, defines the habitats for the user. Using GIS vegetation maps, the user finds that the proposed site is located in "scrub & slash pine" and "broadleaved woodlands". For each of these habitat types, the user may query hypertext or graphics for the following information:

5. DOES THE CONSTRUCTION, INSTALLATION, REMOVAL, ACTIVATION, OR OPERATION OF THE PROPOSED PROJECT INVOLVE: (FILL OUT ONE PAGE FOR EACH ALTERNATIVE CONSIDERED: SEE INSTRUCTIONS. WHEN IN DOUBT, MARK YES)

ALTERNATIVE # AND DESCRIPTION:

	YES	NO	
a. Discharge of any substance to the environment Mark all appropriate media: list substance(s) in Block 6	<input type="checkbox"/>	<input type="checkbox"/>	
Air <input type="checkbox"/>			Soil <input type="checkbox"/>
Surface Water <input type="checkbox"/>			Groundwater <input type="checkbox"/>
b. Land alteration, excavation or dewatering	<input type="checkbox"/>	<input type="checkbox"/>	
c. Construction in wetlands	<input type="checkbox"/>	<input type="checkbox"/>	
d. Construction in floodplain	<input type="checkbox"/>	<input type="checkbox"/>	
If Yes: 100 Year <input type="checkbox"/> 500 Year <input type="checkbox"/> (Mark both if appropriate)			
e. Generation of ionizing or non-ionizing radiation or use of any radiation source	<input type="checkbox"/>	<input type="checkbox"/>	
f. Asbestos-containing materials or facilities	<input type="checkbox"/>	<input type="checkbox"/>	
g. PCB-contaminated materials or equipment	<input type="checkbox"/>	<input type="checkbox"/>	
h. Generation of waste other than normal construction debris If Yes, list waste (s) in Block 6	<input type="checkbox"/>	<input type="checkbox"/>	
i. Use or storage of Hazardous or Toxic Materials If Yes, list materials and quantities for each in Block 6	<input type="checkbox"/>	<input type="checkbox"/>	
j. Aboveground or underground storage tanks If Yes, list material (s) stored in Block 6	<input type="checkbox"/>	<input type="checkbox"/>	
k. Generation of high noise levels outdoors (above 85 dBA)	<input type="checkbox"/>	<input type="checkbox"/>	
l. An area of archaeological significance If Yes, indicate potential: High <input type="checkbox"/> Medium <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
m. Endangered species habitat	<input type="checkbox"/>	<input type="checkbox"/>	
n. Solid Waste Management Unit (SWMU) site	<input type="checkbox"/>	<input type="checkbox"/>	
o. Other issues which could produce environmental impacts If Yes, describe in Block 6	<input type="checkbox"/>	<input type="checkbox"/>	

Figure 3. Environmental checklist used by NASA/KSC resource managers and planners.

# VEGETATION AND STRUCTURES

Launch complexes 39A, 39B and VAB area



Scale



Figure 4. Example of the KSC vegetation map, with existing structures overlay, that can be accessed from the MAPS

	FCFWFC	USFWS	CITES	FCREPA	Global Rank	FNAI	State Rank
<b>Amphibians and Reptiles</b>							
American Alligator	SSC	T (S/A)	II	SSC	G5		S4
Loggerhead Sea Turtle	T	T	I	T	G3		S2
Atlantic Green Turtle	E	E		E	G3		S2
Eastern Diamondback Rattlesnake							
Leatherback Turtle	E	E	I	R	G3		S2
Eastern Indigo Snake	T	T		SSC	G4T3		S3
Atlantic Hawksbill Turtle	E	E	I	E	G3		S1
Gopher Tortoise	SSC	DR2		T	G3		S3
Mole Kingsnake				R	G5		S4S3
Eastern Kingsnake*							
Atlantic Ridley Turtle	E	E	I	E			
Eastern Coachwhip*							
Florida East Coast Terrapin*							
Atlantic Salt Marsh Water Snake	T	T		E	G5T1Q		S1
Florida Pine Snake	SSC	DR2			G5T1Q		S?
Gopher Frog	SSC	DR2		R	G4		S3
Florida Scrub Lizard							
Dusky Pigmy Rattlesnake*							
Florida Crowned Snake*							
Coastal Dunes Crowned Snake*							
<b>Birds</b>							
Cooper's Hawk				SSC			
Mottled Duck*							
Bachman's Sparrow					G3		S?
Roseate Spoonbill	SSC	DR2		R	G5		S2S3
Dusky Seaside Sparrow	E				G4TX		SX
Florida Scrub Jay	T	T			G5T3		S3
Limpkin	SSC			SSC	G5		S3
Burrowing Owl	SSC		II	SSC	G5T3		S3
American Bittern*							

