Field Mission Report and Technical Report of the International Expert in Database Management and Internet

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Abstract

General: **The Brazzaville GIS database is off to an excellent start**. There is clear and strong high-level guidance from the Ministry of Economic Forestry and Wildlife regarding sustained multiple-use forestry and conservation. Please see the hard copy document *"Directives Nationales D'Aménagement Durables des Fôrets Naturelles du Congo"* (March 2004), accompanying this report. The Centre national d'Inventaires et d'Aménagements Forestiers et Fauniques du Congo (CNIAF) GIS technicians are highly skilled and work well together as a team. The GIS Laboratory's physical environment, hardware, software and satellite data are first rate. Together, these human, legal and technical aspects of the CNIAF GIS effort provides the potential to operate at a world class level.

New Architecture: Currently, the Team is taking a traditional cartographic approach to database construction. I recommend that the CNIAF Team switch soon to the new Geodatabase environment for GIS database management. The Personal Geodatabase in ESRI's new ArcGIS 9 software (which CNIAF already possesses) is a departure from the traditional GIS architecture. It provides smooth data flow from field to database to Internet, easy integration into larger databases, and reduced annual maintenance and training costs. The Technical Report section of this document contains a more detailed discussion of this recommendation.

Partnerships: To achieve some of the project goals the CNIAF effort will have to depend on partnerships with neighboring organizations, for the next two to three years. Two important examples, Internet publishing of the database and conservation in Protected Areas, would be especially dependent on partnerships with organizations like WRI, WWF and WCS, until CNIAF and the Ministry develop full technical capabilities in these areas.

Leadership: Harmonizing with neighboring GIS efforts throughout the Congo Basin will require continuous technical leadership for the CNIAF Team. This leadership should be provided by a person who will work with organizations in surrounding countries to develop and follow GIS standards that enable the easy sharing of data between cooperators for wide-scale problem solving. There is an immediate opportunity to develop common data standards for data sharing throughout the Congo Basin, with organizations including WRI, WWF, WCS, CARPE, University of Maryland (Kinshasa Lab), and GIS efforts in Cameroon, Gabon and Central African Republic. The team supervisor should be experienced in data sharing standards (metadata), quality control, and especially Geodatabase management procedures including object modeling and topology.

Part I – Field Mission Report

Activities conducted

During my mission I interviewed CNIAF and Ministry officials, and reviewed official documents and decrees, to determine that sufficient administrative rules and procedures were in place, to define the overall mission of the CNIAF GIS Laboratory and provide the general structure of its data products. In particular, I focused on these areas: commercial forestry management and its permit systems, forest human communities, protected area management, wildlife conservation, and law enforcement monitoring. Please see the hard copy documents accompanying this report as examples of good overall direction.

I talked to key organizations with interests in the Congo Basin, to determine their interest and capability of cooperating with the CNIAF Lab. These organizations included the World Wildlife Fund, the Wildlife Conservation Society, CARPE, the University of Maryland Kinshasa GIS Lab, and some forest concession companies. All are willing to cooperate with the Brazzaville effort. For example, the WWF and University of Maryland's Kinshasa Lab (Didier Devers and Matthew Hansen) is ready to immediately share data with the CNIAF Team, as well as share habitat modeling procedures that will be used across the Congo Basin.

I observed and interviewed the CNIAF GIS Team and Lyna Belanger to evaluate the status of the ongoing GIS project, the current skills of the team members and their training needs, and the current Laboratory technical environment including computer hardware and software. The Team possesses good GIS foundational skills, and can make the transition of the current CNIAF database into an efficient Internet enterprise data warehouse. Please see the Technical Report below for details of this transition.

I familiarized the CNIAF Team with some concepts of the new "Geodatabase environment, including the simple and smooth flow of data from field data recorders into the CNIAF corporate database, and getting their data published on the Internet.

I provided the CNIAF Team a small amount of training to augment their already excellent database digitizing procedures, using the new capabilities of the ESRI ArcGIS software.

I reviewed literature and interviewed my acquaintances at ESRI to survey all the available technical approaches for corporate geographic databases, to determine the best "solution" for the desired future of the CNIAF database. The results are contained in the Technical Report below.

