SYSTEMS INTEGRATION ANALYSIS AND ALTERNATIVES IDENTIFICATION

TASK FOUR: RECOMMENDATIONS AND STRATEGIC PLAN

Prepared for:

FACILITIES PLANNING BRANCH
BONNEVILLE POWER ADMINISTRATION

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RECOMMENDATIONS AND STRATEGIC PLAN

I. INTRODUCTION

BPA's Facilities Planning Branch has undertaken a systems integration study to examine the data integration issues and modernization requirements for survey and mapping activities. This report is the fourth of six phases of the study, and presents recommendations that constitute a strategic plan for systems integration.

Task 1 of the study, "Background Analysis and Data Gathering," (Dueker and Vrana 1990) examined existing systems and documented products, work flows, and data transfers. The Task 1 report found that greater digital integration involves a two-tiered solution: increased file transfers of some digital data, supplemented by more integrated databases to be shared by the computerized systems.

Task 2, "Experiences of Other Organizations," reviewed geographic data processing activities occurring in organizations with similar civil engineering responsibilities. Two trends that emerge are, 1) increased database integration using GIS, and 2) increased integration of CAD, photogrammetry, and image processing technologies. In addition, these organizations generally recognize the need for a strategic plan to phase in a solution for better digital integration. (Dueker and Vrana 1990b)

In Task 3, "Alternatives for System Integration," a number of approaches to modernization and integration are presented and a series of specific options delineated. From discussions on Task 3, and in conjunction with a concurrent Branch productivity review leading to the specification of a Most Efficient Organization (MEO) for the Branch, a consensus has emerged to integrate Branch survey and mapping activities around three core functional areas of responsibility, survey hardshell engineering scale data, regional planning and environmental data, and engineering facilities inventory data. (Dueker and Vrana 1991) This approach is further explained and reviewed, below. (see "Database Constellation Approach" in Technical Strategies chapter)

Greater integration of data and systems within organizations requires time and effort and should be carried out in the context of comprehensive and strategic planning. Task 4, "Recommendations and Strategic Plan" identifies a strategy for integrating and modernizing that will enable the Branch to adapt to the changing environment while continuing to support existing engineering products and information requirements. In part it is a summary of deliberations and decisions
taken within the Branch as a result of the identification of alternatives presented in Task 3. It is also a signpost, if not a roadmap, pointing toward further decisions to be made in the course of implementing a forward-looking strategy. Advances in computer technology and new demands on the Agency combine to provide incentive for modernization that includes:

- upgrading survey and mapping functions,
- integrating systems to reduce redundancy and improve performance, and
- extending geographic data applications into BPA's future.

This strategic plan is presented as a series of technical and organizational recommendations for the comprehensive management of Engineering Division geographic data in support of the BPA and Facilities Planning Branch mission statements. It is organized in the following manner:

1. **Introduction**, describing the purpose of the strategic plan and its relation to other tasks of the integration study.
2. **Goals and Objectives**, elucidating objectives to be accomplished in the strategic plan with respect to the goals embodied in the Branch and Agency mission statements.
3. **Technical Strategies**, which refer to incremental steps for establishing systems integration around three principal data constellations managed by the Branch.
4. **Organizational Strategies**, which address the implications of the technical strategies with respect to the Branch formulation of a "Most Efficient Organization".
5. **Summary of Recommendations**, which reviews the key points of the technical and organization strategies and constitutes an action plan for Branch integration and modernization.

Ultimately, this strategic plan will lead to further discussion and decision making regarding detailed steps and timetables for recommendations to be specified in the **Task 5, "Implementation Plan"**. The subsequent progress of the Branch will be monitored as part of **Task 6**.
II. GOALS AND OBJECTIVES FOR MODERNIZATION AND INTEGRATION

To accomplish modernization and integration, strategic objectives are formulated that stem from the goals of the Agency and the Branch. These goals can be found in the Agency and Branch mission statements. These statements are reproduced below with some additional emphasis and commentary. In the following section the goals are translated into more concrete objectives to be met by the strategic plan.

GOALS FOR MODERNIZATION AND INTEGRATION

The Bonneville Power Administration must be responsible to a constituency which is broader than the customer base of most electric utilities. In addition to power supply and transmission, the Agency is concerned with conservation, resource, and land management activities which impact a geographically vast and economically diverse region. These sensibilities are reflected in the Agency mission statement:

BPA will work in a regional partnership to define and achieve the electric power, conservation, and fish and wildlife objectives of the Pacific Northwest. We will provide our customers a low-cost, reliable, and environmentally sound power supply and transmission system. We will do so in an open and businesslike way, responsive to citizens' concerns and to our obligations as a Federal Agency. We will provide creative leadership and fulfill our responsibilities with professional excellence. [emphasis added]

Low cost and reliable service implies the need for efficient decisions for managing agency facilities and other assets, including geographic data. Doing so in an environmentally sound manner imposes constraints on the analysis and design which require the integration of several engineering and resource management disciplines. Professional excellence for managing geographic information implies thoughtfully devised data standards and exchange procedures to facilitate the application of up-to-date analytical methods for planning and engineering.

At the Facilities Planning Branch a variety of survey and mapping activities support the siting and design of BPA transmission lines, substations, fish hatcheries, microwave radio sites, and other facilities. A recent Productivity Review conducted by the Branch formulated a statement of the Branch mission as follows:

"Using state-of-the art technology, to provide high-quality, comprehensive services that support BPA's mission through facility planning, environmental and geographical analysis, surveying, and mapping for location, design, land acquisition, construction, and maintenance of BPA's facilities." [Emphasis added]
Environmentally responsible support for siting and engineering design is the acknowledged responsibility of the Branch. Performing this responsibility requires accurate, effective data gathering and processing for the planning, analysis, surveying and mapping operations that take place within the Branch. The statement also commits the Branch to provide other parts of the Agency with information products and to support the management and maintenance of facilities well past the siting and design phases. Efficient use of Branch data helps to determine the professional excellence of BPA operations as a whole. Integration and modernization is therefore a key for the continued success of the Agency’s mission in an era characterized by concerns for low cost, reliable and environmentally sound service.

