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Systems Integration Analysis and Alternatives Identification for Facilities Planning Branch, BPA: Task 1: Background Analysis and Data Gathering

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SYSTEMS INTEGRATION ANALYSIS AND
ALTERNATIVES IDENTIFICATION FOR
FACILITIES PLANNING BRANCH, BPA

TASK ONE:

BACKGROUND ANALYSIS AND DATA GATHERING

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May, 1990

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**SYSTEMS INTEGRATION ANALYSIS AND ALTERNATIVES IDENTIFICATION
TASK ONE: BACKGROUND ANALYSIS AND DATA GATHERING**

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TASK ONE INTRODUCTION

Portland State University has been engaged by the Facilities Planning Branch, Division of Engineering, Bonneville Power Administration, to collect background information, analyze current activities, and provide recommendations for greater Branch efficiencies, and the most timely service to its customers, based on current and projected resources and financial responsibilities. This information is to extend and compliment the efforts of an in-house systems integration team which initially addressed these issues. This study is intended to assist Branch management in its effort to identify Branch strengths and increase productivity.

The Facilities Planning Branch is one of three Branches in the Division of Facilities Engineering. The Branch is responsible for environmental analysis, surveys, mapping, legal descriptions, photogrammetry, and image processing (IPS) to support the location and planning of BPA transmission lines, electrical and non-electrical structures and maintenance facilities. Currently there are six computerized systems in the Branch which aid in this work. They are: Survey, Photogrammetry (PHO), Image Processing System (IPS), Geographic Information System (GIS), Computer Aided Drafting (CAD), and Desk Top Publishing (DTP).

This systems integration study is to provide supporting documentation for greater integration of these systems and their associated data. Data and information flows between these systems as well as the information products they provide will be examined. Alternatives and opportunities for increased integration of data and information products as identified in this study will be useful in the Productivity Review Process, and aid Branch management with its determination of a Performance Work Statement (PWS) and a "most efficient organization" (MEO).

This report is addressed to Task One of the Systems Integration Study, "Background Analysis and Data Gathering." It is principally concerned with delineating the basic structure of the Branch's computerized systems and with documenting the flow of data between them. A description of the principal functions of Branch Sections and their computerized information processing systems is followed by a categorization of Branch information products and data sources. This leads to an examination of routine and some *ad hoc* data flows and information transfers between systems. Some approaches to the general problem of systems and data integration are discussed in the following section and finally, an overview of cost efficiency issues with respect to Branch systems is undertaken.

DESCRIPTION OF EXISTING SYSTEMS

In the past, engineering design has been performed using paper maps. This is rapidly changing as engineers are turning to fast interactive computing and high resolution graphics to increase the productivity of their modeling and design work. Networking is necessary for resource sharing and access to common data used extensively by work groups within Sections and Branches. Computing strategies at BPA are advancing toward a more distributed network environment. This distributed network of workstations will incorporate existing minicomputers, mainframes and specialized nodes for CAD, GIS, file servers, printers, and plotters. The Facilities Planning Branch, a key player in this transition, is examining its use of technology in this rapidly changing arena. This section examines the current approaches taken by the Branch to support the planning and design of BPA engineering facilities.

Within the Facilities Planning Branch, the Environmental Section produces environmental documents, supported by a geographic information system (GIS) and a desktop publishing system. (DTP) In addition to studies supporting the selection of BPA transmission corridors and site facilities, the GIS has been used to produce maps of hazardous waste analysis (OM&C), crime patterns (Security Office), BPA's Rivers Study (Power Sales), irrigation facilities (Fish and Wildlife), and a regional data base for multiple mapping and planning needs. The Geographical/Engineering Section performs photogrammetric surveys, danger tree analysis, and image processing services. These activities support a variety of mapping functions within the Branch, as well as provide clearing design requirements, and construction clearing specifications for outside construction contractors and BPA maintenance operations. In addition, the Section carries out applied research and development using stereoplotters and special purpose computer equipment for image processing. The Survey Section plans and either conducts or oversees all surveys necessary to design, build, operate, and maintain BPA facilities. For contracted survey work, the Section provides contract monitoring and quality assurance functions for the Branch. It assists other Branch Sections by providing and maintaining coordinates data for mapping and other applications. The Cartographic and Cadastral Section employs a computer-aided drafting system (CAD) to perform mapping functions for the Branch. This Section also prepares and reviews descriptions for land acquisition, easements and crossing rights required for BPA transmission line projects and facilities siting. For contracted mapping and drafting work, the section provides contract monitoring and quality assurance functions.

The following material is a more detailed description of the functions, resources, and products of the four Sections of the Branch and their associated information systems. This information has been compiled from various personal interviews over the period from August 1989 to April 1990, as well as from agency documentation, particularly the Office of Engineering ADP plan for 1990-1994.

ENVIRONMENTAL SECTION (EFBG)

Functions. The Environmental Section manages and conducts environmental studies for engineering projects, policies, and programs. Section personnel provide guidance to engineering staff concerning the implementation of the National Environmental Policy Act and other federal environmental laws, environmental regulations of State and local agencies, as well as the BPA Environmental Manual. The Section conducts facility location studies to enhance the compatibility of proposed BPA facilities and neighboring environments, and provides assistance to Area Offices in preparing long-range plans for maintenance complexes and substations. Staff plan and carry out public involvement programs, analyze impacts, are members of project planning and design teams, and provide input to project decision making. The Section does research and development for environment, health and safety topics, and audits project impacts to verify impact predictions. The Section maintains two major technological systems, GIS and DTP, that provide support for environmental analysis. They also service other parts of BPA.

GIS: Production and Resources. GIS analysis of alternative transmission corridors and other environmentally sensitive decisions is widely documented within BPA. (Hooson et al. 1990) In addition to supporting environmental studies for transmission line construction, maintenance and redevelopment, the GIS has been employed in toxic waste studies for the Division of System Maintenance, providing the analysis needed for the next stage of the clean-up process. It has provided support to the Security Management Branch to interactively analyze crime patterns around the Lloyd Center BPA offices. The GIS has produced maps and map analysis for the Office of Power Sales' Rivers Study. The Section is continuing development of a BPA operating area regional GIS database. This database is currently used for regional long-range planning; the development of a 10 year plan map for System Engineering; transmission corridor facility studies; and service-area-wide radon concentration mapping.

The Branch's geographic information system has grown steadily in use and flexibility over the last few years, even though staffing levels have remained fairly constant. The GIS software consists of the ARC/INFO system from Environmental Systems Research Institute (ESRI), with a number of additional enhancements programmed in-house to accommodate growing user community demands. The system originally ran on a Digital VAX 11/730 with two terminals. It was upgraded to a VAX 11/750 in FY88 and currently resides on a VAX 11/785 computer. With this configuration, eight graphics workstations are directly supported and numerous other terminals have access through the agency's data switch.

DTP: Production and Resources. The Environmental Section's desktop publishing system (DTP) is used for preparing environmental reports that incorporate text,

graphics, and maps for agency use and public review. Currently, this capability is provided with the Section's Mac II computer which runs a variety of software including Page-Maker, MacDraw, and other programs which can import and incorporate graphic and tabular files sent from the GIS over an ethernet connection to the VAX. The Mac II can either emulate a GIS terminal to directly access the ARC/INFO plotting routines or it can simply download files already prepared by the GIS as well as other Branch mapping software. Hardcopy output for the DTP system is provided within the Section by a laser printer directly connected to the Mac. Another laser printer in Engineering Design, (EFD) is available over the network for output formats up to 11" X 17". For high quality large format output, or for the preparation of color separates, a Linotronic typesetter is available within the Agency. In this case, files are normally written to floppy disk and physically taken to the graphics shop, where another Mac II is directly connected to the Linotronic typesetter. There is currently no pen plotter within the Branch with a direct connection to the DTP system. This limits the availability of color check plotting.

GEOGRAPHIC / ENGINEERING SECTION (EFBH)

Functions. The Geographic/Engineering Section provides photogrammetric, image processing and remote sensing services for BPA. Photogrammetric surveys include planimetric and topographic analysis for transmission line plan and profiles, tower sites, access roads, and the identification of danger trees. The latter function is a specialty of this Section and consists of methods and techniques developed here. Danger tree analysis (DTA) is so important, given BPA's operating region, that up to one man-year, utilizing two to three of the Section's personnel and one of its two stereoplotters, is devoted to this operation. (Price 1990)

The Section produces topographic, contour, and planimetric maps as well as photo mosaics and photomaps for use by the Branch as well as customers in the Construction and System Maintenance Divisions. Applied research conducted by Section personnel supports environmental assessment by providing image-enhanced input data for the GIS. Computer assisted line following techniques promise to improve efficiencies for compiling planimetric data and terrain models from existing maps and photographs. (Pries 1990)

PHO Production and Resources. BPA is recognized as a leader in applying photogrammetry to new applications in support of electrical transmission design. (Price 1990) BPA "firsts" in photogrammetry include methods to determine right-of-way clearing requirements, monitoring structural displacements of a transmission line system, and developing methods to obtain precise three-dimensional spatial measurements using oblique photogrammetry. A pilot project using oblique photogrammetry to field-verify "hot checks" data is now in progress.

Photogrammetric surveys are performed using two US-2 analytical stereoplotters (purchased in 1976/1977) and a Galileo-Santoni II-C analog stereoplotter purchased in 1971. These instruments are also used to generate data for other systems, R&D applications, and for reimbursable work. The US-2 systems incorporate a PDP-11/44 computer for computational tasks and a PDP-11/35 computer for instrument control. Hardcopy output of planimetric and contour maps is performed with two Concord non-programmable table plotters driving a precision pen/pencil chuck.

IPS: Production and Resources. Since an IPS was first acquired in 1985, software has been developed for image enhancement, warping, annotation, and classifying feature data from satellite imagery, aerial photographs and maps. The latter applications are especially useful as input source data for the Branch's GIS.

In addition to the work that supports GIS, digital photomaps are an important IPS product. Photomaps that show transmission lines and their associated access roads have been prepared using analog methods. Digital methods are required to support new requirements pertaining to transmission maintenance (i.e. small-scale photomaps showing entire access road networks). Digital image warping and geometric rectification is providing better spatial accuracies for all users.

The IPS consists of a number of interacting hardware and software subsystems. (Pries 1990) At the heart of this system are the two Model 75 image processors from I²S, together with the associated proprietary software, "System 600". Originally acquired as a turnkey system, extensive in-house software development ("BPA600" software) has been added to support specific BPA image processing requirements. One Model 75 runs on a VAX 11/750 host computer and the other resides on the VAX 11/785, together with the ARC/INFO GIS software.

Scanned input for the IPS is provided with two devices. An Eikonix model 78/99 resides with the image processor on the VAX 11/750, and a Perkin-Elmer model 1010- GM microdensitometer (Micro D) is supported on a VAX 11/730.

The Eikonix digitizer is a push broom scanning device with a 1728 pixel by 2048 line resolution. At BPA it is used to scan map documents to be used for GIS input or combined as a base for overlaid photo-imagery. On occasion it has also been used to digitize color infrared photography as well as cartographic linework.

The Micro D is used primarily for digitizing aerial photographs due to its relatively higher resolution and its ten inch square scanning area. Its positional accuracy is measured in the 1 to 5 micron range and it can distinguish up to 4096 grey tone levels. Compared to the Eikonix, it is relatively slow, requiring up to two and a half hours to scan a 4096 pixel by 4096 line image. Because the Micro D can expose film as well as scan photographs, it serves as the output device for the Section's production of photomaps. With the Micro D, photomaps can be created with a resolution approaching the film grain, or 5000 by 3000 picture elements for a typical

rectangular map. There currently exists no other output option for this product. Since this production essentially competes with the time required for input digitizing, this represents a potential bottleneck. In an era of increasing demand for a wider variety of image products, it may be necessary to acquire additional output capability.

DATA ACQUISITION AND DEVELOPMENT SECTION (SURVEY, EFBI)

Functions. This Section is responsible for planning and conducting all survey work necessary for property acquisition, design, construction, operation, and maintenance of BPA facilities and rights-of-way. Control, location, and site surveys support these activities. Each type of survey has both a property acquisition and a facilities engineering component. (see Table 1) These reflect the principal roles in which survey measurement serves BPA construction and maintenance projects; management of interests in land and management of system facilities.

Control, or geodetic surveying, establishes the basemap geometry of the transmission right-of-way or facility site. Exact coordinates are established by field traverse or global positioning methods for found township and range section corners, property monumentation (if marked), and proposed transmission line points of inflection. EFBI maintains these coordinate data and providing other Sections and Branches technical assistance in determining coordinate locations for a variety of engineering and maintenance objectives. In addition, the control network applied to property lines assists the Cadastral and Cartographic Section (EFBJ) with property description for land and easement acquisition.

Table 1. BPA Survey Operations : A Typology

<u>Survey Type</u>	<u>Function</u>	<u>Project Role</u>
CONTROL	/ PROPERTY	- Tie section and township corners to State Plane coords
	\ ENGINEERING	- Establish transmission line centerline points of inflection
LOCATION	/ PROPERTY	- Locate right-of-way boundary, access roads and other features to support easement and land acquisitions.
	\ ENGINEERING	- Locate towers, clearing backline, cross sections, profiles.
SITE	/ PROPERTY	- Site BPA property boundaries and easements.
	\ ENGINEERING	- Site structures & facilities. Topography for cut & fill, etc.

Location surveys use the established geodetic control to locate the planimetric positions for proposed, and in some cases, for existing facilities along a transmission corridor centerline. A location survey may note the position of towers, roads, various fence lines, water bodies, as well as transmission lines and other facilities associated with non-BPA utility crossings and miscellaneous structures and buildings as noted from field reconnaissance. In addition to planimetric information, the location survey process normally includes a series of cross sections taken periodically along the centerline to establish the topographic relief along the right-of-way.

Site surveys, like location surveys, establish the location of existing and proposed facilities in planimetric as well as vertical dimensions. Site work, however, consists of detailed description of facility locations where the transmission centerline is not the principal frame of reference. Substations, microwave relay towers, and maintenance facility yards require site specific survey data for large scale topographic maps to support construction and subsequent facilities maintenance and landscaping requirements.

Information gathered through all three types of surveys are typically compiled in analog form on a document called a Survey Hardshell. The hardshell is often drafted in the field and is best conceived as a kind of process rather than just a finished product. Survey work on BPA projects is often an iterative process, requiring multiple trips to the field. Preliminary versions of the survey hardshell are compiled and used at various stages of a project for checking the progress of the work, the accuracy of computations, and to support other out-of-Branch users of the survey data. For example a preliminary version of the hardshell featuring geodetic, planimetric, and topographic data furnishes Facilities Design (EFD) the information necessary to specify tower heights, structural characteristics, and conductor sag requirements. A later version may be compiled with the clearing backlines from the danger tree analysis performed by EFBH. The final version may be the result of the location survey establishing tower footprints, specific danger trees, and other notations, such as tower guy wires, noted by personnel in the field. All through the process, the ability to refer to a hardcopy document of existing knowledge of the location is an important component of the quality assurance responsibility for contracted survey work.