Observations

General

The new GIS Laboratory is operating efficiently, and is the equal of any I have seen. The CNIAF and the Club des Amis de l'Environnement Fôret et Faunique (CAE) staff are proficient in general GIS knowledge, in digitizing, and in the principles of forestry and conservation information management. Perhaps most importantly, they work well together as a team. The laboratory itself is a comfortable work environment (an important consideration for consistent, high quality computer work) and possesses all the software and hardware necessary for a high-quality GIS database.

The GIS team is currently constructing these base layers: hydrography (water bodies, rivers and streams), transportation (roads and railroads), UFA's, Protected Areas (PA) and administrative boundaries. They are employing technical GIS standards that allow CNIAF data to be easily shared with neighboring countries, and to be published on the Internet. These standards include the scale of the GIS layers (1:50,000), the techniques used (on-screen digitizing from Thematic Mapper satellite images), and digitizing procedures (topology and connectivity). Again, this combination of standard practices ensures that CNIAF data is of high quality and shareable.

The Pilot Project

The current plan is to use the North part of the database as the "pilot" region, and make sure all components are working together before completing the rest of the database, in the South. During the review period of December 2004 to February 2005, the team will conduct ground-truthing activities, combine individual pieces of the database into one. After making any corrections to the data based on the field review, the pilot database will be assembled and converted into the ESRI "Geodatabase" architecture, by August 2005. After August 2005, the rest of the database production will continue in the new Geodatabase environment, with streamlined editing tools and processes, built into the ArcGIS software.

Under this time line, the pilot Geodatabase should be ready for publication in August 2005. The complete Congo-wide Geodatabase should be ready for publication in January 2007. A pilot database could be delivered earlier if a smaller area were selected (for example, several UFA's only), and if Geodatabase training were accelerated. Please refer to the Technical Report section below for discussion of an accelerated time line.

Information Needs

An Information Needs Assessment (INA) is a critical initial component of any information project, and is underway in CNIAF. The first part of an INA summarizes the high-level business requirements, from which more detailed procedures are identified, and then those business procedures are translated into the correct database architectural components. More importantly, the INA results serve as the information project's scope control. The INA can be a single document or an assembly of related documents, in CNIAF's case.

There is excellent high-level business requirement information published in the Ministry's March 2004 document *"Directives Nationales D'Aménagement Durables des Fôrets Naturelles du Congo"* and other documents, so the first part of the INA is essentially complete. There is currently a significant amount of team discussion and debate about forestry procedures and data needs. This indicates that a bit more clarification of business process is needed, to complete the INA process. Mssrs. BEZOU Bernard, IBARA Marcel and LEMBE Gaspard are leading the team in researching and summarizing all available documented procedures in which the new CNIAF database can play a role.

Business areas that have not yet been included in the INA include:

- General planning procedures for sustainable multiple-use forestry
- Concessionaire company participation in planning processes
- Forest utilization permitting process integration with the GIS database
- Local forest population (cultural) concerns
- Wildlife conservation practices
- Monitoring procedures for the above business areas, including law enforcement
- General guidance for the warehousing and Internet publishing of CNIAF data

The INA process needs to identify the actual day-to-day business process in all these areas in detail, and define how the CNIAF GIS database will contribute to these processes. One specific product of the INA is a descriptive list of GIS layers and data tables necessary to support the identified business processes, and how the data for these layers is maintained. For each business area, a set of questions must be answered in order to correctly design the database - for example, who uses the final data and why? Who updates the information? How often must it be updated? How accurate must it be? Is the data somehow related to or controlled by other CNIAF data?

The answers to some of these questions are already known, but many are still unknown, and should be discovered during the conclusion of the INA. The GIS software that CNIAF possesses actually simplifies some of these processes, if the Geodatabase capabilities of ArcGIS is fully utilized. These capabilities include maintaining a GIS Data Dictionary in the form of ESRI metadata, using the Metadata Tool. Standard metadata, maintained as part of the Geodatabase, is essential for data warehousing and sharing across the Internet. These topics are discussed in more detail in the Technical Report section, below.