Figure 5. Example of chart used in maps showing the listing status of species found on KSC

	Breeding Season	Seasonal Abundance on KSC				Estimated Population Size on KSC	Autecology Characteristics (Noss and Labisky in press)
		Spring	Summer	Fall	Winter		
Florida Scrub Jay	Feb-June	C	C	C	C	2,100	1 R <sub>1</sub> D L U F H
Atlantic Green Turtle	April-Sept.	C	O	C	C	150	
West Indian Manatee	All Year	C	C	C	R	< 300	
Southeastern Beach Mouse	All Year	C	C	C	C	> 5000	
Southern Bald Eagle	Dec-April	U	U	U	U	20	2/3 R <sub>2</sub> W L C
Wood Stork	Feb-July	C	C	C	C	0-600	
Eastern Indigo Snake	All Year	C	C	C	C	> 5000	
Roseate Spoonbill	Mar-July	U	C	U	R	400	
Reddish Egret	Mar-July	O	O	O	O	20	
Florida Long-tailed Weasel	Nov-Feb	R	R	R	R	< 500	2 R <sub>1</sub> R <sub>2</sub> W L
Atlantic Salt Marsh Snake	Mar-Sept.	R	R	R	R	< 500	
Florida Pine Snake	Mar-Sept.	R	R	R	R	< 500	2/3 R <sub>2</sub> N F H E
Florida East Coast Terrapin	Mar-Sept.	R	R	R	R	400-500	
Atlantic Loggerhead Turtle	April-Sept.	L	C			1,200	

Figure 6. Example of chart used in the maps showing the breeding season, population status and ecological characteristics of species found on KSC.