**BRANCH OBJECTIVES FOR GEOGRAPHIC SYSTEMS AND PRODUCTS**

Maps depicting accurate spatial locations of facilities and local and regional characteristics have long been among the key services supplied by the Branch. With the evolution of computerized geographic analysis and engineering applications, survey and mapping data are managed in digital databases. The variety of applications for a geographic data is broad, and thus the rationale for effective data sharing and systems integration directly supports the Branch mission.

Task 2 of this study noted that in this computerized information environment, maps are increasingly regarded as an interface to geographic databases supporting facilities planning, design, and maintenance. Spatial displays are also an end product; the means by which database queries, analyses, and other operations are communicated. A key objective for the Branch is to supply the Agency with these products, which in the digital engineering environment, may consist of some or all of the following: [list adapted from Task 2]

- maps depicting the interacting effects of several data layers
- digital maps, spatial databases, and digital elevation models suitable for engineering design at computerized workstations,
- service and support for ad hoc queries and reports from spatial databases,
- integrated image and vector maps on a geometrically corrected base,
- three dimensional views of terrain draped with vector and image data.

Modernization and integration aim to provide the flexibility to provide analog and digital information for both end user requirements and in-house use. Geographic data in a variety of formats and scales must be managed effectively by the Branch to support its mission. Specifically the data management objectives fall into three categories, 1) supporting geographic analysis and planning, 2) supporting siting and engineering design work, and 3) inventorying data on all facilities to aid future planning, design, maintenance and construction purposes.
Support for analysis and planning

Long range planning for facility construction and renovation requires geographic analysis at varying scales and levels of resolution.

Analyzing geographic patterns throughout the service area benefits service planning and helps BPA monitor the cumulative effects of regional development and environmental decisions. The Branch's ability to carry out geographic analysis projects has benefitted parts of the Agency involved with power planning, radon monitoring, hydrologic modelling and crime prevention.

More locally, planning facilities for BPA rights-of-way and other sites requires detailed examination of natural and man made factors affecting the land. The latter function is an important Branch objective, given the mission statement of the Agency. By law, this objective is incorporated into public construction projects with the requirement of filing Environmental Impact Statements for plan approvals. The importance of environmental assessment to planning is acknowledged by the incorporation of the Environmental Section within the Branch.

Planning transmission lines and substations requires map information for a wide area at relatively low resolution. Environmental assessment and reconnaissance engineering use USGS maps at 1:24,000 and other map and aerial photography. The Branch's GIS is used for display and analysis of corridor route selection and achieves this by combining data from outside digital sources (DLG, DEMs from USGS), digitizing done in-house, and image data processed by the Branch's IPS. Reconnaissance engineering examines a proposed corridor and details the topographic and environmental conditions found there. In both cases, the focus of the geographic data is predominantly areal, supporting site and region evaluation. Given the number of facilities within the service area and considering the small scale of many of the data sources (DLGs at 1:100,000 for instance) this has lead to the development and maintenance of a regional database for the BPA service area used and maintained primarily by the Branch's GIS.

Strategic integration of data that facilitate geographic analysis and information products for planners thus fulfills aspects of both the Agency and Branch objectives.

Support for siting and engineering design

Systems integration must serve the siting and engineering design objective in two ways. Precise planimetry and survey data are required for structural design and locating clearing backlines in the right-of-way. Tower siting and sag clearance specifications require terrain modeling at sufficiently detailed resolution.

A large part of the Branch's work involves deriving geographic data to support the engineering design of transmission lines, substations and other facilities. This work
takes place at much larger scales than the geographic analysis and planning activities. Traditionally, site plans and profiles in mile-length sections are produced as an analog map combining data inputs from surveyors, photogrammetrists, a variety of civil and structural engineers both in the Branch and throughout the Division. These mile-maps are compiled at the inch to 200 ft. scale (1:2400). Support for this engineering objective requires integration of geodetic and location surveys, photogrammetry, cadastral surveys, and other large-scale sources into potentially large digital mapping data sets.

Terrain modeling is useful to facilities engineering in a number of ways. Substation design involves estimating cut and fill volumes for site preparation. Knowledge of terrain is essential for tower siting, leg extension requirements and determining line sag clearance. Estimating structural steel requirements for proposed new lines has been mentioned as also benefitting from a general view of corridor terrain.

Traditional approaches to terrain calculation use survey cross sections and mile-map profiles to obtain measurements in a very local area. Provision of a digital product for incorporation into engineering analysis and design work requires a digital elevation model (DEM). DEMs can be produced at a variety of precision levels depending upon the application, derived from survey and/or photogrammetric inputs.

Support for engineering facilities inventory

Fulfilling responsibilities with professional excellence is stressed as a part of the Agency mission. Each part of the Agency attempts to meet this goal by responsibly managing the assets devoted to its mission. The production of geographic information for digital databases and hardcopy graphics is a responsibility of the Branch. The "high quality, comprehensive services" spoken of in the Branch mission statement requires attention to the quality and availability of reliable and up-to-date geographic information for those databases and graphics. Therefore an important systems integration objective must be to provide adequate means to catalog, index, and access Branch geographic data.

In an organization like the Facilities Planning Branch, where many different personnel require access to geographic information, integration must support the coordination of a number of levels of data users. For strategic purposes, these levels can be described in terms of the "Government Business Pyramid" (Huxhold 1991). Policy, Management, and Operations are the three stepped levels in this pyramid and each one has a different need for cataloging an organization's data. At the base of the pyramid is operations. Personnel engaged in the routine production of maps and reports obviously require knowledge of how to access data that support this function. Management is involved with managing the resources needed to ensure production; a steady stream of current and accurate data is one such resource. At the policy level, information concerning the availability and location of data about BPA
facilities can be helpful in establishing priorities, coordinating activities on large projects, and responding to public and administrative requests for an increased power supply and environmental safeguards.