The responsibility for overall survey quality assurance is especially important since much of the survey field work for BPA projects is performed by private firms under contract to the Agency. Under normal operating conditions, Control survey work for transmission line design or BPA site facility development is performed by Branch personnel in the field. The data derived from this work can then serve as a means for checking subsequent computations and field data from contracted location and/or site survey operations. The technical responsibility for the administration and procurement of survey contracts is an important part of the

work of this Section. A first hand knowledge of the control network is therefore essential to this quality assurance function.

Finally, the Section must continue to keep abreast of technological developments in the field in order to maintain the work load with existing FTE levels. For this reason it maintains an active development program involving cost-effective state-of-the-art equipment and techniques for surveying, such as the recent acquisition of GPS equipment, primarily employed for geodetic control work.

Survey: Production and Resources. The Section uses a variety of modern field surveying equipment for primary data capture and storage, computers to process that information, and printing and plotting peripherals to produce hardcopy and digital media products. These hardware devices, together with the associated software that operate and provide a link between them, can be said to comprise the information system of the Survey Section.

Geodetic coordinate data are increasingly gathered with the use of the Section's newly acquired Trimble 4000ST Global Positioning Satellite receivers. GPS technology provides significant advantages in terms of all weather operations, project scheduling, speed of data gathering, and quality assurance. (For a more detailed discussion of GPS see the "Cost - Efficiency Issues: Survey Efficiency Issues" section of this report) In addition to geodetic surveying, both location and site specific work may employ GPS receivers. More typically, however, these subsequent surveys make use of total workstation instruments (TWS) which, though not employing satellite positioning, are themselves state of the art survey instruments. TWS technology allows the sighting and horizontal distance calculation of a number of unknown points from a single point. As is also the case with GPS receivers, the TWS digitally stores field data to establish point coordinates.

Once back at Facilities Planning, data are uploaded from TWS and GPS receivers to an IBM3270 computer for processing. The Section also uses a Compaq PC and VAX support for computation of survey data and Triangulated Irregular Networks (TINs) as well as hardshell checkplots done with a Hewlet Packard pen plotter. Checkplots of the preliminary hardshell, are useful to determine the quality of contractor survey work, as well as monitor the progress of planned survey programs. Recently TIN data have been exported in digital format to Facilities Design (EFD) in lieu of more voluminous hardcopy transects and cross section drawings to support topographic analysis for site design and tower placement. In addition, coordinates for precisely measured features are supplied to the CAD system to avoid digitizing these locations from the survey hardshell. Of course the final hardshell is also provided to the Cadastral and Cartographic Section, (EFCJ) from which other, less precisely measured locations such as access roads and adjacent state highway rights-of-way are digitized manually.

CADASTRAL AND CARTOGRAPHIC SECTION (EFBI)

Functions. This Section is responsible for planning and conducting automated mapping and archival management in support of the design, construction, operation, and maintenance of all BPA facilities. It is also responsible for updating and maintaining existing right-of-way and facility maps and similar records.

A primary function of the Section is to prepare and review plat maps and land descriptions in support of permission to enter property (PEP) documents and land acquisition requests (LARs). PEP documents describe the property that BPA crews or contractors must enter to perform preliminary assessment and surveying. LARs are required by BPA's Lands Branch for the outright acquisition of property, or for construction or access easements for BPA facilities.

In addition to the principal functions described above, the Section maintains an active development program involving state-of-the-art equipment and techniques for mapping, and provides expert witness testimony by licensed land surveyors.

CAD: Production and Resources. Since 1985, manual drafting of maps at BPA has been replaced by Computer Aided Drafting (CAD). This system's primary responsibility is the production and updating of plan and profile drawings. These "mile maps", as they are commonly known, detail the entire BPA system of transmission lines at large scale and are the primary Branch documents for the description and inventory of the transmission network in the BPA service area. The production of the plan and profile series takes up to 90% of the work performed with the CAD system. (Jackson 1990) But this system is also useful for a number of other applications. In addition to the mile maps, the CAD system prepares detailed site maps for BPA substations, maintenance facilities, radio and microwave sites, fish hatcheries and other facilities. Small scale system maps of the entire northwest transmission grid as well as more detailed maps of the transmission network by BPA region are also produced with this system.

The CAD system consists of six Synercom large format GWS IV workstations, each consisting of two high resolution monitors (Mono and RGB), a keyboard, and a full sized digitizing table. (Actually, two slightly different sizes are used, both essentially full sized.) The tables are necessary because much of the information for the plan and profile maps comes from digitizing the final survey hardshells and photogrammetric manuscripts. These workstations are directly connected to a VAX 11/785 CPU and occupy about 60% of its capacity, the remainder being a shared resource for other Branch and non-Branch users. Although the Branch's GIS (EFBG) also resides on an 11/785, it is not the same machine. Hardcopy output of the plan and profile maps is normally directed to an electrostatic plotter available in the CAD area, supporting a resolution of 400 dpi (dots per inch). For occasional color output, files can be directed to a color electrostatic plotter at 200 dpi through the Intergraph equipment used by Facilities Design, (EFD). A recent example of

color output from the CAD system is the BPA transmission grid system maps. In this case, however, the in-Branch electrostatic plotter was used to output separate hardcopy plots to be used as the photo-positives for the color lithography process carried out by the Division of Administrative Services, Graphics and Printing Services Branch (SSG).

The quality of the maps produced by this system has proven to be highly satisfactory both for customers both within and outside the Branch. Indeed, they are almost universally recognized throughout the Engineering Division as the Branch's product. Synercom was originally selected as the CAD system in part because of the quality of output it provided. However, a substantial software upgrade is required and Synercom will not support existing software beyond the present year. Instead, the Section has decided to standardize mapping around Intergraph's capabilities which today are adequate to support BPA mapping requirements. In addition to filling map production needs, the Intergraph workstation environment also provides a means to enhance integration of mapping and design systems throughout the Division. Therefore Synercom workstations will gradually be replaced (as they become too old to maintain economically) with the newer Intergraph equipment. This gradual transition will provide Engineering with the long-term benefits derived from sharing CAD resources throughout the Division. To this end, the Section already has acquired two Intergraph workstation 245s based on the Intel 80386 technology and has an additional PC 80286 machine running the Intergraph IGDS or Microstation software. By way of the data switch and the DECNET connection, these workstations can also access the same output peripherals. An additional unexpected benefit of the Intergraph equipment has been its ability to write Post Script formatted files for output on the same large format laser printer that the EFBG desktop publishing system uses. While the primary production of plan and profile maps is supported on the Synercom equipment, generally newer applications and special purpose development is now routinely carried out in the Intergraph environment. An example of the latter are the isometric block drawings associated with the Clearing Advisory Reports produced by the danger tree analysis.

In addition to Synercom and Intergraph workstations, CAD production is also supported by a separate relational database management system (RDBMS) which serves as a computerized index to the thousands of CAD and manual drawings and updates that comprise the mile map series. The RDBMS software used for this purpose is ORACLE running on a Micro-VAX II in the Section. Currently, this database is accessible through structured query language (SQL) and does not support a graphical index as an interface. Expected updates to the ARC/INFO GIS software, however, will facilitate the integration of ORACLE databases with GIS graphics.

SUMMARY OF BRANCH PRODUCTS AND CUSTOMERS

The previous section detailed the mandates of each Section within Facilities Planning and described the basic production issues involved with each of its computerized systems. In this section an overview and summary is reported with a view toward identifying not only the information products supplied by the Branch with existing systems, but the customers, both within and beyond the Branch, who use these products. Proposed or experimental products are included here, partly to reflect the direction in which Branch Sections perceive the market for their services, and partly to reflect the shifting demand, particularly from the Design and Maintenance markets within BPA.

One characteristic of the Facilities Planning Branch is the variety of spatial and geographic information products it uses and supplies. This variety results primarily from the differing mandates of the Sections, and the systems they employ to meet their mission. A typology of the various forms that Branch information products take is indicated along with selected examples in Table 2. These include textual materials, analog, or "hardcopy" maps, digital maps and databases, as well as certain image products. A more detailed consideration of the structure and formats of geographic data used in Branch operations is taken up in a later section, ("Characteristics of Branch Data").

For the purposes of this study, a first -cut distinction may be made between those information products that are exported to other BPA Branches and Divisions as a consequence of Facilities Planning's information processing, and those products which are internal to the operation of the Facilities Planning Branch.

BRANCH - EXPORTED INFORMATION PRODUCTS.

The list of products in Table 2 concentrates primarily on the spatial information products that are the focus of this study. This table identifies information products by Section and system bearing primary responsibility for their production. It also identifies the primary form these products take using the typology of product form developed for Table 2. A summary of information products supplied to BPA and outside customers is provided in Table 3, "External Branch Products by Section". This was compiled from a variety of sources, including interviews with Branch personnel and customers, the ADP Planning report, BPA Engineering Conference Proceedings, and other in-house documents and memoranda. Particularly helpful was a definitive listing developed by each Section in preparation for the Division's Quality Assessment Technical Workshop. (April 1990)

Table 2: Form of Branch Information Products: A Typology with Examples.

Product Form (w/ abbreviations)	Example
TEXT - Written reports -TW- Tabular reports and print-outs -TP - Data lists (point lists, etc.) -TL-	FONSI [EFBG] DTA Clearing Advisory [EFBH] Pt. coords for found corners [EFBI]
ANALOG MAP - (plan, drawing) Planimetric Manually drafted -AM- Machine plotted computer driven -AC- stereoplotter driven -AS- Non-planimetric Line and site profiles -AP- Cross- sections -AX- Isometric perspective drawings -AI-	Older T-line Mile Maps (P&P)[EFBI] Current T-line Mile Maps [EFBI] PHO -manuscript contour maps [EFBH] Current T-line Profiles (P&P) [EFBI] T-line Survey Cross-sections [EFBI] Danger Tree clearing diagrams
IMAGERY - Aerial photographs Annotated (manually) -IA- Photomosaics -IM- Digital imagery (digitally processed) Photomap (no annotation) -IP Manually annotated -IPm- Digitally annotated -IPd- Other digital imagery -IO-	... all [EFBH] archived photos w/ drafted linework medium scale supplied on request Current & proposed photomap series Oblique, warped, classed, etc.
DIGITAL FILES - Digital map (formatted for map output) -DM- Digital database (formatted for DBMS) -DB- Digital flat file (point file, for FTN etc.) -DF-	[EFBG] Cnty, hydro, etc. layers (regional db) [EFBG] Attribute data from GIS analysis TIN [EFBI]
COMBINATIONS - Written reports with analog maps with photographs - with photomaps - Machine plotted maps with manual drafting - with digital imagery - Tabular reports with analog map	E.I.S. [EFBG] " " Survey hardshell [EFBI,] GIS maps with draped imagery [EFBG] DTA Clearing Report w/ isometric

Table 3: External Branch Products by Section.

Section / Product / System	Form (table 2)	Customer(s) (see caption)	Primary Function	
EFBG (Environment)				
EIS & other Environmental Reports and Plans	GIS DTP	TW +AM, AC, etc.	ALP, AJ, E, P, R , Areas AL, other Agencies	Planning
Brochures & other Notices and Briefing Papers	DTP	TW + AM AC, etc.	E, AJ, Areas, AL, etc.	Planning
Corridor Evaluation Studies	GIS	AC	AJ, EFD, EFC	Planning
Site Evaluation and Resource Assessments	DTP + GIS	TW, TP, AC, DB,	Areas, MMNC	Planning
Facility Site Plans	GIS	AC	Areas, EFD. EFC	Planning/ Design
Rivers and Irrigation Studies	GIS	AC, DB	PJW, PG	Planning
BPA HQs Crime Analysis	GIS	AC, DM,	SSS	Planning
Hazardous Materials Maps	GIS	AC, DB	Areas, MMNC	Maintenance
Radon Concentration Maps	GIS	AC, DB	RMR, AL,	Planning / Maint.
EFBH (Geographic / Engineering)				
Photo Manuscripts: Planimetric Topographic	PHO	AS	EFD, EFC + internal	Design
Photo - Profiles & Cross Sections	PHO	AS	EFD, EFC, MK, + internal	Design
Danger Tree Analysis (DTA) Backline Report Clearing Advisory	PHO	TP , DB +AC, AX	MK, MM, Areas, + internal	Design / Maintenance
Classification / Interpretation Bldg. heat loss studies	IPS	TP +DM	RM- internal + WaDNR	Planning / Maint.
Land use/cover class.	IPS	DM	EFD, EFC	Planning
Conductor temperatures	PHO	DB	EFD, EFC	Design / Maint.
Photomaps	IPS	IP m, IPd	EFD, EFC, MM, MK Areas, + internal	Maint./ Planning
Photomosaics	IPS	IM	MMEA, Areas, etc.	Planning/ Maint.
EFBI (Survey)				
Control Surveys	Surv	TP, DF	MK, MML, MMN, + EFD, EFC	Design / Maint
Location Surveys	Surv	TP, DF	& internal	
Site Surveys	Surv	TP, DF	Same as above	Design/ Maint.
Preliminary Hardshell + Maps for LAR	Surv	AM, AC,		
Final Hardshell	Surv + (PHO)	AM, AC	Areas, MM+ internal	Design/ Maint.
Profile Hardshells	Surv	AM, AC	EFD + internal	Design
Digital Terrain Model	Surv	DF	EFD	Design
EFBJ (Cadastral and Cartographic)				
New Plan & Profile Maps	CAD	AC	Areas, MK, MM, MO, EFD, EFC + internal	Design + Maint.
Map revisions / "as-builts" Descriptions for LAR	CAD	AC TW +AM	Same as new except MK MML	Planning/ Design
System Maps (Grid etc.)	CAD	AC	all BPA, AL (outside)	Planning
Site Facility Maps	CAD	AC	EFD, EFC, + internal	Design
Isometric DTA drawing	CAD	AI	EFBH	Design / Maint.

Customer Abbreviations used in Table 3:

AJ	BPA Administrative Assistant for Environment
AL	BPA External Affairs
ALP	... External Affairs, Public Involvement Program
Areas	BPA Operation Area Engineering Offices; Lower Columbia, Puget Sound, Upper Columbia, and Snake River
E	Office of Engineering
EFC	... Facilities Engineering, Project Management Branch
EFD	... Facilities Engineering, Facilities Design Branch
MK	Division of Construction (OM&C)
MM	Division of System Maintenance (OM&C)
MMEA	...Maintenance, Transmission Line Maintenance
MML	...Maintenance, Land Branch
MMN	...Maintenance, Non-Electric Branch
MMNC	... Environmental Protection Section
P	Office of Power Sales
PG	Power Sales Coordination and Review Staff
PJW	... Division of Fish and Wildlife, Project Management Branch
R	Office of Energy Resources
RM	... Division of Resource Management
RMR	... Residential Programs Branch
SSS	Division of Administrative Services, Security Management Branch
WaDNR	Washington State Department of Natural Resources

Table 3 also contains a summary of the important customers within and outside of BPA for Branch information products. These customers are abbreviated for the table by the routing designation used by the agency. Of course many of the products that are exported, are also useful for various purposes internally. A number of products therefore, have also been labelled as having internal customers, in this case, internal meaning, within the Facilities Planning Branch. Only products which are both external and internally useful are described in Table 3.