## PRIMARY & SECONDARY SCRUB JAY HABITAT ON KSC

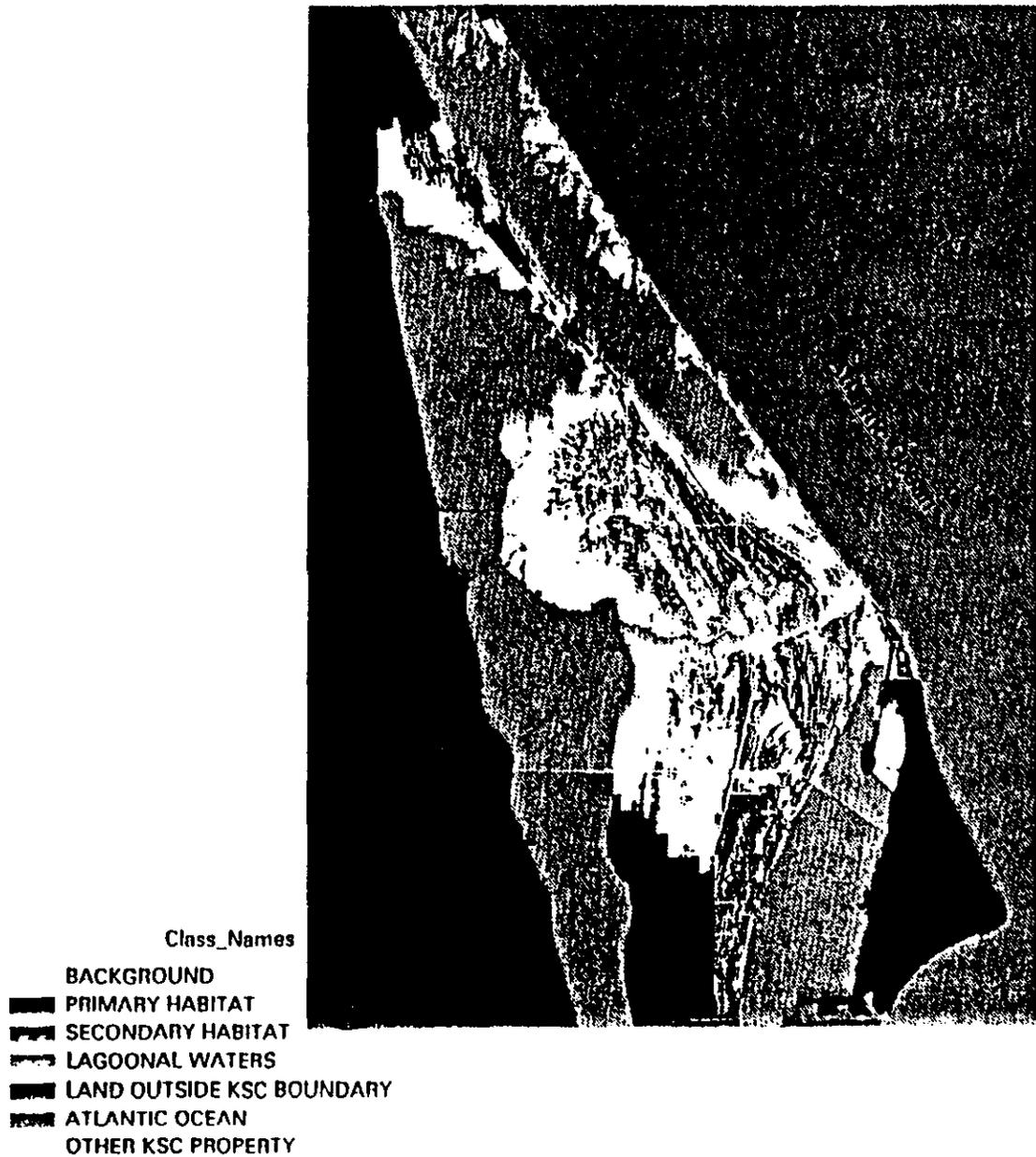


Figure 7. Example of species-specific information that can be accessed from the MAPS. This map shows the locations of primary and secondary habitat for the Florida Scrub Jay on KSC.