While the policy, management, and operations pyramid describes the use of an information system throughout an entire organization, its application to the Branch is appropriate on a more moderate scale. A variety of individuals require access to data on facilities and much of that information is in map, or digital map form. For coordinating production within the branch, for sharing information with other branches in Facilities Engineering, and for disseminating facilities data to Construction, Maintenance and Operations at BPA, an index to geographic data describing the extent, essential attributes, and currency of mapped information is essential.
III. TECHNICAL STRATEGIES FOR SYSTEMS INTEGRATION

Support for geographic analysis and planning, siting and engineering design, and facilities data inventory are the Branch objectives which must be translated into a strategic plan for system integration. This entails technical and organizational issues. In this chapter strategies are proposed that address the technical means of meeting these objectives.

DATABASE CONSTELLATIONS AS A FRAMEWORK FOR INTEGRATION

Constellations in support of Branch goals and objectives

In Task 3, "Alternatives for System Integration," options for modernization and integration have been presented and discussed within the database constellation framework. The basic premise of the database constellations framework is that clusters of data and products are developed in response to specific core functions for the Branch. These functions are recognizable by a high degree of system interaction and data transfers that take place around three broadly defined geographic information processes that correspond to the Branch objectives outlined above:

- Corridor and regional analysis,
- Survey and engineering design, and
- Transmission line inventory and reference.

As proposed in the "Alternatives for System Integration" report, the collection of databases and inter-system processes that address these functional areas are the Regional Database, the Digital Hardshell, and the T-Line Index.

These three broad information processes are intimately linked in the Branch's mission because they share the fundamental property of spatial location as a key data component. They are conveniently grouped into three processes, however, because of their different data product orientation, as well as their position on a continuum of infrastructure data life cycle function and scale of analysis. (Figure 4-1)

Life cycle function refers to the position of the data product with respect to the Plan - Design - Operate - Maintain cycle described in the infrastructure management literature. (Kinzy 1989. See Task 1 report, p. 42) Within each constellation source data scales may vary to some degree. But between constellations, predominant spatial and temporal scales differ, as Planning, Design, Operations, and Maintenance require varying levels of resolution and take place according to different temporal and update cycles. (Dueker 1988) These differences argue for the development of somewhat separate systems, rather than a highly integrated one which provides too much detail for one use, and not enough precision for another.
Figure 4-1: Database Constellations and Strategic Objectives in the Infrastructure Life Cycle Management framework.
The Branch brings together the specialized technology and expertise of several geographic data systems and professionals. GIS, Survey, Photogrammetry, Image Processing, and CAD are all linked throughout the life cycle of Branch information flows. Each of these systems may be used with more than one of the principal constellations, even as one system or another may predominate in the preparing a given information product. Systems retain identities and data gathering, processing, and analytical roles. The constellation concept is the explicit framework for integrating these systems while preserving the flexibility to specialize within the requirements mandated by the Branch's planning, design and inventory objectives.

Data exchange and file transfer mechanisms

Generally, within constellations, data integration is best achieved with a common database description and file format while between constellations, data exchange can be facilitated with the adoption of a file transfer standard. (see figure 4-2)

Routine production takes place within constellations. For example, mile-maps are compiled in CAD from Survey and Photogrammetry inputs. Coordinates data are maintained efficiently in integrated databases accessed by systems reading a common format. Standardization around the CAD .DGN file structure is recommended for the Digital Hardshell since survey software and photogrammetric systems can write to this format. For the Regional Database, the Arc/Info format is most appropriate, while either the Intergraph or the Arc/Info standard would serve the T-Line index.

Data are sometimes transmitted between constellations. This occurs with hybrid products such as the T-Line viewing applications, terrain models, design renderings, and the main grid map. ASCII transfer formats are appropriate for between constellation data transfers. Industry standard formats, such as DXF, may be useful and contractors often produce in this format. DXF is well known, supported by many applications and has much flexibility for symbolization. Careful attention must be paid, however, to how data entity definitions differ between constellations. What is a point-based settlement to one scale of analysis, for example, may be an aggregation of parcels and/or land cover polygons to another constellation. For this reason as well as in linking with tabular databases, the integration task force may wish to customize an in-house ASCII transfer standard for maximum flexibility. This would decrease dependency on single vendors when systems are upgraded.

There are a number of proposed models on which to base this. The integration task force can consider which is best suited for BPA but any standard should be in conformance with the Spatial Data Transfer Standard (SDTS). (USGS, formerly published as DCDSTF 1988) This specification, now adopted as a Federal Information Processing Standard, provides for system independent transfer of geographic data between Federal Agencies. The SDTS provides a blueprint for specifying CAD to GIS linkages and will facilitate data trading and purchasing with other agencies.
Figure 4-2: Data integration by predominant system formats within constellations. SDTS file transfers apply to spatial data flowing between constellations.
Integration will proceed by building common databases for geographic data systems and file transfers between systems when that is not feasible or attractive. Data exchange, database compilation, and new ways of doing things in general should be introduced incrementally in order to evaluate the effect of discrete measures as well as to mitigate unwanted or complicating effects. (Chrisman and Niemann 1985)

Specific issues to be addressed by an integration task force and recommendations about the incremental development of each of the database constellations follows.

INCREMENTAL IMPLEMENTATION OF THE REGIONAL DATABASE

The Regional Constellation is a series of GIS coverages and databases. Base layers (boundaries, townships, hydrography, and transportation) are digitized from small scale maps (1:100,000 - 1:2,000,000) or acquired as USGS digital products (100K DLGs, etc.) These data differ from other Branch data in that they are topologically structured for GIS analysis and that the domain of the Regional Constellation is the entire service area and not just BPA facilities.