In addition to the systems that create the products and the customers who use them, each of these information products can be further distinguished in terms of the engineering and other functions they support within the Agency. For the purposes of this study, the investigators have delineated a functional typology, consisting of information products which serve a primarily Planning, Design, or Maintenance role. The products and their customers are discussed below in terms of this functional typology.

Products Supporting Planning Functions. In one sense all of the work of the Facilities Planning Branch can be considered generally as planning related. Certain exported Branch information products, however, directly support the needs of customers who work with facilities subsequent to the actual planning phase, for design and maintenance applications.

Branch products specifically related to a more strict sense of planning objectives include much of the end products of the Environmental Section (EFBG). These include Environmental Impact Statements, Environmental Assessment reports, Findings of No Significant Impact (FONSI), as well as various other notices of intent, public involvement plans, briefing papers, research reports and brochures. Sometimes these products involve the integration of text and graphics accomplished by the DTP system and output onto high resolution laser printers or prepared for black and white or color lithography.

Often in this process, the Section's GIS has been used to analyze the interplay between environmental factors, hazards and conditions (such as soil characteristics, slopes, and land cover for a site evaluation, for example) by spatially registering the individual maps of this information. Through the process of overlaying and recombining these data layers, a synthesis of information pertaining to a particular planning issue can be assembled. Especially useful in this regard is the ability of a GIS to weight variables independently. This ability aids in the analysis of the importance of various criteria for planning purposes; it facilitates multiple views and iterations of an analysis, and it aids in the flexibility with which the resulting output, whether in the form of a map or as tabular output, can be assembled and presented.

Maps and tabular data produced by the GIS can be incorporated into Section products and reports output with the desktop publishing system as indicated above. In some cases, however, they are directly useable to outside customers. The Table lists several examples of specific projects of this nature. Project Management Branch (EFC) recently needed maps of the site geography for the Captain Jack substation project. Still other examples involve the analytical work performed for the Security management Branch concerning the Lloyd Center area crime study, monthly updates of radon concentration for the Division of Resource Management, maps of irrigated land and fish hatcheries for the Office of Power Sales, hazardous materials mapping done for the Division of System Maintenance, and other ad hoc requests originating out-of-Branch that make use of the extensive regional database maintained by the Section, or of the analytical capability of the GIS.

In addition to the Environmental Section, certain products produced by other Sections also assist the planning related activities of other BPA units. Notable among these are several image products produced by EFBH. Small scale aerial photography is assembled and reproduced in the form of photomosaics on demand for the Area Offices and the Division of System Maintenance. On a larger scale are the existing and planned production of photomaps, geometrically corrected images with line and text annotation for both maintenance and planning oriented users. Finally, the BPA system maps, also known as the main grid or transmission grid maps, are produced by the CAD system for a wide range of users both within and outside BPA.

Products Supporting Design Functions. In addition to planning studies for the location and development of BPA facilities, Facilities Planning also is mandated to assist other Branches and Divisions with maps and other geographic information products and services. Especially within the Office of Engineering, this particularly refers to functions which can be characterized as design oriented.

Design oriented geographic data and information products can be defined as those maps and other services that support an analytical function with regard to the location or structural alignment, design or construction of facilities. Branch information products that support this function are numerous. They generally share the characteristics of large scale representations with accuracy and precision adequate to support measurement and analysis.

Design oriented products include the preliminary and final versions of the survey hardshell as well as the planimetric and topographic photogrammetric manuscripts. These maps are iterative versions of an evolving body of knowledge regarding a site or location along a right-of-way. From time to time a preliminary version of the hardshell, or the photogrammetric manuscript may be required by Facilities Design (EFD) or Project Management (EFC) personnel to support the design of structures and overall project management functions. In addition, since the survey hardshell contains property information, portions of it accompany LARs and PEPs, prepared by EFBJ and sent to the Lands Branch.

The Branch's production of the plan and profile map series is widely used throughout the Agency as the cartographic compilation of the set of design decisions that go into the construction and upgrading of BPA transmission lines. Other site facility maps produced with the CAD system support a similar design function for substations, fish hatcheries, microwave and radio sites, and maintenance facilities.

By no means do analog maps represent the only external products relevant to designing functions at BPA. Digital spatial data have been transferred from Survey (EFGI) to Facilities Design (EFD) in the form of coordinate files and TINs (Triangulated Irregular Networks), which consist of elevation data in a format useful for the three dimensional modelling applications to support cut and fill calculations and other landscape design requirements. This demand for digital data is expected to increase.

Design supporting information products also include the danger tree analysis Backline Report, and the associated Clearing Advisory Report produced with the photogrammetry system (PHO). Branch personnel use this system to evaluate planned transmission line rights-of-way with respect to the need to cut or save individual trees. Up to one FTE per year is spent in this endeavor, (Butcher 1990) the primary purpose of which is to facilitate transmission line designs consistent with BPA's continuing commitment to a minimum right of way width (Driessen and Dewey 1990) and the necessity to mitigate the visual effects of clear-cut corridors.

Products Supporting Maintenance Functions. In addition to the planning and design functions of out-of-Branch customers for Facilities Planning geographic information products, a number of facilities maintenance functions at BPA require the maps and other information available from the Branch.

Site specific maintenance products include the GIS analysis of hazardous material dumping sites at substations and surrounding areas. The Environmental Protection Section within the Division of System Maintenance uses this analysis in an ongoing program of toxic waste cleanup at BPA. From time to time also, Control and Site survey work supplied by the Survey Section may be required to support a facilities maintenance function.

Perhaps the biggest facilities maintenance function at the BPA is concerned with the more than 1,000 miles of transmission line rights-of-way. In addition to their function as design products, the mile maps are useful for field maintenance personnel since they represent a graphic inventory of every mile of the system. For this reason these 1:2400 scale drawings are photographically reduced to 1:4800 and compiled into bound volumes convenient for field operations. An attempt to have maintenance crews use microfiche versions of these maps in the field proved impractical, and the demand for a hardcopy, bound compilation of the transmission system seems assured for the foreseeable future.

One reason for this outcome to the microfiche reproduction of the mile maps is due to the longstanding habits and familiarity with paper maps. The analog output serves another function, however. On it, field personnel can note changes and additions, and "as-built" corrections to the transmission line as designed. If correctly noted and sent back to Facilities Planning, EFBJ can not only update the individual drawing, but keep a record of when the change was made and reference it to related drawings and profiles. This feedback function, though an important part of a facilities maintenance function, is not as systematic as it should be at BPA.

While the mile maps provide an adequately detailed view of existing facilities along a transmission right-of-way, maintenance crews and others sometimes need a more comprehensive view of the geography through which the line traverses. This need takes on two aspects, first, reference landmarks and other characteristics of the area not shown on the mile maps can be useful for determining one's location or finding a specific structure or facility. Second, a somewhat smaller scale view can be useful for determining access roads and other geographic features of interest to maintenance and area engineering personnel. To support these users, the Branch produces a number of related image map products.

Photomaps consists of the digitally enhanced and geometrically corrected aerial photography of a section of right-of-way, generally at the same scale as the mile maps. These photomaps depict the surrounding vegetation, structures, landforms

and other visual information not necessarily contained on the design drawings. In addition, they are annotated with text and other labelling which may include roadway and stream names, survey station mile numbers, and marginal notes indicated the distance to the nearest town. Line symbols that indicate the transmission line centerline, right-of-way boundary, section lines and other information are also routinely included on the photomaps.

At a smaller scale, aerial photomosaics of a region may be compiled from photography and reproduced to portray a wider view of the surrounding geography. Such products are not routinely produced, but have on occasion been the result of specific requests by area engineering or maintenance personnel. These products are distinguished from the photomaps by an absence of linework and text annotation. Future planning in EFBH for regular production of photomaps include geometrically corrected and annotated products at both the mile map and the smaller scales formerly representative of the photomosaics.

The results of the danger tree analysis work done with photogrammetric methods has already been cited as an example of Branch products supporting a design function. These products, particularly the Clearing Advisory Report, are also useful in a maintenance sense. Since the objective of the danger tree program is to preserve as many trees as possible, eliminating only those that pose a clear hazard to the transmission line as constructed, many trees are left standing both within and along side the right-of-way that must periodically be checked to see if continued growth or blow-down has created additional threats to the line. The Clearing Advisory Report includes information on trees to be cleared within the conductor swing area as well as outside of it. Growth rate data are included for trees that are not a hazard at the time of design, but may become so, later.

WITHIN - BRANCH INFORMATION PRODUCTS.

In addition to products supplied to other BPA Branches and Divisions, as well as outside agencies and the public, certain information products are produced and used internally within the Branch. These generally fall into two categories; those which are produced for use within a Branch Section, and those which are produced by one Section to support the work of another Section. As there is considerable overlap between external and in-Branch information products, as noted above, this section describes in detail only those products which are specifically internal to the operations of the Facilities Planning Branch. Table 4 is a summary of internal Branch information products. In some sense, these may be considered sub-products or interim products since they are normally used as input into information products such as the mile maps for example, that are considered an external product of the Branch. Nevertheless, because they represent a significant compilation or data processing effort by one Branch Section, or the final output of a particular Branch system, they are considered information products for the purposes of this study.

Table 4: Internal Branch Products by Section.

Section / Product / Form	Customer	Systems/ Environment	Form of Transfer	
EFBG (Environmental)				
Corridor Evaluation Maps	AC	EFBG	Arc/Info -> Mac	Digital via network
Other maps for EIS, EA, etc.	AC	EFBG	Arc/Info -> Mac	Digital via network
Facility Site Plans	AC	EFBJ	Arc/Info -> SYNC	Digital via network
Regional Database	DB DM	EFBJ	Arc/Info -> SYNC, + IGDS	Digital via network
EFBH (Geog. / Engineering)				
Photo Manuscripts:	AS	EFBI, EFBJ + EFBH	US2 -> Arc/Info US2 -> Surv. US2 -> SYNC US2 -> I2S	Digital via network Analog, no redigit Analog w/ redigit Digital via tape
Planimetric maps				
Topographic maps				
Profiles & Cross Sections	AP AX	EFBI, EFBJ	US2 -> Surv. US2 -> SYNC + IGDS	Analog, no redigit Digital via tape transfer or network
Danger Tree Analysis (DTA)	TP	EFBJ, EFBI	US2(DTA) -> Surv	Formatted report
Backline Report	AC		US2(DTA) -> IGDS	Digital via tape transfer or network
Clearing Advisory	AX			
Classification / Interp.				
Land use/cover class.	DM	EFBG,	MicD -> I2S I2S -> Arc/Info	Digital via tape transfer
Photomaps	IPd	EFBI	MicD ->	Analog no redigit
Image rectification (warp)	IP	EFBH	MicD -> I2S ...	Digital via tape/ disk
Photomap output	IP	EFBH	...MicD ->	Analog no redigit
EFBI (Survey)				
Control, Location, and Site Surveys	DF	EFBI	GPS or TWS -> Surv	Digital via disk transfer
Preliminary Hardshell or maps for LAR & PEP, etc	AC AM	EFBI, EFBH + EFBJ	Surv -> US2 Surv ->	Analog no redigit
Final Hardshell	AC AS AM	EFBJ	Surv -> SYNC US2 -> SYNC	Analog with redigitization
Pt. Lists for field coords	TL	EFBJ	Surv -> SYNC + IGDS	Anlog w/ redigitization
Profile Hardshells	AM AC	EFBJ	Surv -> SYNC + IGDS	Analog w/ redigitization
EFBJ (Cadastral/Cart.)				
New Plan & Profile Maps	AC	EFBJ, all	SYNC or IGDS->	Analog no redigit
Map revisions / "as-builts"	AC	EFBJ, all	SYNC or IGDS ->	Analog no redigit
Site Facility Maps	AC	EFBG	SYNC or IGDS -> Arc/Info	Analog w/ redigit

Systems Environment Abbreviations used in Table 4:

ARC/INFO	ESRI ARC/INFO GIS, VAX supported version.
Mac	Apple MacintoshII PC with associated software and peripherals
SYNC	Synercom CAD mapping system on GWS IV workstations
IGDS	Intergraph "Graphic Design System" (note: Microstation, or TIGRIS, Intergraph GIS-like upgrades may eventually be used by the Branch)
US2	The stereoplotters currently most used by EFBH.
DTA	The danger tree analysis sub-system on the US2.
Surv	Data processing hardware and software supporting survey operations.
GPS	Trimble 4000ST Global Positioning Satellite receivers.
TWS	Total Workstation field recording devices.

Interim Section Products. Some data and geographic information products are outputs of one process and inputs to another. Several Sections maintain more than one system or subsystem engaged in spatial data processing that result in separately identifiable information products. For these Sections, these are interim products.

In the Environmental Section, both the DTP and GIS are utilized. As has been noted previously, certain map products as well as tabular output resulting from analysis with ARC/INFO is routinely an input to the integrated text and graphics of an Environmental Impact Statement or other reports prepared with DTP.

The Geographic / Engineering Section (EFBH) contains the IPS as well as the PHO system. The former consists of relatively autonomous scanning, image manipulation, and display subsystems. Thus the MicroD or Eikonix scanners may digitize an image to be warped or enhanced with the Model 75 image processor. Conversely, the enhanced image may be the input to the MicroD's film writing functionality. On the PHO side, two US2 stereoplotters perform photogrammetric functions but the specialized application of the danger tree analysis (DTA) requires additional software support and entails a workload that allows it to be considered as a separate subsystem. The DTA output clearing report may be accompanied by an isometric drawing of a section of corridor accomplished with the Intergraph workstation. Although this latter system is part of EFBJ Section functions, DTA data are fed into a macro program operated by EFBH personnel to produce this graphic accompaniment to the Clearing Advisory Report. Aside from the output of the DTA, additional US2 contour and planimetric data may be used in preparing the control necessary for image warping on the I²S software of the IPS.

Several subsystems constitute Survey's spatial data processing. GPS and TWS data are inputs to microcomputer programs that process the data, check completeness, and calculate the adequacy of the control network. The output may be used to create the TIN and / or hardcopy profiles supplied to out-of-Section customers.

Within the Cadastral and Cartographic Section (EFBJ) it is more difficult to identify internal information products. Digital transfer of data occurs between the Synercom

and Integraph CAD systems, but no output product of one is an input to the other due to the essentially duplicative nature of these two systems. The emphasis of the Cadastral and Cartographic Section is primarily on the production of hardcopy maps, such as the mile map plan and profile drawings. These are considered more or less final products and exported outside the Branch for the most part. However, the plan and profile maps as well as facility plans prepared by the CAD system do support the efforts of the property description personnel within this Section.