The Internet

The northern half of the Congo's forestry database will be ready for Internet publishing in August 2005 or thereabouts. However, operating an Internet website is fairly complex. To publish the data in the Geodatabase, a high speed Internet connection is required, with a server computer and Internet software for GIS publishing, such as ESRI "ArcIMS" (Internet Map Server). This arrangement allows anyone on the Internet to create their own maps with CNIAF data. For those who just wish to get copies of CNIAF GIS data via the Internet, the simpler FTP software is required.

One of the CNIAF GIS Lab computers could operate as the Web server computer, but obtaining the high speed Internet connection will probably require a lot of time and coordination. The database may well be ready before CNIAF or Ministry Web hosting can occur, so an alternate approach may be taken in the

interim. I think an arrangement with an international partner could be explored for Internet hosting of CNIAF data until local Web hosting begins. WRI or other NGO's operating in Central Africa are good candidates for this kind of partnership.

The Geodatabase

As of today, it appears that the ESRI Geodatabase structure is the best choice for the CNIAF database architecture. The Geodatabase is ideal for warehousing spatial data, for use inside CNIAF on an internal network, and to work with a Web Server for Internet access. It is the new international *lingua franca* of spatial data management. The "Personal Geodatabase" version of the Geodatabase is a perfect fit for the CNIAF project. It provides a simple and powerful data management environment, and requires no additional software.

Since database production has already begun in a non-Geodatabase format, one approach would be to continue production in the same way, and then convert the final northern part of the database to a Geodatabase in August 2005. The conversion process is very simple and reliable. Due to its simplicity, training requirements for maintaining a Geodatabase are relatively modest. Further, the French language version of the ESRI software could be on site by December 2004, which would facilitate the efficient training of the team in Geodatabase management procedures, in time for the conversion in August 2005. Please refer to the Technical Report section below for a discussion of an accelerated time line for the Geodatabase conversion.

The Personal Geodatabase also provides simple and powerful GIS editing tools, to keep the data current. It also enables handheld field data devices to upload and download information to the database very quickly and simply. This feature is essential for efficient law enforcement and permit system management.

Data Security and Authentication

There several aspects of data security to be considered. One essential security concern is to protect the CNIAF database from catastrophic loss, due to floods or other general emergencies. Current backup procedures employed at the lab are sufficient for early stages of database development, but once a substantial amount of information resides in the database, a system of multiple off-site copies of the database should be implemented.

Another data security issue is assuring that information used by the Ministry for law enforcement and other sensitive operations is official and authentic, free from tampering. Simple authentication procedures will allow CNIAF and its parent Ministry to distribute authenticated data to its law enforcement officials, as well as to cooperators and concessionaire companies. There are several simple, reliable and inexpensive methods of data authentication available, like public key encryption, and should be incorporated into data management procedures.

Recommendations

1) Complete the Information Needs Assessment (INA) to describe business requirements for GIS layers beyond the current basic layers. These business areas include general planning procedures, concession company participation, law enforcement, wildlife and habitat conservation areas, and the forestry permitting system.

Preparation of an INA for these fairly complex business areas may be accomplished over a 6 to 12 month period, as the basic data layer construction continues. The results of the INA will allow the construction of effective new GIS layers that integrate well with the existing basic layers.

As described above, much of the basic research has already been done, and CNIAF personnel have the practical knowledge about forestry and related practices to complete the INA, and carry that information into the new layers in the Geodatabase., to be added after the basic layers.

2) Switch to the Geodatabase environment as soon as practical.

The Geodatabase typically offers a 25 to 35% savings in time during data entry, over the traditional methods now being used. However, this added efficiency has a cost. The costs are to design and test the new Geodatabase structure, to convert the current data from the old format and add it into the new Geodatabase, and to train the CNIAF Team in Geodatabase editing and other data management processes.