A "regional database" application, known in-house as "RDB", has been developed with Arc/Info. In addition to the base layers, coverages pertaining to the whole of the region are maintained. Current themes include the BPA main grid digitized at 1:2,000,000, locations of substations and other facilities, a point coverage of place names, 7.5' quadrangles, airports, and boundaries for wilderness areas, national forests, and area offices. This store of data is essentially dynamic and exists at various scales. It is used as a reference map view and is a valuable resource for base mapping and for addressing geographic analysis originating outside the Branch.

Graphic elements on the display can be queried for identification and linked to tabular data. Analytical functions such as polygon intersection, line buffering, and point-in-polygon searches can be accomplished and reported as map output.

This work is done regularly for corridor assessments, site evaluations, and special projects for outside Branch customers. Data are obtained from digitizing in-house, obtaining digital data from USGS or other agencies (cooperative agreements for compiling these coverages have also been used, e.g. with USGS-Water Resources Division), or used directly from the existing regional database. In the latter instance, the data layers themselves may have been acquired for a previous project and have been maintained in the Branch for future analysis. In addition to planimetric and thematic map data for natural and cultural features and socio-demographic information, the Branch has used digital terrain data (DTM) from USGS and DMA at 1:250,000 scale for corridor analysis. Over time, all these data, together with the "regional database" have become a major BPA information resource.

Larger scale coverage is needed for reconnaissance engineering or for projects such as maintenance facility upgrades and hazardous waste studies. While regional data may be used at some scales of analysis, much of this work requires site specific data.
An important source for site planimetry has been rectified photography from the IPS system of the Branch. The I2S system can export rectified images as raster files directly to the GIS for an image background for presentation and display, but it is also used to derive land use polygons for large scale studies of this kind. In addition, coordinates and elevation data from site surveys or photogrammetry can be used to create large scale terrain models for analysis of BPA site facilities.

The "regional database" application currently developed provides a good starting point for constructing the Regional Constellation. Below are a few recommended strategies for moving this work forward.

**Strategy:** Integrate environmental project data with regional database

The map coverages that make up the regional database are usable together because they are tied to an in-house coordinate system. Data from all sources are translated into coordinate feet and stored in a Lambert Conformal Conic projection centered on standard parallels convenient for displaying BPA's service area. Layers can be selectively combined and used as base maps, transformed into other desirable projections or combined with raster imagery in oblique views. Environmental project data and other data pertaining to larger scale site analysis also are available for areas where BPA facilities exist. In some cases therefore, there are data at larger scales than that which is shown in the "RDB" application. These project sites can be referenced and "patched-into" the "regional database" using the existing application, running in the DEC workstation environment.

**SUPPORTING ACTIONS**

- Convert project and site data to the common coordinate system.
- Obtain corrected coordinates for BPA facilities from Survey for use in the regional database.
- Catalog all regional and project coverages, imagery, and tabular data associated with the regional database application.

**Strategy:** Maintain IPS capabilities for auto-digitizing and for image backdrop

The role of image processing for GIS analysis has already been mentioned in connection with automated digitizing and image backdrops for site facility studies. Refinements to the existing I2S - Arc/Info interface could reduce data entry costs significantly and are compatible with the long range development of the IPS system at the Branch. Integrated map and image views (vector- raster integration) will become an increasingly important tool for analysis and presentation. The Regional Constellation, though centered on GIS, will continue to include a strong IPS component as more emphasis is placed on image data for backdrop and GIS input.

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1 For these and the recommendations that follow, the authors understand that some or all of the practices mentioned may have begun or are planned for implementation.
SUPPORTING ACTIONS

• Gather planimetry for natural and cultural features for site locations from rectified imagery for conversion to polygon data to be used by the GIS.
• Incrementally update old USGS 1:250,000 LULC files (up to 14 years out of date) from new satellite imagery or photography.
• Use IPS to update existing maps, especially in urban areas using change detection methods of analysis.
• Participate in cooperative programs for interpreting, classifying, and maintaining imagery wherever feasible.

Strategy: Create area wide DTM with varying levels of resolution

USGS digital elevation data are available at the 1:250,000 scale for the entire region\(^2\) and at the 7.5', 1:24,000 scale for selected quads. In addition, survey and photogrammetric methods produce elevation data along BPA rights-of-way and elevation contours are derived for other site facilities through the same or through image processing methods. In no one place is all terrain woven together in a unified view. The Regional Constellation can provide this for the entire service area although this may not be judged a high priority item at this time.

SUPPORTING ACTIONS

• Using Arc/Info TIN, create digital elevation models for BPA rights-of-way and facility sites using the best available data.
• For a convenient tiling unit (7.5' quad?, Township?) create an integrated DEM combining in-house, and USGS DTM data.
• Retain break lines and slope inflection data indicating source, and therefore resolution, changes. Use with future TINs.

INCREMENTAL IMPLEMENTATION OF THE DIGITAL HARD SHELL

Numerous activities are performed or coordinated by the Branch that pertain to the survey, mapping, design, and maintenance of transmission line rights-of-way and facilities within them. These activities include, cadastral, geodetic, location, and photogrammetric surveys, danger tree analysis, CAD mapping, and digital engineering design. They produce a variety of analog and digital products sharing stringent accuracy and precision requirements at or around the engineering scale of 1:2400 (inch to 200'). As has been noted in Task 1 and elsewhere, analog documents have been redigitized in the Branch to produce BPA right-of-way mile-maps. This process has been made more efficient as incremental work in file transfers linking the Survey and Cadastral Sections has been undertaken. This should continue and intensify, incorporating common databases as well as file transfers between systems.