Section to Section Products. A number of the information products listed in Table 4 are the outputs of one Section within the Branch and inputs for an analytical or mapping process which takes place in another. Spatial and attribute information developed by one Section are relevant and necessary to the functioning of other Sections. In Table 4 these products are listed as originating within one Section and having another Branch Section as its customer in column two. These are the information products of special interest to the systems integration study and will be examined in a later section of this report ("Data Flows Within the Branch"). Here they are considered as a group as products with an in-house customer base.

These products are produced in order to meet the responsibilities of the Branch which include the production of large scale engineering drawings of transmission lines (plan and profile, "Mile Maps"), the provision of regional environmental analyses, the development of large scale site plans and environmental analyses, the acquisition of property and access and egress rights, and the maintenance of an inventory of existing BPA facilities. They can generally be considered as six types of geographic information products:

- 1) The GIS regional database.
- 2) Photogrammetric manuscripts (planimetric, topographic, and profile)
- 3) The survey hardshell and related information.
- 4) The danger tree analysis, backline clearing report.
- 5) Image maps in the form of the various photomaps and mosaics.
- 6) The plan and profile maps.

The requirements of processing and compiling geographic information requires the integration of the efforts of the several Sections. This list of interim products is simultaneously the result of that integration and the cause of it. That is, in most cases each of these products depend on the existence of the others in house for either primary data, or as an integrity and quality check. For example, the survey hardshell is often updated with information from the photogrammetric manuscript which itself has been compiled from a stereo model created with the aid of field survey data. The danger tree report is created with photogrammetric and survey data, then used by survey crews on subsequent field visits to mark the backline. The mile maps also are used within the Branch as a check on the integrity of photomap products, or as an inventory of site and transmission line facilities.

A narrow view of the Branch mission persisting from the era of large construction projects is that it exists only to provide support for transmission line design. If so, then the work of the Survey Section is solely to provide control and planimetric information to other Branch Sections, Geographic / Engineering exists solely to add topographic information from aerial photography to the mapping process, or that the Environmental Section's principal function is to provide maps and data to the surveyors and others. This report recognizes that this is a distorted and restrictive view of the Facilities Planning Branch. The mandate to support organizations throughout the Agency with the geographic information needed to carry out their functions has been responsible for the development of external Branch products and customers as noted above. In some cases, these customers have approached Facilities Planning with requests for assistance with a particular map oriented product and in other cases, those organizations have found their own uses for existing Branch products. Because the Branch is expected to support an Agency-wide customer base, both the adoption of interim Branch information products, and the ad hoc requests for specific information are considered appropriate and necessary. Given this, the Branch has decided to examine the range of products and services it has to offer and wishes to identify other likely areas in which it can contribute.

POTENTIAL PRODUCTS AND CUSTOMERS.

It is left to Task Three of this study to examine a range of alternatives for systems and data integration and the impacts of these on organizational structure and product offerings. For this report, the Branch requested that some potential as well as existing customers be identified. This discussion is not intended to be exhaustive, but merely suggestive of the kinds of markets that exist for Branch products and data services that are either currently produced, or easily derived from existing processes.

Within the capability of the existing GIS are a number of additional services. The flexibility of the GIS for integrating spatial data has already been demonstrated by the range of products and services it provides to BPA Offices from Engineering, to Administrative Services. Use of the GIS for the modeling and display of electrical demand and supply, forecasting the spatial implications of continued growth, and/or conservation were noticeably absent in the authors' investigation of Branch products and services. The Power Forecasting Branch of the Division of Resource Management (RPC) would be one likely customer of this type of information.

In many organizations, the GIS is used for facilities management. While this has not been the focus of The Branch GIS work up to now, there may be a number of database development services that could be offered to the System Maintenance Division to facilitate its operations. Whether the product would be of a developmental service and data sharing nature, or consist of actual analysis and maps, of course, depends on that Division's willingness to incorporate GIS technology into its own operations.

The image processing research that has been carried out in EFBH shows promise for a number of applications throughout BPA. Existing photomap series have been widely used in the past for operations and maintenance personnel in the Area Offices, as well as various Branches in the Division of Construction, and the Division of System Maintenance. In addition to these customers for the photomap series, Branches in the Resource Management, Resource Planning, and Fish and Wildlife Divisions may also find annotated photomaps useful for both field visits and other reference purposes. There has already been interest expressed by at least one Area Office for photomaps at an intermediate scale, larger than regional mosaics and smaller than the mile map approximation. Throughout BPA a range of scales may be required by different organizations.

The ability to provide a range of digital imagery selectively combined with user required line and text annotation makes this an external product line with potentially high demand. While a standard product series to match the mile maps may remain useful to existing customers, the ability to produce photomaps with custom symbolization is the real benefit of the IPS. In addition to the photomap products, the possibility of supplying digitized imagery for GIS databases in other Branches and Divisions is also demonstrated by the work currently done for EFBC.

The provision of data files consisting of topographic information in the form of Triangulated Irregular Networks (TINs) has already been noted as an external product of the survey operations of EFBI. More widespread adaptation of such products is dependent on the digital processing and design methods employed in another Branch. Aside from EFD, however, there may be customers for digital terrain data in Area Offices and the Office of Energy Resources. At any rate, the same customers who can make use of digital image and classification products from EFBH might use TINs and other DEMs (digital elevation models) derived from EFBI data.

It has already been noted that the production of the plan and profile hardcopy maps takes up to 90% of CAD production of the Branch. These maps are extensively used at Area Offices, Construction, Maintenance and Operations Divisions and elsewhere. As the Intergraph workstations in this Section become more prevalent, as more operators are trained on them and as they are better integrated with existing data, there will be more opportunities to supply other Branches in Facilities Engineering with CAD products such as landscape drawings, floor plans, and substation site plans.

CHARACTERISTICS OF BRANCH GEOGRAPHIC DATA

Given the principal responsibilities of the Facilities Planning Branch, the focus of this analysis is on geographic data. Geographic data are considered to be data which describe the location of features and/or the spatial distribution of phenomena of interest. This includes data that describe the underlying geodetic reference framework to which all other data are registered. Of primary interest are the location and other attributes of BPA facilities. These include transmission lines, substations, rights-of-ways and easements, clearing zones, access roads, and other sites. In addition, more general characteristics of the geography of the system service area, such as environmental factors, load and population forecasts, and land use/cover data are employed by the Branch in its planning and geographic information service roles.

SPATIAL AND ATTRIBUTE DATA.

In general, geographic data consist of observations concerning spatial and non-spatial aspects of a feature or pattern. Primary spatial aspects of geographic information include the location, position, or orientation, of a feature with respect to some reference. Secondary, or derived spatial data may include variables such as area, length, perimeter, shape or other spatial measures of relevance. Non-spatial data include feature name, class, ownership, voltage, ... essentially information concerning what is known about, or attributed to a feature occupying space. For this reason, non-spatial geographic data are referred to as attribute data.

The distinction between spatial versus attribute data is nearly universal in information processing and prevails from pre-computerized cartography and spatial analysis. It is important to remember that the distinction is essentially an arbitrary one, and is a function of how features and phenomena are conceived, abstracted, and represented. For example, while location is considered a spatial aspect and street address an attribute, the coordinates that describe a point in space are certainly attributes of that point on the one hand, and the street address certainly describes location on the other. Different conceptual models of geographic features and distributions will describe different entities and attributes for those entities, and the ease with which data may be exchanged between databases depends upon the compatibility of the underlying models expressed by those databases. These database models describe the content of the system's data.

While nearly all data used by the Branch can be usefully described in terms of a spatial and an attribute component in the conventional sense, the conceptual models of geographic features vary between the Sections, and by the kind of work being done on individual systems. To the user of a the main grid map, for example, a transmission line corridor is conceived as a series of two dimensional cartographic line segments, spatially, and attributed with a color indicating a voltage. To those

who survey or map the transmission rights-of-way, that corridor is an area of a standard width, cleared to a varying width, and comprising numerous line, point and area features within it.

In general the distinction between spatial and attribute data is useful for most of the geographic data handled by the Branch. Aerial photography may be one possible exception to this rule, as an image without any manipulation or interpretation has neither spatial features identified within it or attributes associated with them. As soon as processing takes place, however, features are assigned location and other attributes according to the purpose for the processing. Data in the various GIS databases are stored and processed according to whether they describe spatial geometric objects (ARC) or attribute data about those objects (INFO). While CAD systems are not concerned with the analytical functions for which a GIS maintains attribute data such as land use, soil classification, etc, these databases nevertheless also maintain the essential distinction between spatial versus attribute data. In a CAD system the attributes describe information known about the graphic representation used to depict the mapped features. Line width, color fill, point-marker type and so on, are examples of attribute information in a CAD database. For the surveyor, the primary features of interest are points which can be assigned spatial location. These points may be freestanding section corners, property markers, spot elevations, and tower locations; parts of a linear feature such as points of transmission line inflection; or areal features such as a computed parcel centroid. While the spatial location is the primary information sought by the surveying process, the name or station number of the point for which the coordinates are known is the attribute data.

The point being emphasized in the preceding paragraph is that systems which handle geographic data differ according to how the spatial and the attribute data are modelled. For most large scale representations, location can be represented in terms of State Plane Coordinates (SPC). Exceptions to this are the estimated 40% of all rights-of-way that were located according to older, local grid surveys. At smaller scales, regional GIS coverages and some imagery are normally stored in Lat - Long coordinates, requiring conversion to SPC if integrated with other information. The coordinate framework that defines zero-dimensional points, then can be used to specify one-dimensional linear features, two dimensional areal ones, and three dimensional volumes. Data in different systems may define different features according to different dimensional characteristics as has already been noted with the transmission line right-of-way example.

Attributes too, differ with respect to the way in which the data are modelled. For the most part, attributes are single valued (scaler) variables that pertain to the geographical features. The structure of how attribute information is stored and processed varies, however. The ARC/INFO GIS, as well as the Oracle CAD index database, for example, store attributes essentially as tables, manipulating them with a relational database management system (RDBMS). Other systems use hierarchical or network database structures for attribute data. In normal practice, this does not

preclude the integration of attribute data from one system being used by another. It just necessitates a translation from one format to the other.

In the sections below, the several forms and structures by which spatial and attribute data are handled in the Branch are discussed. Systems integration assumes that a variety of formats for geographic data are useful and valid for the many functions of an organization. The objective is not to uniformly represent all data with one structure, but rather to inventory the models by which those data are represented in order to recommend procedures for improving the way they work together.

FORM OF THE DATA: DIGITAL AND ANALOG.

Traditionally, geographic information is conveyed with maps. Hardcopy maps have served as visual displays as well as a convenient medium for the transmission, storage, and exchange of geographic information. It is not surprising, therefore, that the incorporation of data processing and information system technology has continued the practice of map production by the Branch.

The widespread adaptation of digital geographic data processing is due to the increased flexibility for representation and editing possible with the aid of computers. Still, digital geographic data require software to facilitate their display and analysis, just as analog data required drafting and other graphic rendering tools. In addition, certain analog products remain useful in environments, such as in the field, where a digital display device is not readily available.

A simplified version of a transmission line design project is illustrated by analogy in Figure 1. Before automation, each stage results in a map product. In contrast, an automated process is proposed where digital outputs of one computerized process are inputs into the next logical step. The extent to which this is an ideal situation must be determined by the Branch with knowledge of the the range of information products available and the environments in which they are used. To a great extent, current automated systems tend to replicate traditional maps, producing digitally processed information in an analog form. Many external products for Branch customers are demanded in analog and produced with a digital process. Part of Task Three of the systems integration study will be to identify where interim analog information products ought to be substituted with digital ones. While time, cost and error reduction are achieved by some digital transfers, by no means is it assumed that all analog map products should be eliminated in favor of digital file transfers. It is probably worth noting that the display of geographic data in a form interpretable to the human eye is still an important part of the production process. The identification of digital data transfers in place of the analog re-digitization of hardcopy maps is intended to streamline communication between digital systems, not to eliminate the valuable role of visualizing map displays.

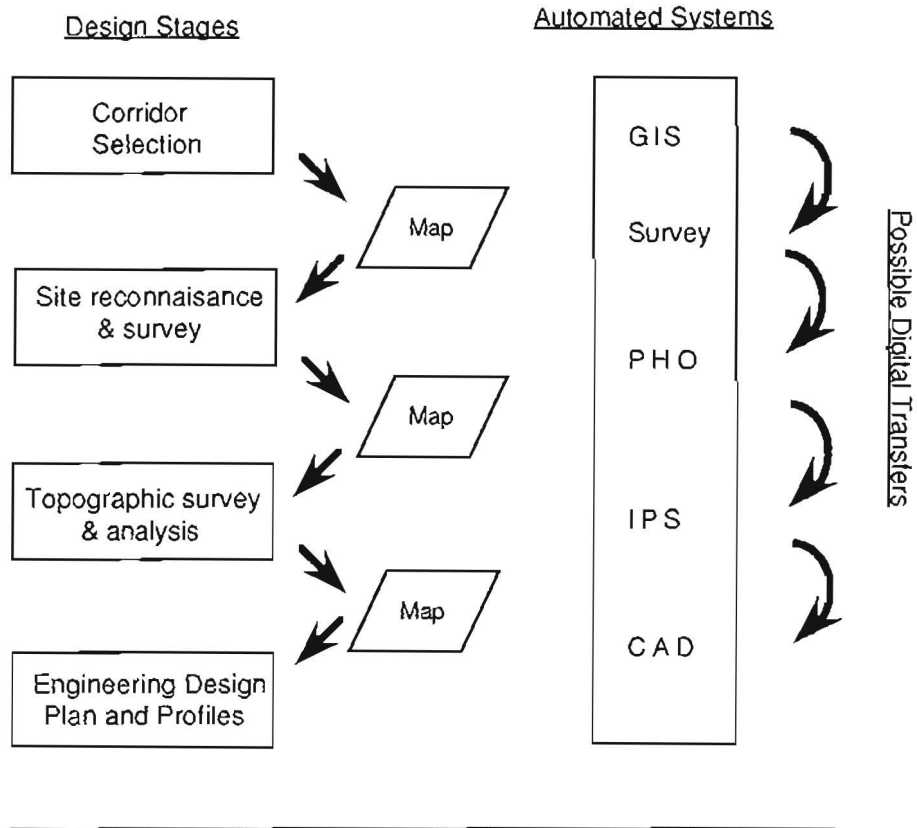


Figure 1: An idealized notion of analog versus digital procedures in the work flow of a transmission line design project.

FORMATS OF ANALOG AND DIGITAL DATA.

Beyond characterizing geographic data by their general analog or digital form, the format and structure of the information is naturally relevant to a systems integration study. Both analog and digital information can be said to have a format and structure. It is useful to consider the relevant characteristics of each in order to discern the advantages and disadvantages of a particular method of representing geographic information.

In Table 2 (page 12) the form of Branch information products was described in terms of text, analog map, imagery, digital files and/or combinations of these. This typology was sufficient to describe the external and internal final products of some geographic processing or compilation procedure. For the purposes of discussing the data used in these processes, however, a more detailed hierarchy of form, format and structure, is presented in Table 5 and summarized below.