Since it is inevitable that the CNIAF database will be converted to the Geodatabase, the sooner the conversion takes place, the greater the time savings. The French language version of ArcGIS is now available, and will help the Team members become familiar with the Geodatabase more quickly, but they will need two weeks of training to make the transition. One logical conversion point is at the completion of the North portion of the database, but the transition can be made at any time earlier, after the new Geodatabase structure is ready to accept the converted data, and the Team is trained. The attached Technical Report's Time Line illustrates one early conversion possibility.

3) Develop partnership agreements and procedures for Internet hosting, secure data caching, remote sensing data and habitat tools, and training.

Utilize partners such as WRI operations in Cameroon, WWF, University of Maryland (Kinshasa) and CARPE until CNIAF develops full capabilities in these areas, over the next 3 to 4 years or so. Please see the attached Technical Report section for fuller discussions.

Part II - Technical Report

Database Architecture and Management

Recommendations:

1) Convert the current CNIAF traditional GIS data structure to the ESRI Personal Geodatabase architecture as soon as practical.

2) Purchase 2 or 3 Portable Data Recorders with ArcPad and built-in GPS to collect field information and feed it into the Geodatabase, and then to the Internet.

The Geodatabase

The Personal Geodatabase architecture is perfect for CNIAF's current needs and for future expansion as well. The Geodatabase is the centerpiece of ArcGIS 9, and provides for simple and reliable data management, from field collection to the database warehouse to the Internet.

CNIAF's GIS software (ArcGIS 9) offers a new opportunity to significantly reduce the time, training and effort required to produce and maintain a high-quality GIS. These efficiencies can be realized by converting the current GIS layers being produced in CNIAF to an ESRI "Geodatabase", a special type of GIS database. The Geodatabase allows for the efficient and simple flow of new information collected in the field into the Geodatabase, for efficient storage and analysis of the data, and for easy sharing of the data across an internal network or the Internet.

The "Personal Geodatabase" is the version of the Geodatabase that is included in the software that CNIAF already possesses. It is perfectly suited for the CNIAF information environment for at least the next 5 years. The current version of the ESRI Personal Geodatabase has a maximum database size limitation of 2 gigabytes. This provides ample room for the CNIAF vector (point, line, and polygon) layers, but is insufficient for the large LandSat image files. However, large image files are typically not stored in Geodatabases, and can be managed efficiently by traditional means.

When CNIAF data grows significantly in size, or is combined with other Ministry databases, the ESRI Enterprise Geodatabase software could be purchased to manage the more complex data structure of the future. The Enterprise Geodatabase software requires a large Relational Database Management System, such as Oracle or SQLServer, as well as highly trained database administrators. It should be kept in mind as a future "upgrade" option. The Enterprise Geodatabase can directly import Personal Geodatabase information, and so does not require any reconfiguration of the GIS data during the upgrade process.

The Geodatabase provides not only a data warehousing structure, but a streamlined data entry and editing environment as well. When the CNIAF Team begins working in the Geodatabase environment, they will be able to use many automated processes that save time and avoid mistakes, compared to the traditional approach they are taking now. For example, they will no longer have to type in data, but simply select items from lists, avoiding typing mistakes and saving time. They will also be able to use advanced GIS editing tools for spatial data entry, which make digitizing easier and faster.

Several layers of the Geodatabase are dependent on other layers – for example, UFA boundaries frequently follow river courses, and in such cases, the UFA boundary line can be thought of as the "child" of its "parent" river line. If the location of the river is re-mapped due to new, more accurate location information, the UFA boundary must move with the re-mapped river line. Previously, the GIS specialist had to move the parent line first, and then find and move all other dependent child lines, in several GIS layers. The Geodatabase allows these "parent-child" and other similar rules to be built into the database, by the use of a "topology" layer. The topology layer contains rules that will automatically move child lines when a parent line is moved by the specialist, thus saving time and reducing errors.

Maintaining GIS metadata (standard information about the contents of the Geodatabase) is vital to assure that the CNIAF Geodatabase information is easy to use for CNIAF and Ministry users, and for Internet users as well. CNIAF should use the simple built-in metadata manger in ArcCatalog to maintain the Geodatabase's highly important metadata along with the data itself.