\(^2\) These data were compiled by the DMA but are available through the USGS.
The result is the Digital Hardshell, a constellation linking photogrammetry, survey, CAD, and IPS in support of the siting and engineering design objective.

The name implies the preeminence of the survey hardshell. Traditionally these are analog maps compiled from field notes and measurements. Hardshells are dynamic documents, taken out to the field, modified, annotated and further compiled. Field use of the survey hardshell will continue to be an important requirement for survey work, but will now be compiled from the digital database of the evolving hardshell for a segment along a project. Updated versions and annotation can then be entered into the versioned digital hardshell plan map database for compilation into the mile-map series. These maps, currently in wide use as an analog product, can be available eventually as an on-line map composition, or as a scanned image.

Another important component of the mapping of rights-of-way concerns photogrammetric compilation. Additional and upgraded stereoplottling capability is required and should be directly linked to CAD-editable cartographic files. Additional work on either the new or existing stereoplotters for designing clearing backlines and danger tree programs should also be incorporated into CAD formats for output through the Intergraph system and eventual incorporation into the digital hardshell or finished mile-map, itself.

**Strategy:** Convert survey hardshell to digital documents early in project

A key premise of the Digital Hardshell constellation is to convert survey data into a digital map early in the mapping process. Data obtained through GPS receivers and Total Work Station theodolites are currently post processed in a PC environment and stored in flat files for transfer to the CAD system at mile-map compilation time. Ultimately the Digital Hardshell will store existing versions for interim plotting and field use, then receive changes and updates as project work continues or is revised. Updated versions are prepared for final compilation into the mile-maps, which are periodically revised with new input from current revision to the Digital Hardshell.

**SUPPORTING ACTIONS**
- Establish CAD workstation in the Survey Section and do survey correction and post processing directly in the CAD environment. Result is a CAD version of the preliminary hardshell.
- Establish procedures for the versioning preliminary hardshells as further survey field work and annotation proceeds.
- Use the Survey CAD workstation to compile property lines form cadastral research and COGO operations where needed.
- Mile-map compilation becomes a process of map design from the latest version of the hardshell and integrated with output from photogrammetry, CAD, and engineering design.
**Strategy:** Adopt digital editing capability for photogrammetric output

Digital output in CAD format has become a key feature of modern photogrammetry. This capability can aid mapping and design at BPA by simplifying and reducing the editing and checking procedures for photogrammetric operators and by providing clean digital transfers for integration with the hardshell in the mile-map process.

**SUPPORTING ACTIONS**
- Acquire a new stereoplotter capable of digital editing and stereoinposition of vector data on the model image. (see Price: "Denver Issue: Integrated Digital Mapping and Editing System")
- Produce or acquire conversion software from the stereoplotter to Arc/Info and CAD and possibly AutoCad (DXF) formats.
- Transfer of Danger Tree Analysis output to new stereoplotter for digital editing and preparation for CAD integration.

**Strategy:** Create variety of digital terrain products for engineering design

Engineering design for transmission and other facilities increasingly takes place in a digital environment. At BPA, this work is done in other Branches and makes use of the Intergraph CAD. Some design work requires elevation data for rights-of-way and other facilities. Traditionally this information has been supplied by generating contour maps or centerline profiles and periodic cross sections at break points.

TIN software for creating digital elevation files for output as contour maps already exists in the Survey Section for use in making topographic check plots. Survey should continue to provide Engineering Design with elevation data, but now in direct digital form as either TIN files or grided DEMs.

**SUPPORTING ACTIONS**
- Include TIN software on Survey CAD workstation. Connect with existing pen plotter for check plots and interim use.
- Develop digital DEM product standards in consultation with other Facilities Engineering customers.
- Facilitate file transfers to Arc/Info for site evaluation studies.

**Strategy:** Phase out production use of Synercom GWS IV workstations

In 1988 Synercom informed BPA that upgrading the CAD workstations would require an additional quarter million dollars and that Informap II, used for mile-map production, would no longer be supported. A decision was made to migrate CAD production to Intergraph. All CAD workstations mentioned in this strategic plan are assumed to be either the MGE Interpro or Microstation PC platforms.
SUPPORTING ACTIONS
- New survey workstation to be Intergraph Interpro.
- Stereoplotter editing workstation to port directly to Intergraph environment (DGN format output).
- Incremental development of all Digital Hardshell on CAD.
- Danger Tree stereoplotter analysis integrated with CAD.
- Evaluate MGE environment for GIS capabilities with CAD.
- Evaluate/ acquire Intergraph modules (InSurv, In Roads) as necessary to support digital integration of hardshell activities.

INCREMENTAL IMPLEMENTATION OF THE T-LINE INDEX

The third major data management objective for the Branch is to provide inventory and access to Facilities engineering data. All phases of life cycle infrastructure management are dependent upon a tool for cataloging available data and for determining the most current versions of maps and plans for right-of-way and site design. The T-Line Index has been proposed as the vehicle to support this important Branch objective. It is essentially a graphic interface to a database that can cross reference a variety of information products corresponding to shared locations along the right-of-way. It can also be used as a queryable map, to identify a named facility or feature for every symbol element on the display.

The T-Line index will cross reference and eliminate separate indexing efforts for branch maps, photo products, one-line diagrams, and other geographical data. The incremental implementation of the T-Line Index will require prioritizing the incorporation of a large number of information products and data sources about BPA facilities into a graphically accessible GIS database. Some of these have been listed in the Task 3 report and are here reproduced:
- The Drawing Information System
- The Line Names Cross Index System
- The ORACLE implementation of part of the Drawing Information System
- Analog hardshell indexing to mile-maps
- Hanging file reference look-up books for the plan and profile maps
- Rotating drum with USGS 7.5' index
- Graphical index to photomaps and other photography
- One-Line Diagrams and Project Data Books (originals will also remain)
- Hot-Check and EMF databases developed by project engineering.
- The Strip Maps

The development of a T-Line comes at comparatively little marginal cost. As is shown above, much of it involves indexing that already occurs less systematically. The index database and the application(s) that access it should require no unique hardware or workstation investments.
Maintaining a centralized index will benefit 1) Branch users needing data from other systems, 2) managers needing overviews of products and databases, and 3) non-branch customers of Facilities Planning. Therefore, the T-Line assumes major importance as an integration tool. It not only alerts users to available data, but integrates and cross references data and ties them to a queryable graphic display.