Table 5:
FORM, FORMAT, & STRUCTURE OF GEOGRAPHIC DATA

FORM	FORMAT	STRUCTURE	(Examples)
Analog	Image	- Stereo photography - Other planimetric photography - Oblique photography	(9X9 aerial panchromatic, and others)
	Map	- Base, reference or thematic - Various scales and sizes	(Radon, Mile maps) (Mile maps, Main Grid)
Digital	Raster	- Picture file - Compressed raster	("paint"-type files) (run length encoded...)
	Vector	- Points in x,y,z - String (no topology) - Vector-topologic	(Flat file listing) (DXF + other CAD) (ARC/INFO, ...others)

Analog Formats. The general format of analog products is described as either an image or a map. The distinction is based on the degree of generalization and interpretation evident in the graphic. Photographs represent all features visible to the sensor, whereas maps are essentially generalizations. An important corollary of this distinction concerns the comprehensive nature of photographs with their attendant massive data storage requirements for digital conversion, and maps, which can be digitally represented by a more abstract, linear structure.

Much of the outside information to the environmental analysis function of the Branch comes in the form of analog maps which are digitized for input into the GIS. USGS maps, state and local government maps of transportation systems, ownership parcels, and utility company line maps are examples of this data format commonly in use. Analog maps are still widely used as a medium of information exchange between systems in the Branch as well. The survey hardshell is essentially an analog product, often the compilation of a number of hands, from different sources. The manuscripts from the PHO system are analog map products. Together with the the survey hardshell, these constitute the analog inputs into the production of the mile maps.

Aerial photography is an analog image product in widespread use throughout the agency. In the Branch an archive of photography is maintained by EFBH, and aerial mosaics and stereo pairs are available to users within and outside the Branch.

Digital Formats. The predominant digital formats are raster and vector representations. The distinction reflects uniquely different and mutually exclusive spatial conceptions.

Raster data can be conceived as a representation of continuously distributed phenomena in discrete spaced abstracted into tessellations. For data collection, the value of an attribute variable is determined at the level of resolution of the tessellation and generalized to individual cells. For data display, from where this term arises, rasters are scan lines of discrete picture elements, or pixels, each of which are individually symbolized with the hue or tone that represents its attribute value collected.

While some GIS and computer aided mapping systems have been designed to operate with raster only data, the systems in use at Facilities Planning are not of this type. However, the ARC/INFO GIS does include a raster-to-vector translation facility that enables it to import raster encoded data. More prevalent uses for raster data are in the arena of digital image processing. The Eikonix and MicroD scanners of the IPS system in the Branch scan imagery and store it in a raster format.

Vector data can be conceived as representations of discrete features in continuous space. For data collection, point, line, and areal features are represented as zero, one, and two-dimensional spatial objects and specified in terms of a coordinate system. Analog output devices, such as pen plotters, require data in a vector format. The raster form is used for CRT displays and, increasingly, for hardcopy from electrostatic plotters.

The vector format for digital geographic data is most prevalent at the Branch. GPS and TWS survey data, photogrammetrically derived point and elevation data, point, line, and area symbols in the CAD system and most of the spatial data used by the GIS are all in vector format.

DATA STRUCTURES FOR GEOGRAPHIC INFORMATION.

The structure of data is the logical representation of information concerning the spatial entities, their attributes, and the relationships between them. It is common to consider digital structures only, but an informative analogy with analog data helps to define the meaning of structure for information access strategies.

Map and Image Structures. The visual interpretation of an analog map depends on the success with which graphic symbolism communicates information to a user. Graphic elements such as symbol size, orientation, hue, tone, spacing, etc., are employed in combinations familiar or obvious to the map reader. Where the exact

meaning of a symbol is not familiar, a map usually contains a legend identifying the interpretation of a particular symbol. The manner in which combinations of these graphic symbols are presented constitute cartographic structures for geographic information. Thematic structures include representations of generalized distributions across geographic surfaces. Reference structures employ symbolism intended to represent an inventory of all geographic features in an area, especially with regard to their precise location. The distinction between thematic and reference structures for analog information concerns the purpose for using the map. A complex set of relationships between scale, output size, and locational versus thematic objectives determine an appropriate graphic structure for a particular communication objective. The use of analog map inputs to digital geographic databases requires knowledge of the graphic structure of the map. For this reason, simply scanning thematic maps, for example, is rarely sufficient, since individual symbols must be separately identifiable for the association of attribute data in a digital system.

Analog imagery also exists in a number of differing formats. Film characteristics, such as grain resolution, film speed, and spectral sensitivity limit the applications for which analog imagery can be used. As with analog maps, knowledge of the structure of analog imagery is required for digital processing.

Several analog map and image structures can be identified within the Branch. Aerial photographs exist for example, as stereo pairs for the photogrammetric process, or in other planimetric and even oblique structures. Similarly, analog cartographic products exist with structures that can be characterized primarily as base reference, or thematic structures. The plan and profile as well as the survey hardshells are essentially reference documents whose primary function concerns the representation of precise locations among mapped features. The analog maps from the GIS, on the other hand, while occasionally serving a reference function at smaller scales, are more often thematic maps supporting Branch environmental studies and special projects. In contrast to the line-dominant format of the plan and profile, these thematic maps typically depict areal features and reflect the polygon overlay and buffer generation procedures employed in various spatial analysis.

Raster Data Structures. Raster data may be encoded in a number of structures. A bitmapped format ("Paint"- type file) holds a binary value for every pixel in a display field. This can quickly become a massive data storage problem and contain a great deal of data redundancy, especially when large areas of the map or image so encoded are the same value. Compressed raster formats such as run-length encoding can reduce the storage requirements for raster files. In this case the graphic is represented by encoding a value, followed by a numeric describing the number of pixels along an individual raster to which the value applies.

As noted above, remotely sensed satellite or digitally processed aerial photography are encoded in a raster structures. Software development for processing and storing

this voluminous information necessarily is concerned with methods for increasing the speed and reliability accessing and processing raster data. Data partitioning and addressing schemes such as quadtree structures, are further refinements of the raster format to facilitate the speed of data retrieval.

Vector Data Structures. Vector data are encoded in a number of different models and at least three are identified as existing within Branch system databases. Data expressed as simple x,y,z coordinates describe points in USGS digital terrain data used in some GIS applications. In addition, certain field survey measurements can be regarded as having a similar format if digitally encoded such as output from GPS or TWS. More typically, vector data are mathematical descriptions of linear structures, from where the term derives. At least two important structures are used for linear data, topological and non-topological, or string data.

Strings, also called "cartographic spaghetti", consist of descriptions of linear segment geometry only, without corresponding information on a segment's connectivity with other segments, points, or adjacent areas. This structure predominates in CAD databases, where lines are principally distinguished as to associated data layer, and within layers, by line type according to graphic requirements.

Vector-topological databases, most notably that employed by the ARC/INFO GIS, encode geographic features as zero, one, and two dimensional nodes, chains, and polygons. These objects are distinguished from the point, line and area objects of string data by graph-theoretic relationships enabling each object to be topologically related to objects of the same and of other dimensionality. With this structure software can be developed to access these objects and associated databases for spatial queries, overlay, and network analysis.

DATA SCALE AND GRANULARITY.

In the context of geographic information, scale can be considered as a cartographic relationship, the ratio of map distance to ground distance, most conveniently expressed as a representative fraction, eg. 1:24000. In considering the Branch's geographic data in terms of scale, a rough division between large scale and smaller scale operations are identified by the series of cartographic products produced by Branch systems. Table 6 provides an overview of selected Branch cartographic products categorized by small, medium and large scales.

Small scale map products are produced mainly with the GIS in support of Branch environmental analysis or special projects for external Branch customers. Although some of these have been indicated in the table, the scale of input data can vary considerably. Digitized USGS quads and DLG (digital line graphs) are public domain sources used for base map and other feature data captured at 1:24000, whereas the DTM (digital terrain model) data supplied by the same agency is at 1:250000. For

medium and larger scale GIS analyses, a variety of maps depicting local regions around BPA substations and transmission rights-of-way are employed at different scales. Part of the utility of the GIS is its ability to spatial register and integrate data compiled from varying scales. With this comes the possibility of compounding error when data are used at scales larger than that for which it was compiled. For this reason, data are usually obtained at input scales greater than the output product. Exceptions to this general rule of thumb can be made when precision locational accuracy is not a primary concern, but these occurrences should then be documented and well labelled. The Digital Cartographic Data Standards adopted by the DCDSTF (1988) provide the guideline for appropriate reporting of the lineage and derivation of compiled cartographic data in this regard.

Most of the Division's spatial data consist of large scale representations of site and right-of-way facilities. The survey hardshells produced from GPS or TWS data and sometimes including photogrammetrically compiled data are large scale. Within the Branch, it is common to refer to the scale of the hardshell as, "one inch to 200 feet". As a representational fraction, this is expressed as 1: 2400. CAD production of the plan and profile map series is also done at 1:2400, making this a somewhat standardized working scale for in-house data related to transmission line projects. Although the finished plan and profile map sheets are available in the 1:2400 format, a plot approximately 32 by 24 inches, they are also photo-reduced to a half-scale representation and bound in volumes for archival purposes, as well as use in the field by the Area Offices and Maintenance Division. This scale, familiar to many external customers of the mile map series, is therefore at inch to 400 feet, or 1:4800.

Table 6:

TYPICAL SCALES OF BRANCH GEOGRAPHIC DATA.

<u>System</u>		<u>Small Scales</u>		<u>Medium Scales</u>		<u>Large Scale</u>		
		<u>1:250,000</u>	<u>1:100,000</u>	<u>1:24,000</u>	<u>1:4,800</u>	<u>1:2,400</u>		
GIS	in out	regional db layers, DTM, " corridor studies		DEM, DLG rivers study,		data for site analysis Crime study... others		
IPS	in out	Landsat & SPOT satellite GIS classification, shoreline vegetation,			recon. aerial photos, aerial mosaics,		photomaps	
PHO	in out				recon. aerial photos,		survey data photogram. mss	
CAD	in out	layers from GIS regional db. system grid maps,		Ross facilities	Mile maps: bound, ...		hardshell data sheets	
Survey	in ... out	N/A					TIN &	hardshell

The scale of input reconnaissance photography varies with aircraft, camera and flight conditions and is precisely calibrated in the photogrammetric process. For the most part as used at BPA, aerial photography in support of transmission line design and site evaluation is at one inch to 2000 feet, or 1:24000, the same scale as a 7.5 minute USGS quad map. Because of the greater film resolution, and the continuous nature of data compiled in the photogrammetric process, output from this system typically consists of data at scales considerably larger. Most of the photogrammetric manuscripts produced by the Branch are at 1:2400, consistent with the survey hardshells and representing a tenfold enlargement from the stereo photography.

The interpretation of the granularity of spatial data has slightly different meanings with respect to raster or vector structures. Both meanings, however, concern the ways in which input scale and output generalization processes interact.

The resolution of the raster device employed in either data collection, storage, or display determines the granularity of these data. That is, while data values may be aggregated into larger and larger units, the cell size represents an absolute lower bound beyond which data may not be disaggregated. Data accuracy and precision are relevant only with respect to this granularity, which also influences the visual appearance of raster produced hardcopy output.

Granularity with respect to vector data reflects not only the precision at which digitized coordinates are captured from analog maps (and thus, indirectly a function of the accuracy of the input cartographic product) but also the database design considerations for handling and storing that level of precision. In addition, the scale of the analysis can influence which features are modelled as points, lines and areas. Thus, dimensional collapse is a data granularity issue when comparing spatial data at differing scales. A relevant example concerning BPA facilities concerns a database describing the entire northwest power system distribution, in which individual substations would be represented as point objects. A database representation of a portion of that region to support analysis at larger scales, would model substations as polygons. At still larger scales substations would no longer be single objects with associated attributes, but complex objects composed of many other point, line, and polygonal entities. Therefore even when systems contain similarly identified features, their digital transfer may be complicated by the granularity, or dimensional representation associated with either database.

DATA FLOWS WITHIN THE BRANCH

A major objective for this study is to provide information necessary to improve the efficiency of data exchange between Branch information systems. Certain exported and internal information products handled within the Branch were examined and noted in the system description and product identification sections of this report. The variety of products and formats suggest a high degree of flexibility on the part of the Branch for products and services that support geographic analysis and facilities design and maintenance. In this section various internal information products are examined again, this time with respect to the structure and characteristics of the data flows required for the production of external Branch products.

To account for the widest perspective on this phenomenon, a data flow view of information was taken; that is, inputs and outputs of each system were regarded as data, whether in a relatively unprocessed form such as a digital flat file, or compiled into an information product such as a map. Primary concern was given to identifying data flows between Branch systems that were cumbersome, time consuming or redundant, often involving the analog-to-digital transformation. A general typology for data transfers can be found in Table 4, (page 19). The typology closely parallels the general forms of analog and digital data and consists of the following categories.

- ANALOG TRANSFERS:
 - Analog with re-digitization
 - Analog with no digitization
- DIGITAL TRANSFERS:
 - Digital via network, with or without reformatting
 - Digital via tape or disk transfer

Because many of the internal products and data flows support the production of a set of Branch products relating to transmission line design, most of the data flows discussed in this section directly pertain to this effort. Not all Branch data directly support transmission line design, but in some cases they result from internal products produced in conjunction with processes that do. A very generalized picture of the transmission line design process was presented in Figure 1 (page 27) which suggested a number of work processes that required digital or analog geographic information exchanges. A more realistic schematic of the process is presented in Figure 2, itself still a generalization of the entire process. In Figure 2, procedures that support transmission line planning, design, and maintenance are indicated and important data items between them, recognized.