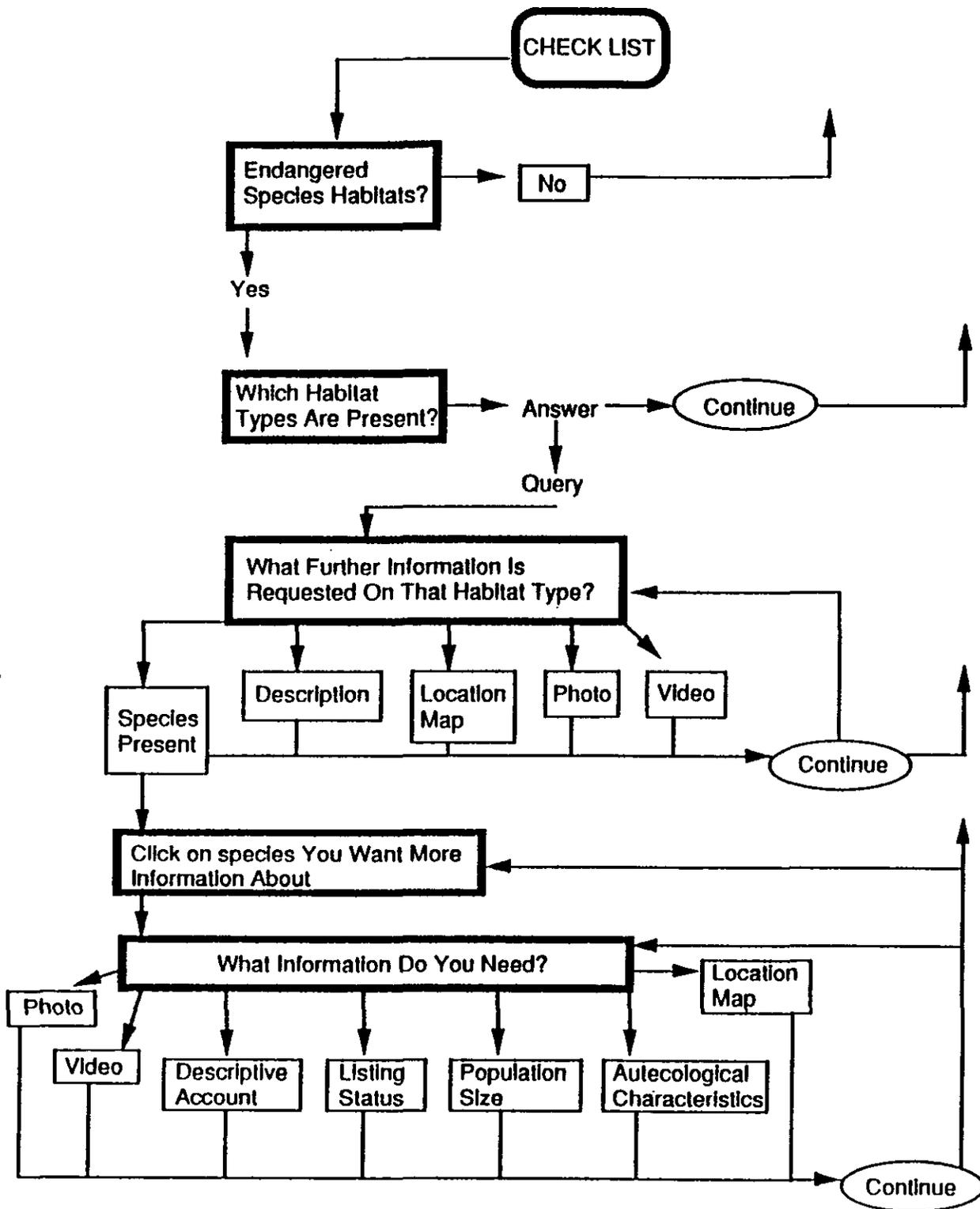


Figure 8. Flowchart of query process for endangered species habitat

- 1) A written description of the habitat. This description will include physical parameters, historical view points, plant and animal species typical for that habitat and NASA's influence on the habitat type within KSC.
- 2) A map showing the locations of that habitat on KSC (Figure 4). Further links with ARC/INFO and ArcView will provide access to finer scale maps of the site or LANDSAT and SPOT images. It will also enable the user to manipulate the map in order to query more information such as getting geographic coordinates or producing a measured radius from a site to look for possible contamination impacts.
- 3) Photographs and video segments of the habitat type.
- 4) A list of species found in that habitat. Each species can then be further explored to provide the user with detailed information on the ecology of each species.
- 5) The protected status of each species for five main listing agencies: U.S. Fish and Wildlife Service (USFWS), Convention on International Trade of Endangered Species (CITES), Florida Game and Fresh Water Fish Commission (FGFWFC), Florida Committee on Rare and Endangered Plants and Animals (FCREPA), and the Florida Natural Areas Inventory (FNAI) (Figure 5).
- 6) The species population size, breeding season, and seasonal abundance on KSC (Figure 6).
- 7) A map showing the locations on KSC where appropriate habitat for supporting that species is located (Figure 7).
- 8) A detailed, written account of each species which includes a description of the species and its typical habitat, listing status, reasons for endangerment, discussion of the species status on KSC, research results, behavioral notes, and general ecological attributes.
- 9) Photographs of the species.
- 10) A video segment of the species.

The flowchart in Figure 8 show a summary example of how a topic can be explored. One of the main advantages of this program is its ability to adapt to different user's requirements. A user can go through the query only as far as they need. For instance, not all users will need to know what certain species or habitats look like while others may need a photograph or video to confirm sightings. More users may need the listing status or population size for a species and the location of certain habitats on KSC. The user drives which information is presented. The available database can be readily updated as more information becomes available or as changes occur in legal status such as species' listings or permitting requirements.

#### SUMMARY

This brief paper outlines several of the development strategies and the status of the MAPS decision support process for environmental management issues at KSC. Environmental compliance and management is recognized as a multidisciplinary activity that requires large volumes of data for management and engineering decisions. Much of the data is by nature spatial or geographic. Storage, manipulation and analysis of this type of information is performed most effectively in current GIS software environments. Problems that can be addressed include facility design and siting, environmental monitoring, habitat mitigation, impact assessment and documentation, and many others. The attractiveness of adding knowledge-based expert-system software to the decision making process stems from the fact that such systems represent models of "experts" in various fields. The combination of GIS and expert-systems represents a tool that supports and enhances the reasoning and judgement process rather than only automating the procedure through prescribed computation [9], [10]. This approach will allow managers and engineers to access "expert

knowledge", covering the highly diversified set of topics associated with a pro-active environmental management strategy, easily and directly from their computer terminals.

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