As the focus for integration in the Branch, the T-Line Index simultaneously reconciles the areal orientation of the regional analysis and planning, with the linear orientation of right-of-way design. Areal representation of geographic features nearby and adjacent to transmission lines can aid in orienting a user by showing the coincidence of facilities and local geography. Point and linear objects at the display scale (towers, centerlines, substations, crossings, etc.) are represented by milepoint or coordinate data obtained from the digital hardshell process. In this way the T-Line Index is a tangible integrator of GIS and CAD based tools.

**Strategy:** Establish pilot project and expand to system-wide area coverage

Unlike some products, such as digital mile-maps, which logically proceed on a day-forward strategy, the index is mainly valuable if it references facilities everywhere on the BPA system. Completing the Index for the entire service area will allow system-wide totals and statistics to be generated concerning transmission line conditions and characteristics, and the locations of all facilities meeting specified criteria, etc. Of course, the T-Line Index cannot be implemented overnight. Therefore the recommendation is to demonstrate its utility in a pilot project for an area of current interest, then expand to cover the entire service area. Because of the widespread intended benefits for the Index, the choice of pilot project may involve discussions with other Division data users. Initially the Index would contain limited attribute information and pointers to other databases. It could later be enriched by bringing in more links to Branch information products and databases.

**SUPPORTING ACTIONS**

- Choose pilot project area for initial development of Index. Puget Sound or the Columbia Gorge have been tentatively identified.
- Create Index development team for design and implementation.
- Consider areal tiling schemes and graphic interface issues.
- Develop work plan for systematic expansion to entire service area with limited attributes.
- Document and prepare user manual to make Index useful to managers and non-Branch customers at early stages.

**Strategy:** Incremental expansion of attribute content for Index

Incremental development of the T-Line Index means quick expansion to entire service area with the gradual filling in of detail. Tower locations, line ratings,
conductor characteristics, utility crossings and access roads are key attributes of interest to many parties who will use the T-Line Index. In addition, the index should guide users to mile-map plan and profile drawings for every section of transmission line. These attribute data and database pointers should be included in the Index in its initial phase of development. Reference to structural information on towers, substation plans, photo products, property information, local topography, clearing requirements, danger trees, and other ties to Branch and Division databases concerning facilities can be added later.

**SUPPORTING ACTIONS**
- Design team establishes priorities for graphical reference data based on availability and most likely query requirements. (Example: graphics from regional database layers including PLSS)
- Establish priority for attribute database linkages. Early on, include mile-maps, one-lines, and site plans.
- Incorporate design and operating names cross referencing.
- Check with area offices for data of value to field operations.

**Strategy:** Determine platform(s) for T-Line Index

The T-Line Index is essentially a GIS application since it uses location as the key to access tabular data with graphical queries, or to produce graphic representations by tabular query. The Branch has two systems that offer the necessary spatial data handling capabilities. In addition to the current GIS, Arc/Info, the Intergraph MGE offers an alternative.

In either case, Index attribute data can be managed with ORACLE, a standard SQL relational database system that can interface directly with Arc/Info and MGE. A "Drawing Information System" (Tuckett) for cross referencing plan and profile maps already has been partially ported to ORACLE. (Noted in Task Report 3, p. 35)

Additional cross-referencing with operating names and other data may require redesign. Still, implementation can take advantage of work already accomplished.

With Arc/Info and Intergraph software both available, the Branch faces a decision concerning which platform to support the T-Line Index. The choices are:

1) Establish the T-Line as an Arc/Info application on DEC Workstations accessing ORACLE,
2) Establish the T-Line as an Intergraph application on the existing CAD workstations accessing ORACLE, or
3) Establish T-Line views in both environments to accommodate the needs of both large-scale vs. regional oriented users.

The latter approach is recommended. It lends itself to customized user orientations and eventually for integration with image products. (Figure 4-3) The design team will develop actual scenarios for these applications. Below is a suggested approach.
T-Line Index Dual Platform Strategy

**ARC/INFO**
DEC wksta.
GIS

Base Graphics
from 100K regional db
and 24K DLG

Displayable scales
1:100,000
1:24,000

**ORACLE**
VAX 11/785
RDBMS

**INTERGRAPH**
Interpro wksta.
CAD/GIS

Base Graphics
from main grid map
and hardshell

Displayable scales
1:5,000,000
1:2400

**SPATIAL QUERY**

**ATTRIBUTE QUERY**

---

Figure 4-3: Views of the T-Line Index can be customized for different user groups.
User views for the index are provided on Arc/Info and Intergraph platforms which correspond respectively to a planning and management orientation versus a survey and engineering orientation. While preprogrammed query and menu options may differ between views, the primary difference lies in the graphical representation of the T-Line with respect to scale, detail, and how the graphic is used.

Figure 4-3 indicates two of possibly more orientations toward the T-Line Index. For each interface, the essential T-Line Graphic consists of angle point coordinates taken from the Digital Hardshell, and tower locations and right-of-way lines either by coordinates or computed from milepoint references along the transmission centerline. This T-Line Graphic is combined with two different base graphics.