Three important observations about this process should be acknowledged before undertaking a more detailed description of individual data transfers. First, the construction of a transmission line corridor involves a variety of disciplines and

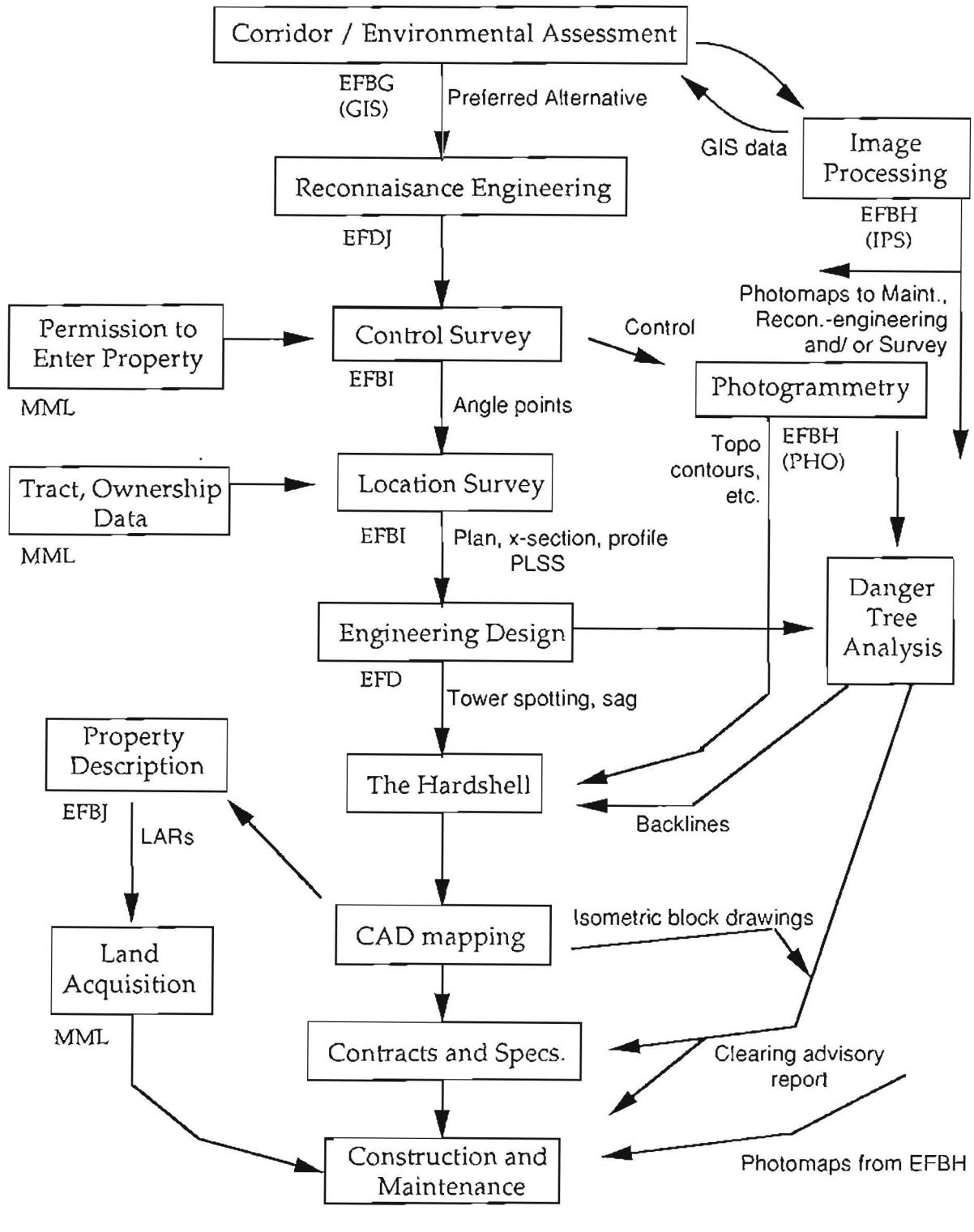


Figure 2 : Processes and products involved in transmission line design.

operations. Some, such as corridor selection and environmental assessment logically precede others, such as tower and conductor design. Figure 1 supports this interpretation of the process. The actual process, however, involves functions that occur in parallel and involve some BPA organizations outside the Branch. A detailed project management chart has been compiled by the Branch's integration team as mentioned in Jackson, 1990. Figure 2 abbreviates this, indicating roughly parallel processes concerned with land acquisition, right-of-way surveys, and photogrammetric support that occur simultaneously with various electrical and non-electrical facilities design processes.

Second, while there is a temptation to consider the plan and profile drawings or "mile maps" as the end product, in reality there are a variety of Branch products that are generated in the overall process supporting transmission line design. These include the preliminary and final versions of the survey hardshell, the various environmental reports, property descriptions, and image products as has been mentioned in the products section of this report. Each of these products in turn can be used for planning and/ or maintenance functions not directly connected with engineering design work.

Finally, the third general observation concerns the primacy of the locational (spatial) component of the data. Central to obtaining and maintaining precision spatial data are the several surveying operations concerning property and engineering functions as described in Table 1.(page 6) These efforts culminate in the survey hardshell, which often incorporates the results of photogrammetric surveying for areas of difficult accessibility and little tree cover. The mix of ground survey and photogrammetric data on any one hardshell varies by project, even by mile within projects. The hardshell itself is a process as much as it is a product, undergoing several versions for different users during a line design project and plotted at various points for its utility in field compilation and data quality assurance.

Each of these three general considerations result in definable information products that are justified in terms of a unique customer base, time demand, or level of precision. Therefore, while similar graphic depictions of the right-of-way may exist, for example in the hardshell and plan and profile maps, the customer base, level of detail, and stage in the overall process must be considered carefully before deciding that the information product is redundant or otherwise a duplication of effort.

ANALOG DATA TRANSFERS.

The usefulness of an analog hardcopy version of mapped data has been discussed elsewhere in this report and is not questioned here. The typology of information products used earlier distinguishes between analog and digital data transfers between Branch systems. For the purposes of this report, an analog data flow consists of the transfer of geographic attribute or spatial information in the form of a

hardcopy map, or photographic image. While many of these flows might seem to be candidates for digital transfer strategies to be recommended in Task 3, some considerations as to how and why they are presently analog exchanges is important to note here. This can be described in terms of two concepts, the re-digitization of interim products, and the analog map as a final information product.

Re-digitization. The Survey Hardshell is an analog map produced as the result of control, location, and site surveys which may also include spot elevations if known, cadastral boundaries with reference to PLSS monumentation, and a mix of photogrammetrically derived information as well. Since the Branch normally contracts out the actual surveying work, the original hardshells may be produced out-of-house. An important responsibility of the Survey Section, however, is the oversight and management of these contracted services and so this Section also maintains the original control coordinate data which can be used to check for errors in subsequent compilations.

Given the advancement in digital instrumentation in the surveying field, (TWS and GPS), private contractors are often recording coordinate data in digital form and producing the hardshell with a computer assisted process. In many instances, this will be accomplished with a commercially popular CAD product such as AUTOCAD. This system encodes graphic information in a format that has become a *de facto* industry standard, known as DXF (Digital eXchange Format). Specifications for the survey hardshell currently do not require the contractor to supply the DXF version of the survey hardshell. Subsequent recapture of this digital information is therefore dependent upon the error prone process of manual digitizing.

At various points along the transmission line design process, a preliminary version of the hardshell is useful for checking data quality, making corrections, and other analog work processes. In some cases where Survey (EFBI) has the planimetric as well as control data in TWS or GPS disks, the Section's HP plotter can produce such a plot. In other cases, new planimetric or topological contours may be overlain on the analog hardshell directly through drafting or using the stereoplotter.

The final hardshell is in turn, an important source of data for the plan and profile mapping effort of the Cadastral and Cartographic Section (EFBJ). These analog plots are manually digitized for input into the CAD system. They are routinely augmented with printouts of coordinate data in a tabular format, which are keyed in by the CAD operators. The final plan version of the mile map may therefore involve 1) digital data capture, 2) conversion to analog plot by the survey contractor, 3) addition of analog lines and point data from subsequent checking and field visits, 4) addition of analog data from the photogrammetric process, 5) digitization of line and point data from the analog map into the CAD system, and 6) the addition of precision coordinates supplied as a list and keyed into the CAD system.

Another important source of analog map data originates with the various photogrammetric manuscripts whether plan views or as cross-sections and profiles.

Proposed upgrades of photogrammetric equipment in the Branch may provide for a CAD interface in the form of a digital editing workstation which typically accompanies the new generation of stereoplotters. Such systems are in routine production use in the metropolitan area, and provide increased flexibility for output options, editing, and products when compared to the traditional reliance on hardcopy contour plots.

Re-digitization of digitally produced analog maps can also occur when either the hardshell or photogrammetric manuscript is used as an input source for a GIS analysis. However, since the GIS focus is often concerned with much smaller spatial scales, this rarely occurs. In addition, much of the routine GIS analysis done for transmission line planning occurs at a stage prior to the actual creation of the hardshell or photogrammetric manuscript. Digitization of analog map products are routinely done for GIS input, particularly when the scale, coverage area, or thematic content of a map is appropriate for the geographic analysis and does not elsewhere exist as a digital file. When digital products such as DEMs and DLGs are available, they are normally preferred.

Analog as Final Product. Some of the analog data flows exist as maps, or map-like products produced by the Branch that are not destined to be redigitized in support of any objective of the Branch. These can be considered "finished products" and proudly rendered in as presentable a hardcopy form as possible given the hardware constraints on the production process.

One such particularly useful analog product is the Photomap series, produced with the film writing capability of the IPS. The photomaps are most often used to provide maintenance and operation crews with a convenient and very readable tool to identify facilities and surrounding landmarks in the field. While in practice their use for engineering design is somewhat limited, their 'near orthophotographic' properties do support measurement along the alignment and in any case are a cost efficient substitute for more expensive orthophotos. Subsequent digitization of the analog photomap is rare and no cases of this have been noted in this study. Site specific GIS work may require land cover information available from a photomap, but the digital link between the ARC/INFO software and the various IPS components together with format translation software makes a digital transfer the more desirable option.

Check plots and some final analog map products are also produced with the ARC/INFO GIS to meet a variety of presentation and display objectives. A recent substation site design involved a series of GIS maps exported to the Project Management Branch (EFC). Additionally, digital perspective views of terrain and land cover have been useful for public review processes. Through the DECNET, ARC/INFO plots can address several plotting devices and a small format color ink jet printer is available also within the Section.

Finally the 1:2400 sheet and 1:4800 scale volume bound versions of the plan and profile drawings of transmission line rights-of-way are a very identifiable Branch cartographic product in analog form. No instance of a re-digitization of these products were found in this study but as an analog product they are maintained, archived and sometimes used for reference purposes by other operations within the Branch. When information concerning updates and corrections arrives back in house from the field, these products can be digitally updated and logged. Although the use of the Synercom system was in part predicated on the ease with which they are used for cartographic production, the future may indicate that the digital databases behind each drawing are more valuable to the Branch than the analog product itself. As engineering design functions are increasingly migrating to CAD workstations, there is expected to be a demand for the digital transfer of the plan and profile maps. The four year ADP plan recommends the eventual phasing out of the Synercom workstations in the Cadastral and Cartographic Section and the adoption of Intergraph workstations Division-wide for all CAD production. However, while the ability to provide Facilities Design and Project Management Branches with digital versions of the mile maps will become increasingly important, the analog versions of existing and future plan and profile maps will continue to be an important Branch product, especially for use by customers in the Construction and System Maintenance Divisions.

DIGITAL DATA FLOWS.

Increasingly common are digital data flows between Branch computerized systems. In some cases these have been routinely implemented and in others are only of a prototype or experimental nature. While the transfer of digital data might be considered theoretically less susceptible to the propagation of spatial error inherent in re-digitization, a number of other scaling and data quality issues emerge with respect to digital transfers and digital exchange standards.

IPS to GIS. An important digital data flow via DECNET occurs between the IPS and GIS in the form of land cover classification, feature extraction and other data obtained from image processing of aerial photography. From within the IPS the classified raster images are converted to a vector format suitable for ARC/INFO. This is considered to be a potentially useful alternative to analog digitization of land use and surface feature information from analog maps obtained from outside sources, maps which would inevitably be more out of date than recently obtained aerial imagery.

The digital transfer of these data is facilitated by the availability of translation software available on both the IPS and GIS sides. In normal practice, however, it is the IPS image processing module itself, in which the raster to vector conversion for the GIS data takes place. The data flow takes the form of a file transfer over the communications link and thus is useable directly as an ARC/INFO coverage. The

spatial precision and accuracy requirements at the scale of GIS analysis allows for whatever generalization of data is present in a raster to vector conversion. At any rate, digital information from photogrammetry is available for use in image warping the digital image product before classification.

GIS to DTP. Digital data transfer via network also exists between the GIS and the DTP systems within the Environmental Section. This communication assists the production of E.I.S. and other reports with thematic maps and various map-based information by the Section. In this case the GIS (ARC/INFO) has the capability of generating a PostScript formatted file which can be directly read by the desktop publishing software running on the Macintosh computers.

Subsequent to the importation of GIS graphics into the DTP environment, the addition of text and other graphic takes place and may be output on the Section's own laser printer. When output is directed to the linotronic at the Graphics and Printing Services Branch (SSG), a disk transfer is used since that output device is directly connected to another Macintosh equipped with an identical disk drive.

CAD to CAD. Within EFBJ there are two different CAD environments, the Synercom and Intergraph systems. Translator software has been written or acquired which facilitates the file transfer of digital data from one system into the other. In addition, while output is normally directed to the Section's electrostatic plotter, a digital transfer of graphic data to a large format laser printer in the Facilities Design Branch can also be accomplished with the Intergraph connection to the DECNET.

CAD to GIS. Digital data transfer has occurred only sporadically between the CAD and GIS. This has been in conjunction with hazardous waste analysis which required site plans for BPA substations. Even in this case, since site plans for older stations may not always be available in digital form, they will sometimes be digitized from existing analog plans into the GIS. Nevertheless, the Cadastral and Cartographic Section has been successful in demonstrating the exportability of digital cartographic data between these somewhat dissimilar systems.

The general conversion problem from CAD to GIS consists of converting a graphic layer model to the topological structures for geographic features characteristic of data models for GIS. This consists of extracting features from the graphic layers and building the topology required for spatial analysis.

GIS to CAD. The system main grid maps have been cited as an example of a digital data transfer that takes place between the GIS and CAD systems. In this rare case where CAD production required spatial data at the small scale and of the regional database, county boundaries, hydrography, and place name data were transferred via DXF format in the opposite direction from the GIS to the CAD. Obviously, the

routine provision of these data from the regional database to be used for 1:2400 drawings done on the CAD would involve a process of scale enlargement entirely inappropriate given the source data from which the regional database was digitized.

PHO to GIS and CAD. The most prevalent form of output of the PHO system are the analog photogrammetric manuscripts. In some cases, however, a digital file of spot elevation and other point data has been transferred between the US-2 stereoplotters and the GIS via DECNET between the PDP and VAX computers.

Another instance of the digital flow of data from PHO has been the transfer of data from the US-2 stereoplotters to the Intergraph based CAD for the isometric perspective drawings illustrating danger trees lying outside cleared rights-of-way as a result of the danger tree analysis done by Section EFBH.

A closer examination of integration issues for specific databases within the Branch will be taken up in Task 3 of this project. It is useful, however, to consider some of the cost and efficiency issues associated with further integration as well as a review of conceptual frameworks within which systems integration effort is perceived and implemented.

CONCEPTUAL FRAMEWORKS FOR DATA INTEGRATION

At the heart of a systems integration problem lies the essential distinction between logical representation and digital transfer file formats. The latter are usually handled by translator routines and/ or special purpose programming for reading and writing input and output formats. It is the former issue, that of the representation of the spatial and attribute data in models that support system integration that provides the greater challenge.

A conceptual framework for systems integration is needed to provide guidance for further study. Two can be found in the literature. One was developed by Steve Kinzy, now at McDonnell-Douglas (1989). It is called Infrastructure Life Cycle Management. The other is from Tim Nyerges, at the University of Washington (Nyerges 1989). It is called an Information Integration Methodology. They are quite compatible frameworks. The first deals with the data and information systems used to describe and analyze infrastructure. The second framework deals with the design and implementation of the information systems about the infrastructure. These frameworks will be used in the remaining phases of this project.