The CNIAF Team could complete underway on the northern portion of the database, continuing to use the current data entry procedures. Upon completion, this northern portion of the database can be imported into the pre-constructed empty Geodatabase. After data import, the new Geodatabase can serve as a “pilot” database, and can be published immediately on CD’s or the Internet as an official CNIAF product. Or, the Team could switch to the Geodatabase sooner, and complete the pilot in the new GIS environment.

Publishing could be accomplished in several ways:

- Distributing CD’s of the data files
- Posting the data files on an Internet FTP site, or
- Serving the data on the Web via an online Internet Mapping Server, hosted by a cooperator

ArcPad

Collecting data in the field and entering it into a database simply and efficiently is one of the most important steps in good information management. ESRI has dramatically streamlined this process by introducing ArcPad, which is a software program for hand-held field data collection devices. ArcPad communicates directly with the Geodatabase, and permits field data entry without extra computer programming. Acting as an extension of the Geodatabase, ArcPad uploads and downloads data from the Geodatabase almost automatically.

When installed on a portable Pocket PC device with a built-in GPS receiver, ArcPad greatly reduces the number of steps and the likelihood of mistakes associated with previous field data collection methods. Formerly, to collect GIS data, a person had to use a separate GPS to collect locations, enter attribute data into a database (that had to be programmed), convert the GPS file into an ESRI shape file, attach the attribute file to the shape file, import the shape file into the GIS, convert the shape file into the final database format, and combine it with existing data.

The recommended Pocket PC/GPS/ArcPad device connects to a PC, downloads a portion of the official Geodatabase, and then allows the user to capture new field data directly into the Pocket PC's portion of the Geodatabase. The user then returns to the office, plugs the device into their PC, and uploads the new

data directly into the Geodatabase format, ready for final inspection and immediate entry into the official Geodatabase. This is called the "check in and check out" process, and is much simpler than the old method described above.

No computer programming is necessary for this new process – ArcPad downloads the necessary "intelligence" into the Pocket PC to make this simple process work. The user only needs to know how to use ArcPad, rather than 3 or 4 separate kinds of software, as previously required. Pocket PC's with color screens, built-in GPS and ArcPad can be purchased for approximately $500 USD. Here is an illustration of the proposed data collection process:

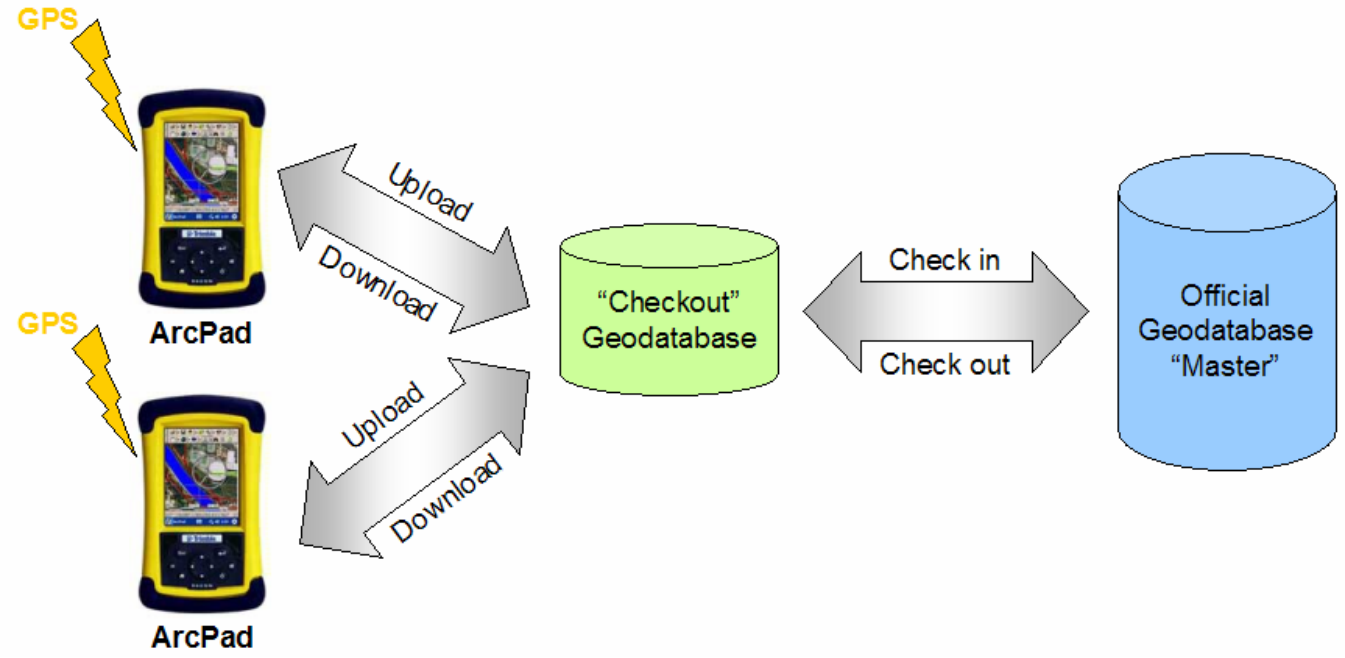

Figure 1. Data flow from field to database.

Database Interface with the Internet

Recommendation:

Use ESRI's ArcIMS Internet Map Server software to publish the CNIAF Geodatabase with the help of partners, in the short term.

The Geodatabase structure is quickly becoming the international standard for GIS databases, and several commercial software products are available to serve the CNIAF Geodatabase to the Internet. Perhaps the easiest and quickest method is to use ESRI's IMS (Internet Map Server) program. If an Internet server connection (a "domain") is already available through an ISP (Internet Service Provider) company, the CNIAF Geodatabase could be published on the Web with only one week of work, by a GIS

specialist familiar with IMS. CNIAF does not currently possess IMS software, but it is reasonably priced.

ESRI's IMS product provides a simple, effective interface for anyone on the Internet to view and query the CNIAF data. However, IMS and all other Web Server programs require an Internet website, and operating an Internet website is rather complex. To publish the CNIAF Geodatabase on the Web, a high speed Internet domain connection is required, with a server computer and Internet software for GIS publishing (IMS). This arrangement allows anyone on the Internet to create their own maps on line, with CNIAF data. For those who just wish to get copies of CNIAF GIS data files via the Web, the simpler FTP software is required.

One of the CNIAF GIS Lab computers could operate as the Web server computer, but obtaining a high speed Internet connection will require substantial time and coordination. The database may well be ready before CNIAF or Ministry Web hosting occurs, so an alternate approach should be considered in the interim. An arrangement with an international partner like WRI could be explored for Internet hosting of CNIAF data until local Web hosting begins.

Web Connectivity – Software and Procedures

Recommendation:

Use existing CNIAF software to help automate the Internet publishing process.