On the Arc/Info platform, the base graphic is an extract of the regional database at 1:100,000 scale. Portions of this are reasonably accurate for index referencing at 1:24,000. Users can see the location of facilities in relation to local geographic features. Graphic selections on objects directly associated with the T-Line graphic query the T-Line database itself and may return identification, selected attributes, and/or a reference to a CAD drawing or one-line diagram etc. Selections on objects from the regional database could be translated into a query to the regional database "RDB", and return a display of useful vicinity information, from which further spatial analysis, such as crossing of federal lands, could be determined.

On the Intergraph MGE platform, users obtain a more schematic view of the T-Line. A graphic selection is made on a portion of a transmission line from a base graphic of the system grid map; the application then displays that portion at a larger scale. (1:2400, mile-map scale, or half this, at 1:4800) This larger scale representation consists entirely of the T-Line graphic and only those entities directly represented in the index are shown. If stream crossings and clearing backlines are represented as centerline milepoint offsets, for example, their linear representation can still be computed and displayed schematically with straight line interpolation between referenced points. A graphic selection on an object queries the T-Line database and returns the identifying attributes plus a pointer to the location of CAD or other drawings. Users may then be offered the additional option to directly display those drawings and/or image products which are stored digitally.

SUPPORTING ACTIONS
- Examine existing ORACLE application for design revisions.
- Build T-Line Graphic from indexed coordinates and milepoints.
- Implement pilot T-Line Index in Arc/Info using T-Line Graphic and 100K DLG regional database base graphic.
- Demonstrate link to scanned images and mile-maps.
- Port to Intergraph. Add system grid and drawing display options.
- Customize T-Line views with additional queries, menu options, and defaults appropriate for different user groups.

3 If necessary, this same approach could be taken on the Arc/Info platform as well.
**Strategy:** Utilize dynamic segmentation for T-Line indexing

Recent incorporation of dynamic segmentation in GIS is welcome news to the T-Line Index design initiative. With a dynamic segmentation capability, linear features do not need to be decomposed into homogeneous segments a priori. A priori segmentation is a particular problem when there are many attributes tied to the feature, such as with transmission lines. The conventional method of managing these data is to divide the right-of-way centerline into many segments defined by unique combinations of attributes, such as backline clearing width, crossings, political administrative units, etc., and storing each segment as a record in the database. Dynamic segmentation allows various attributes along the line to be referenced without prior segmentation by computing coordinate location by the milestone reference of individual facilities or features at run time for queries pertaining to these features. (Figure 4-4)

In the Index, centerline geometry is stored with $x,y$ coordinates for angle points, Point features (towers, crossings, etc.) can be referenced by milestone along the centerline. Segments of the line defined by attributes such as conductor type or Kv rating, can be referenced by beginning and ending milestones. Since the milestone identifier is stored as attribute data, the line is not decomposed into millions of separate elements. At query time any combination of coincident attributes can be spatially represented by computing $x,y$ locations of milestones "on the fly".

One of the design decisions for implementing the T-Line Index is to decide what data to reference by milestone alone and what data to include in the background base graphic. For instance, towers and other features occurring along the line itself would be represented by milestone in the T-Line Graphic. Certainly mile-maps, one-line diagrams, and photomaps could also be indexed with starting and ending milestone since finding these drawings for facilities could then take advantage of dynamic segmentation. Other, related data could also be integrated using dynamic segmentation. Access road intersections, right-of-way boundary inflections, even danger trees and clearing backline angle points could be represented by milestone and directional offsets. The decision rests, again, on user orientation assumptions and the level of detail appropriate for the planning/management view versus a survey/engineering view. ORACLE tables can include milestone identifiers for all spatial objects represented either on or in relation to the transmission centerline.

**SUPPORTING ACTIONS**

- Investigate dynamic segmentation implementation of ESRI and Intergraph. Do differences require separate ORACLE databases?
- Test query and reporting procedures with T-Line Index demo unit adapted to dynamic segmentation.
Dynamic Segmentation: Example application along BPA right-of-way.

Distance from tower to angle pt. 1
\[
\frac{6.63 - 5.13}{9.13 - 5.13} = \frac{1.50}{4.00} = 0.375 \text{ or } 37.5\%
\]

Distance from crossing to angle pt. 1
\[
\frac{7.63 - 5.13}{9.13 - 5.13} = \frac{2.50}{4.00} = 0.625 \text{ or } 62.5\%
\]

Calculate proportional segmentation from Mile Points

Compute coordinates of tower and crossing:
\[
\begin{align*}
x_{\text{tower}} &= 1500 + 0.375(2500 - 1500) = 1875 \\
y_{\text{tower}} &= 500 + 0.375(1000 - 500) = 687.5 \\
x_{\text{crossing}} &= 1500 + 0.675(2500 - 1500) = 2175 \\
y_{\text{crossing}} &= 500 + 0.675(1000 - 500) = 837.5
\end{align*}
\]

Figure 4-4: Dynamic segmentation can reference data along transmission lines. Milepoint values at angle points and for selected features are used to proportion the x,y location of those features along the centerline. For example, a section of transmission line between a tower and a crossing is dynamically segmented and can be highlighted for display. First the distance from an angle point and these features is calculated. Then the coordinate values are calculated at which to begin and end the new segment for display or to link to other attribute databases.
LONG TERM STRATEGIES FOR INTEGRATION AND MODERNIZATION

The strategic choices discussed above involve the incremental development of the Database Constellations as a framework for Branch system integration. Branch management should decide on priorities and time lines for these actions, some of which are dependent on others. In some cases, similar data gathering or database design activities will be applied to more than one area of effort. Consolidating the Regional Database, for example, will benefit the development of the T-Line. In others cases, there may be some initial duplication. For instance, it is recommended that development of the Digital Hardshell proceed on a day-forward basis while the T-Line expand in extent quickly from a pilot project to the entire service area. Ideally, the T-Line Graphic for the index should be obtained from the Digital Hardshell but while this is still under development angle point coordinates from the survey database will be used. Attribute data for towers and crossings will have to be read in from the one-line books, mile-maps, or other sources.