INFRASTRUCTURE LIFE CYCLE MANAGEMENT.

Infrastructure life cycle management is described as a continuous process of plan, design, construct, and operate, illustrated in Figure 3. In applying this concept to infrastructure it takes on components of strategic planning, engineering design, and facilities management as illustrated in Figure 4. The opportunities to consider integration in terms of this framework are obvious if one recalls the functional typology of Branch products as indicated in Table 2. (page 12) Branch products are already identifiable as to their planning, design, or maintenance based uses.

Supporting the infrastructure management process with new technologies results in modification of the life cycle concept to include geographic information systems, computer-aided drafting, computer-aided engineering, and facilities management tools as also is illustrated in Figure 4. Since all of these functions require geographic information, the key feature of an integrated system is a common spatial database. As a result, changes made by part of the organization are available to all.

Applying this infrastructure life cycle management concept to facilities planning and engineering at BPA illustrates both potentials and problems. The chief problem is one of scale differences. Planning, design and construction, and operations often require different spatial as well as temporal scales that often make it easier to develop and support separate systems, rather than integrated ones (Dueker, 1988).

The scale at which to support engineering design and construction involves computer-aided drafting and computer-aided engineering systems that deal with

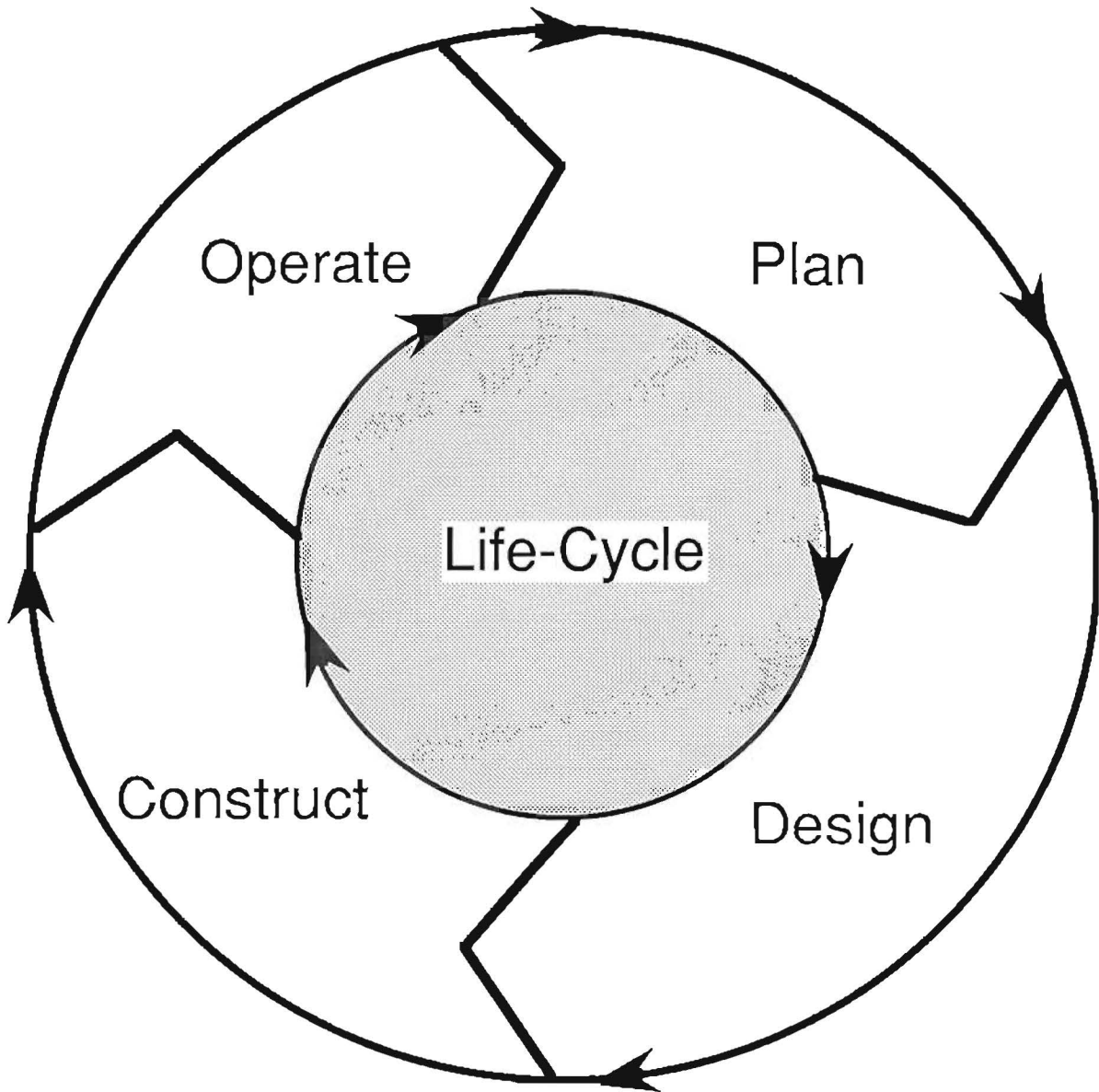


Figure 3: Infrastructure Life-Cycle Management

Engineering Design & Construction

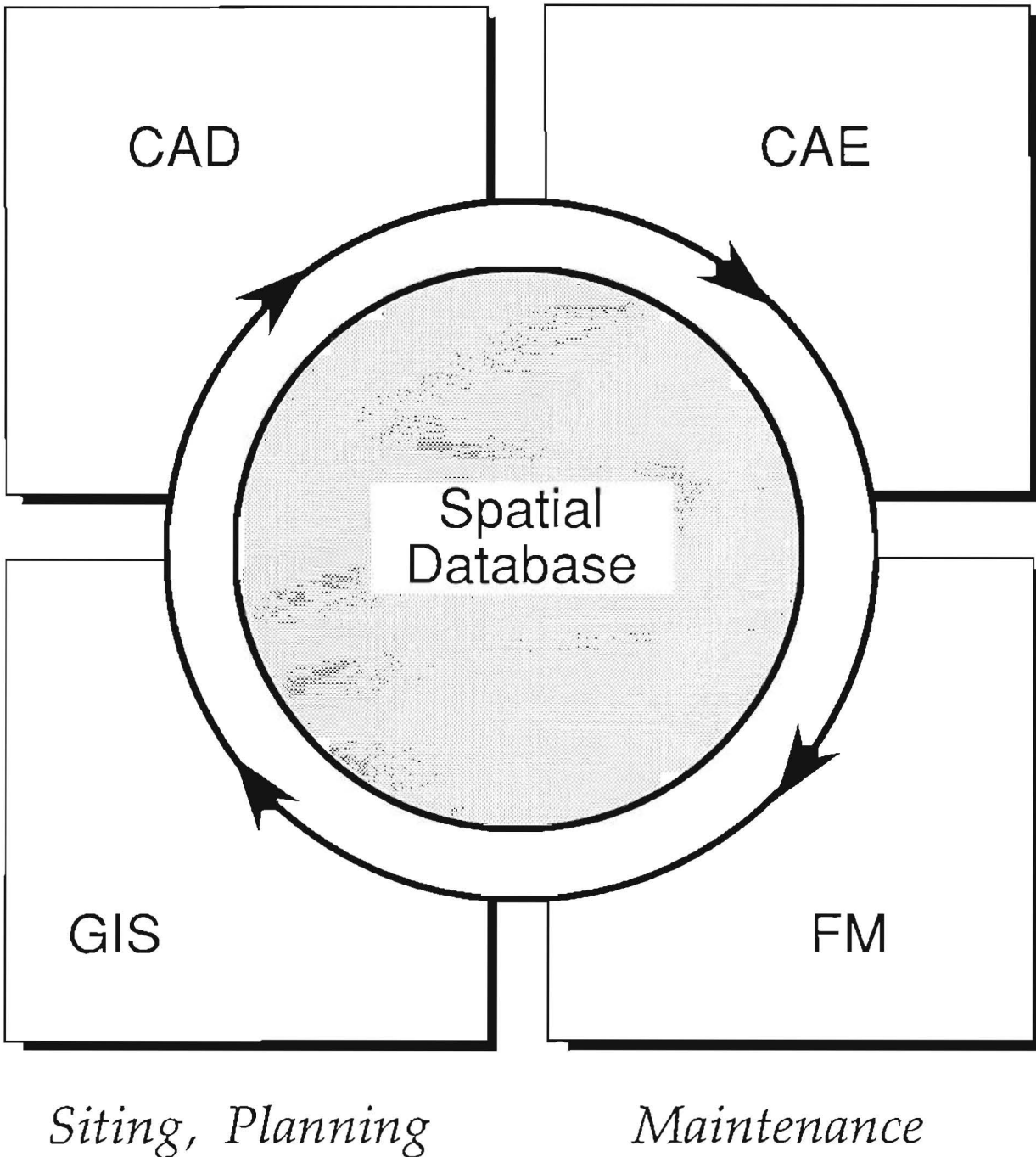


Figure 4: Facilities Management in the context of the Infrastructure Life-Cycle.

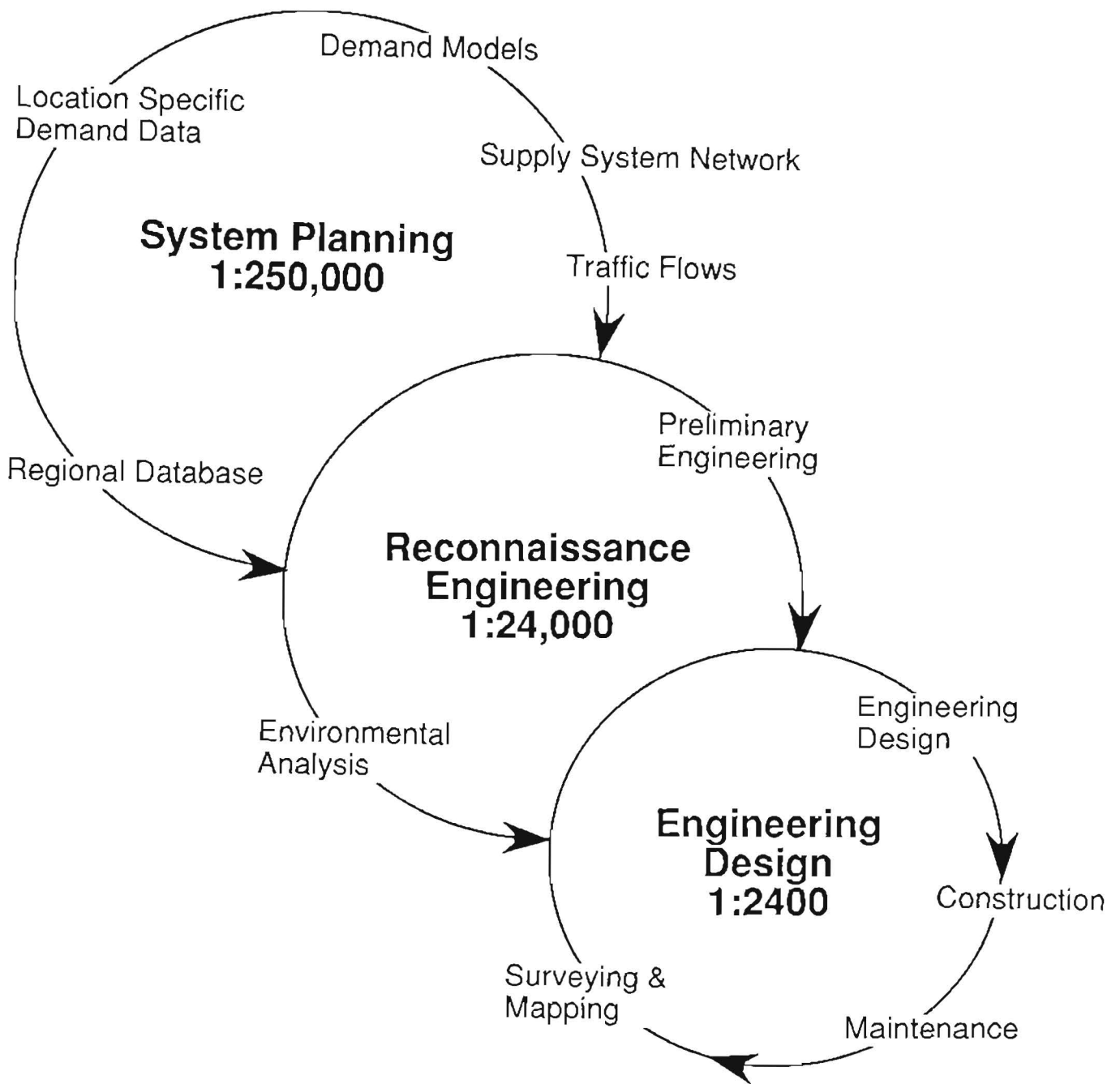


Figure 5: Geographic data scale differences in infrastructure life cycle management.

transmission line plan and profile information. The facilities maintenance function would use and keep current as-built plans. The planning function, related to this detail would include danger tree analysis and site planning of adjacent land uses that might require access and encroachment. Again, the key feature of this integrated system to support engineering design and construction, facilities management and detailed planning is a common spatial database. Changes made by one group are available to all and everybody is assured of up-to-date data.

Most planning is not done at an engineering scale, but at more generalized corridor or system scales. Operating at another spatial-temporal scale is another information life cycle. Maintaining data about power flows or natural resources does not warrant the spatial detail of transmission line design and construction. Consequently, another cycle whose spatial database contains more generalized data, is useful. This more generalized spatial database would be regional rather than project specific, representing transmission line elements as single lines rather than as rights-of-ways containing facilities. This spatial database would have the following characteristics:

- a transmission line system consisting of links and nodes for use in minimum path routing and power flow models,
- an accurate cartographic representation of links of the transmission line system for mapping purposes,
- locating facilities within rights-of-way using stationing or mile point referencing systems. (Nyerges and Dueker, 1988)

Applying the infrastructure life cycle management concept to BPA results in three dimensional cycles as shown in Figure 5. In the foreground is the direct application of the concept to transmission line and substation engineering. The spatial database to support engineering design, construction, and maintenance must be detailed and accurate. However, the preliminary engineering analysis, which consists of environmental analysis and reconnaissance engineering is accomplished with a less detailed and less accurate spatial database at 1:24,000. This is generally adequate to select corridors and alignments for engineering design and construction.

Organizing the spatial database for the transmission line system in this way will enable data integration. Inventory data that are normally recorded by station and/or milepoint can be related easily, displayed, and incorporated into models.

INFORMATION INTEGRATION METHODOLOGY.

Nyerges(1989) describes the Information Integration Methodology as, "the bringing together of information parts into a working whole, controlling redundancy where appropriate". The term "Information integration" is a concatenation of "information sharing" and "systems integration." Information integration can apply to data, hardware, software, and/or personnel. Several stages of information integration would be definable in this process.

"Data integration requires at least two steps: integration of data descriptions for a database, and integration of the data itself. Two types of data descriptions are important for data integration. These are descriptions contained in a schema, and descriptions (definitions) contained in a data dictionary....