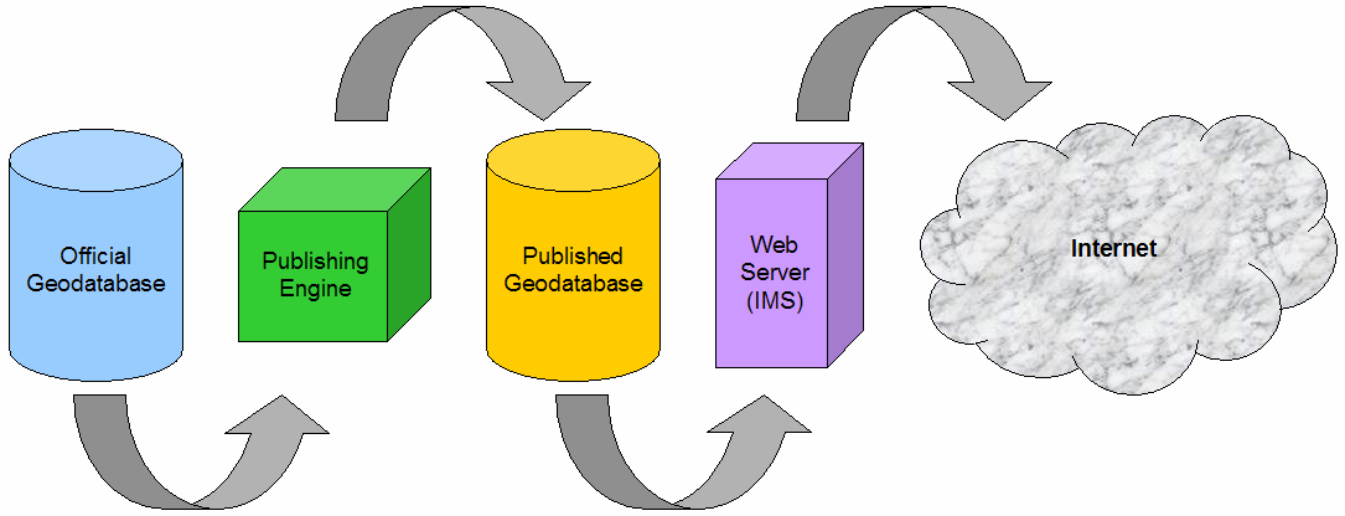

Figure 2. Automatic data flow from the database to the web server.

The ArcIMS software is simple to install and maintain, and delivers fast Internet performance with databases the size of the CNIAF Geodatabase. However, regardless of the Internet publishing software used, it would not be desirable to publish the entire Official Geodatabase directly to the Internet. Like all working databases, the CNIAF Official Geodatabase will contain some data in the early stages of development, and data that is either confusing or of little interest to the public. The solution I propose is to maintain a "snapshot" copy of part of the Official Geodatabase, called the Published Geodatabase.

The Published Geodatabase contains only the information suitable for publishing, and is automatically generated from the Official Geodatabase by a push-button process called the Publishing Engine. This Engine (constructed in ArcGIS Model Builder) simply executes a series of ArcGIS commands that builds the Published Geodatabase with only the data that is desired to share via the Internet. CNIAF already possesses Model Builder, as a component of its ArcGIS software. A specialist with moderate ArcGIS skills could build the Publishing Engine in one week.

Although the Published Geodatabase could initially be constructed manually, by late 2005 the CNIAF database will be too complex to maintain the snapshot Published Geodatabase without automation. The Model Builder is an ideal tool to accomplish this automation, by building the Publishing Engine as a model.

The publishing process would be simple. Periodically, when a certain amount of new data has been entered into the Official Geodatabase, a CNIAF GIS specialist can activate the Publishing Engine, and generate an updated Published Geodatabase for immediate connection to the Internet Map Server. This solution also provides an additional layer of data security, because the Official Geodatabase is isolated from the publishing process by the Publishing Engine and Published Geodatabase.

Integration with a Future Larger Forest Data Warehouse

Recommendation:

Implement the Personal Geodatabase architecture as CNIAF's database structure. The CNIAF Geodatabase can be quickly integrated into a larger "Enterprise GIS" database whenever necessary, without modification.

The recommended ESRI Personal Geodatabase structure of the CNIAF database serves as an efficient data warehouse on its own, containing both GIS objects and tabular objects, and directly feeding Internet Map Server and other Web server programs. If the CNIAF database in the future becomes a component of a more extensive Enterprise Geodatabase in the Ministry, it can do so very simply, with virtually no changes.

The electronic forestry permitting system of the near future will probably be non-spatial tables, but can link directly to layers in the Geodatabase. These tables with permitting data can even reside inside the Geodatabase as "object classes" for tight GIS integration, if desired.

Training Needs of CNIAF GIS Lab Technicians

Recommendations:

1) 1 week of general Geodatabase training.

2) 2 to 3 weeks of specific training on CNIAF data entry, ArcPad field data collection, quality control and security processes, and database publishing.

3) Purchase of French language extension for ESRI ArcGIS 9 software.

The CNIAF Team has a good foundation of basic GIS theory and procedures, and would require only relatively brief training on general Geodatabase operations, if they were delivered a pre-configured working Geodatabase ready to receive their data. Beyond the basics, CNIAF database-specific training on the new field data collection methods, database quality control procedures and database publishing steps would be required.