"Functional integration involves bringing together separate software/hardware components to enhance or extend the analyses in a system; or reducing/eliminating database management system duplication. This process involves the integration of dissimilar software and/or hardware. Software integration usually involves the merging of data-structure constructs. Hardware integration involves the physical linkage of computers or the linkage of peripherals with computers to enhance data manipulation....

"Personnel integration involves the merging or reorganization of staff. These approaches might be required for implementation of large multipurpose land information projects."

Table 7 illustrates the relationships between stages of information integration. They are 1) strategy planning, 2) analysis, 3) design, and 4) implementation. Each stage is furthermore described at three levels of abstraction, a) conceptual understanding of the issue, b) techniques which express concepts and data constructs, and c) the tools, both software and hardware, that are applied to them. (from Navathe 1985).

The conceptual understanding (top row of Table 7) refers to a basic understanding of each phase of the project of information integration. By proceeding through the levels of abstraction the problem is approached with a systematic methodology. Such a clearly spelled-out methodology provides guidance to implementing the stages of integration independent of whatever techniques and tools are employed.

"The results are:

- a set of integration goals, objectives, and requirements developed as a plan in stage 1,
- a set of specifications focussed on "what "information content exists and should exist in stage 2,
- a design for "how" that information content should exist in stage 3, and
- a plan for carrying out the actual integration implementation in stage 4." (Nyerges 1989)

This methodology provides a framework for design and implementation of data and information systems related to the physical infrastructure systems, which is described using the Infrastructure Life Cycle Management concept.

Table 7

An Information Integration Methodology

Stages in Integration Process				
Level of Description	1 Integration Strategy Planning ----->	2 Integration Analysis ---->	3 Integration Design ---->	4 Integration Implementation ---->
Conceptual Understanding of	General Plans v	General Specifications v	General Designs v	General Systems v
Language Techniques for Use in	Planning v	Specification v	Design v	Implementation v
Software/ Hardware Tools Assist in Creating Results	Specific Integration Plan	Specific Integration Specification	Specific Integration Design	Specific Integrated System

Source: Nyerges (1989)

COST-EFFICIENCY ISSUES

ADP PLANNING FOR SYSTEM REPLACEMENT.

An expanded ADP planning process results in a tightening of procedures for justification of computing equipment requests. Currently, this is reflected in more rigorous ADP planning and documentation. New equipment to increase the efficiency of individual computerized systems has been identified by the Branch, but these specifications are being examined again as part of the Productivity Review.

Review of the ADP Plan results in the identification of several issues:

- Available technology has been identified to improve Branch productivity,
- Equipment costs have associated implementation costs that are not well specified, and
- Benefit estimation is extremely difficult. Office automation productivity methods are not very appropriate.

New equipment identified in the ADP plan could increase Branch productivity. The ADP planning process has identified current bottlenecks that can be eliminated by high priority equipment requests.

The cost of vendor hardware/software systems is only part of the total application development and implementation cost of a system. All costs have to be identified and considered. Similarly, the benefits consist of avoided costs (the difference between the current operating cost and the future lower cost) and the gain in effectiveness that may accrue because of new and more powerful methods of analysis or design. In some instances, large effectiveness gains may justify future operating costs that may be greater than existing operating costs.

An example of this difficulty was encountered when trying to identify the benefits of replacing the existing analytical stereoplotters. The photogrammetrists indicated their costs may increase and indicated that the benefits would accrue to the CAD system operators who would not have to digitize from the photogrammetric manuscript. In turn, CAD operators do not see a large benefit. They point to larger benefits to design engineers. If the design engineers were to "engineer" at workstations using digital plan and profiles, their work would not need to be digitized back into the CAD system. Thus, the end user is the greatest beneficiary of a fully integrated system. The classical digitizing of map data and engineering design results from paper copy CAD function would be largely replaced.

EFFICIENCY AND EFFECTIVENESS.

The various systems within the Branch are subject to changing cost structures brought about by technological innovations. This analysis focuses on the relative

efficiencies among the systems in the Branch to provide guidance in their integration. Specific efficiency estimates are beyond the scope of this task.

A broader perspective is one of cost-benefit analysis. In cost benefit-analysis, the benefits are categorized as:

- benefits due to increased efficiency,
- benefits due to better (more effective) decisions, and
- intangible and unanticipated benefits. (Prisley and Mead, 1987)

Efficiency is measured in terms of cost per unit of output. In survey and mapping terms this would be expressed in terms of cost per acre of substation, per square mile of large area mapping, or per mile of transmission line. These costs could be broken down into component parts, survey control photogrammetry, and CAD, and computed for different map scales. For GIS projects it may be more appropriate to measure efficiency in terms of cost per data volume, which would take into consideration area, layers, complexity, scale, and attribute detail.

An efficiently produced map is of little value if not used. Consequently the real measure of success is effectiveness, or the cost per unit of utilization. However, utilization is a difficult concept to operationalize. This leaves Prisley and Mead's (1987) distinction that an efficiency benefit is a cost saving or cost avoidance, and that an effectiveness benefit is a better and more useful product.

In forming the "most efficient organization"(MEO) for survey, mapping and geographic analysis, the Branch is concerned with the efficiency of producing new and improved mapping products, not just being more efficient in producing current mapping and analysis products. Thus, the emphasis of this cost-efficiency analysis is directed to the relative efficiencies of the systems within the Branch, with an eye on opportunities to integrate the technologies. The life cycle management concept is crucial to the true meaning of effectiveness, that is, the utilization of the Branch's products. The engineering and construction of transmission lines and substations constitute the primary use of the survey and mapping products of the Branch. Consequently, if computer-aided engineering is adopted by users of survey and mapping products, new digital mapping products may be needed to replace the existing paper products now used. Similarly, outputs of the computer-aided engineering design will result in new as-built mapping products for the Division of Maintenance and Operations to handle in terms of facilities management. In turn, this will shape the sources of data for another cycle of survey and mapping.

BRANCH SYSTEM EFFICIENCY ISSUES.

Survey Efficiency Issues. Technological change is having a major impact on surveying. TWS and GPS technologies have increased the efficiency of surveying dramatically. GPS is reducing the cost of geodetic control by an order of magnitude. Wise (1990) reports that the Trimble 400ST receivers can acquire coordinate data

with accuracies up to one foot per 100,000. Data can be obtained in two modes of operation, static and kinematic. In static mode, up to an hour is spent fixing on a single point. From this point, other coordinates can be determined. With modification, survey data will soon be routinely obtained in kinematic mode. In this operation, one receiver is stationary at a known point, and another one moves about, perhaps on a vehicle. Accuracies equal to the static mode may be acquired in this manner with as little as several minutes per reading, provided the instrument calibrations are stable and at least four satellites are simultaneously available.

Aside from the issues of positional accuracy and acquisition time, the technology offers advantages for rough or wooded terrain and poor weather conditions. Unlike other methods, line of sight between points is not a necessary condition for GPS control surveys. This eliminates additional surveying on projects where additional lines are located to account for the inability to keep line of sight along the main line is encountered. Similarly, crews can operate in adverse weather, since radio contact with satellites is independent of cloud cover or precipitation.

The trade off with using GPS technology is that greater planning and post processing time is required. The benefit that accrues from the more limited field exposures makes up for this however, with the added benefit of the use of GPS data as a quality check for subsequent survey operations.

Finally, another efficiency issue concerning the application of new survey techniques, the total work station (TWS) may be more cost efficient than photogrammetry for mapping of many sites under twenty acres that are not topographically constraining to field crews, particularly if the data can flow directly to earthwork programs (Gross,1990). Consequently, this relative efficiency gain in surveying warrants an examination of mapping product alternatives for site planning and substation design. Digital elevation data may become more relevant than conventional maps for many digital engineering applications.

Photogrammetry Efficiency Issues. Stereo digitizing is not only efficient, but necessary in a CAD and CAE environment. It is inefficient to continue utilizing an analytical stereoplotter to generate a paper product that then must be digitized in the CAD system when cost efficient solutions are readily available in the form of digital editing workstations.

There are several issues concerning proposals to enhance or replace the existing analytical stereoplotters. First is the need to generate digital data for direct input to the CAD system. The proposed purchase of currently available photogrammetric technology would generate digital data and minimize the need to redigitize analog manuscripts produced by stereoplotters. This would improve efficiency and effectiveness. However, three concerns have been raised about acquiring a new analytical stereoplotter:

1. Would it be more efficient and /or effective to contract out photogrammetry services than performing them in house?
2. Should the product line be modified, with less reliance on planimetric maps and more on a mix of stereo digitizing vector data for superimposition on imagery or orthophotography? If so, what does this do to the equipment cost and the amount of contracting out?
3. Is digital camera technology a suitable substitute for photogrammetry for large-scale mapping?

Definitive answers to these questions requires detailed analysis by EFBH staff, and will be addressed by Task Three of the Systems Integration Study.

The lack of stereo digitizing capability is a major deficiency in digitally integrating the various systems to achieve effective life cycle management. In-house digital photogrammetry appears essential for the development of new applications. Particularly, unique applications, such as danger tree analysis may not be efficient to contract out while routine conventional project work might be, provided effective procedures and specifications are established. In this manner, photogrammetry would be used for application development, more than a production tool.

Replacing the existing analytical stereoplottter can be accomplished in two ways:

1. Retain the US-2 optical system, but replace the PDP computer that drives the stereoplottter with a VAX and add a digital editing workstation for stereo digitizing with an interface to the existing Intergraph CAD system. This would be the least cost approach from a hardware perspective, but may require more in-house developmental work to interface the various elements.
2. Replace the entire US-2 system with a turnkey system. This would be a more expensive initial investment for equipment, but would not require as much staff cost for interfacing with existing equipment.

Either alternative should increase the benefits of photogrammetry. Thus the choice should be based on cost, including equipment and application developmental costs.

Image Processing Efficiency Issues. Most image processing systems are heavily used for land cover classification, whereas it is projected that only twenty per cent of the Branch's image processing system will be devoted to classification. Forty per cent of the use will be for the photomap production, and forty per cent for supporting GIS applications, mainly image and vector superimposition.

Currently, efficiency of the IPS is limited by the speed of the densitometer on the input side and the lack of an output device, which requires that the densitometer must double as an output device. A raster plotting device would increase output efficiency of image processing applications. Staff in EFBH are currently investigating several options for this. Some thermal wax output devices are capable of high resolution, up to 4096² pixels but offer a high cost per sheet, up to \$3.50. Other laser output devices offer lower unit costs, but afford resolutions only in the 2048² range.

CAD Efficiency Issues. A free-standing CAD system that digitizes from a survey hardshell and a photogrammetric manuscript and produces a paper map on which engineering designs are drafted is a process in transition. With digital transfer of inputs from stereo digitizing, the input to CAD could be earlier in the design process. Currently, the CAD process occurs too late to be a productivity tool for the design engineers. It mainly serves the specifications, contracts, and construction processes. In the future, engineers will be requiring digital products for interactive design at workstations. Saving the results of their design process will obviate the need to digitize the designs into the CAD system. This release of manpower from digitizing current jobs will enable personnel to devote attention to capturing data from as-builts of previously constructed transmission lines and substations in conjunction with photomaps, thereby improving the efficiency and effectiveness of maintenance engineering and the records pertaining to existing facilities.

GIS Efficiency Issues. The GIS is becoming an important productivity tool, particularly for applications at intermediate (1:24,000) and small scales (1:100,000 or smaller). Its primary purpose is to support the environmental impact analysis and the corridor analysis missions of the Branch. The versatility of the GIS has enabled its use in a number of other ways, such as the Northwest Rivers Study and other regional scale analyses. Hooson et al. (1990) have pointed out that a North Cascades database constructed to evaluate new transmission corridors has since been used to evaluate proposed reinforcement of existing transmission lines. This illustrates how unforeseen cost benefits can accrue from the construction and maintenance of GIS databases, which represent a considerable integration of existing spatial and attribute data. Consequently, a regional database development effort is underway that will provide base data for the entire BPA service area.

The GIS with a regional database enables the Branch to assume a service center role for the whole of BPA. Facilities Planning is providing GIS leadership by developing and maintaining the region's basemap and the various data layers making up the land and facilities base. In this way, the Branch can provide assistance to power planning units as well as facilities engineering. This external product should be seen as crucial to closing the loop of the life cycle management BPA's infrastructure.

An important interface of the GIS and IPS is in the superimposition of vector data on images. This capability will not only aid in the design process, but serve as an

effective communication tool for presenting proposed designs for public review, particularly 3-D renderings of proposed designs for transmission rights-of-way and site facilities.

GIS applications have and will continue to grow as the technology, the databases, and the experience develop. As the workload grows this Section may have to become more systematic in its organization, by separating application development and database administration from project work.

Desk Top Publishing Efficiency Issues. Both the GIS and CAD system can produce Postscript files for more efficient report preparation. The efficiency of the DTP system itself is not crucial to the support of spatial data processing in other Sections, nor does it currently provide inputs to cartographic products produced by the Branch. It is, however an important platform to consider from the point of view of published Branch products that integrate maps and other text. It supports an operating environment that is generally user friendly and requires little operator training. Furthermore, with emulation software and communications networking, the Mac II can conceivably serve as a terminal for other systems, particularly GIS, with which a range of possible interactions exist.

CONCLUSION

Improved interfaces for the systems in the Branch will result in increased efficiency of operations. As a result the systems will be integrated, which will make it more difficult to isolate or extract one from the others. The set of integrated systems must function under internal control. Work done externally must be carefully specified to ensure accurate and smooth transfers from one system to another.

Better integration of existing databases and systems involves a two tier process of file transfers and data definition. File transfers can be accomplished with the use of existing digital networks and in some cases, disk or tape transfers between host computers. In cases where reformatting is necessary, translation software for widely used systems in standard transfer formats is available.

In addition to file transfer issues, careful attention to the set of data models used to express the spatial and attribute components of geographic information will facilitate information integration in the Branch. Scale and resolution issues are relevant in determining appropriate data models for system databases. Because applications differ with respect for scale and resolution, features represented as objects of one dimension may be replicated as objects of another dimension in different databases. Examples of this have been cited as points for small scale representation of urban areas, polygons for larger scale representations, and complex sets of point, line and areal objects for large scale urban data. Transmission line rights of way are similarly represented as linear objects at small scales and polygonal features at larger scales. Topological connectivity and graphic editing capabilities are additional characteristics that distinguish data models of systems used for different applications.

It is reasonable to expect that cost-efficiency and program effectiveness can be increased by better digital integration of Branch systems. Improved data flow will bring greater efficiency and promote greater effectiveness. One of the ways this effectiveness can be recognized is through improved visualization of geographic data. Flexible visualization is the key to providing customized user views of Branch geographic data. Thus, a more flexible and effective organization also implies increased data and systems integration, with respect to both digital and analog products. How these issues are faced in other organizations and production environments will be the focus of Task 2. An examination of the technological, database, and organizational issues that pertain to these integration efforts will be addressed in Task 3: "Alternatives".

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