When the team is able to run the French language version of the ArcGIS software, they will more easily be able to teach themselves about many details of the Geodatabase, and update their Operations Manual, which was begun by Lyna Belanger.

Time Line for the CNIAF Geodatabase

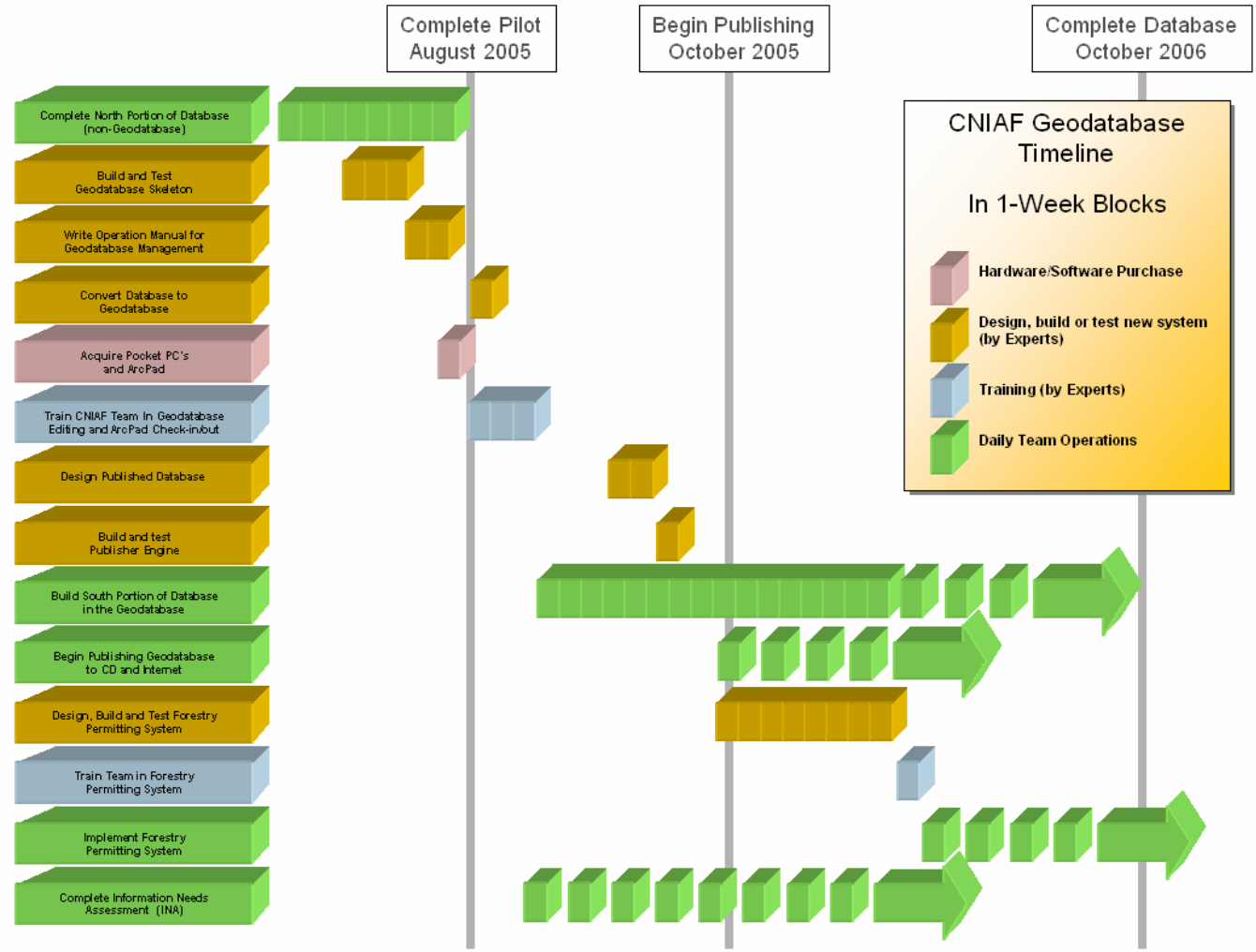

Figure 3. Time line for the Geodatabase proposal.

Contacts Made

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