The short term objective of developing the constellations, common databases and standardizing data formats is aimed primarily at providing updated versions of traditional products for Branch customers in Facilities Engineering, Operations, Construction, and Maintenance. Shifting to a long term integration strategy involves focusing on inter-constellation integration and the development and marketing of new geographic engineering products for BPA.

**Strategy:** Establish standards and procedures for inter-constellation exchanges

In reviewing the logic of the database constellation approach, above, this report noted that data transfers within constellations could be standardized mostly around existing system formats while data transfers between constellations may require adoption of an ASCII file transfer standard. In general, where file transfer standards can be handled with proprietary formats (.DGN, eg.) careful examination should be undertaken to determine if a common database would instead suffice. Between constellations, ASCII data file transfers may be reasonably efficient, provided good documentation and translation software is used. What should be avoided, however, is the intermediary reformatting involved with data transfer via plot files!

In addition to data exchanges between Branch data constellations, some GIS data, imagery, and other map files occasionally will be obtained from outside sources. As a major Federal agency with mapping requirements, BPA itself can provide digital data to other regional Federal, and State agencies. Facilitating these exchanges is the purpose of the newly proposed SDTS - Spatial Data Transfer Standard (DCDSTF 1988). The standard provides common definitions and formats for transfer modules as well as specifies the contents of a data lineage and quality report to accompany data transfers. BPA should model an internal data documentation procedure to accompany the exchange of data between constellations based on the SDTS. This would benefit the Branch in terms of the QA/QC effort, providing every data file
with documentation on expected accuracy, lineage and date. These attributes of data files should be provided for all spatial data, whether vector or image.

**SUPPORTING ACTIONS**
- Identify opportunities for common databases for shared systems.
- Establish quality assurance for data accuracy and precision.
- Model internal meta data documentation after federal SDTS.

**Strategy**

Formulate priorities and objectives for image processing system

Research and development with the image processing system has been directed to digital photomap production and the quantitative results have been disappointing. Doing development work simultaneously with production caused output to fall behind schedule. To address this issue, the Branch initiated a study of photomap utility and backlog in May, 1991. (Cimmery and Butcher 1991)

The findings show widespread use of photomaps by Maintenance and the area offices. Few users, however, required precision measurements from photomaps. Consequently, continued research in efficient rectification should be driven not by precision measurement needs, but by the accuracy requirements for registration of imagery to digital data from other sources, particularly the T-Line Graphic.

Despite their utility to field crews and out-of-Branch personnel, this study found that half the photomaps booklets were as many as twelve years old, and that 75% were nine years or more out of date. Based on these findings a decision was taken to eliminate the backlog of current photomaps by reverting to an analog production method, contracting out the function as needed to outside sources.

This does not argue for the demise of a Facilities Planning IPS capability. There remain compelling arguments for resumption of digital production of photomaps once the backlog has been addressed. First, long range product changes and enhancements, many identified in the Cimmery and Butcher report, will be facilitated with digital methods. Second, independent digital processing and storage of imagery and lineework will facilitate updating with both vector annotation and new imagery. Third, variable scales and user-customized photomap views could be the long term future of the photomap product.

Much IPS development has benefitted other Branch efforts. The database constellation approach to integration can capitalize on this trend in several ways.
- Continuing development of the Regional Constellation requires GIS coverages of land use and other physical and cultural data. Classification techniques, image enhancement, and vectorization with I2S and BPA software has been developed to provide this.
- Digital Hardshell terrain models to other engineering branches may initially rely on photogrammetric and field survey inputs but in some
cases TIN and elevation data may be supplemented with IPS inputs in the emerging digital engineering paradigm.

- IPS procedures under development and continued digital production of photomaps can benefit from the use of the T-Line index. Drafting the centerline and annotation should be automated as soon as possible.

In the short term, IPS effort may be directed to focus support to photomap production or GIS input in order to increase efficiencies in more limited production functions. However, the marginal cost of using IPS to obtain data to support additional applications may be quite small. For example, reconnaissance engineering may benefit from images prepared to accompany public review and E.I.S. documentation. Site design image rendering might use oblique digital image procedures also beneficial to clearing reports and danger tree analysis.

An extension of the Cimmery and Butcher study could research the market at BPA for image map products that involve raster and vector integration. Branch management can then prioritize product development, ADP purchasing and FTE levels in accordance with a long term plan for IPS development.

SUPPORTING ACTIONS

- Acquire output devices for better speed and eliminate photomechanical steps involved with current film writing output.
- Catch up on existing backlog for photomap series with analog production. Then shift to digital photomaps incorporating new design and updating strategies.
- Prioritize IPS contributions to Regional Database, Digital Hardshell, and T-Line Constellations.

**Strategy** Consolidate 1:24,000 products in support of constellations

Several disparate processes are oriented toward the 1:24,000 scale in the Division. Environmental analysis is often performed at this scale. Reconnaissance engineering uses USGS 7.5' quads to determine approximate alignments. Although engineering design takes place at larger scales, plans are generalized for the 1:24,000 strip maps issued with construction specifications. In turn, these strip maps can provide the annotation and other linework that are drafted onto the photomaps. The strip maps also could be used to guide the development and maintenance of the T-Line Graphic for the T-Line index application on either the Arc/Info or Intergraph platform. From the T-Line, attributes can be selected for intermediate scale production of photomosaics and other data useful for environmental assessment in the same area. Figure 4-5 indicates how these inter-related products can be viewed as an integrating cycle between constellations. This cycle could be developed as a constantly evolving product combining environmental assessment, survey, photogrammetric, and image processing inputs. From this ability could come new geographic information products benefitting an expanded customer base at BPA.
In addition to the inner cycle, 1:24,000 product depicted in Figure 4-5, an outer cycle of inter-related activities can be viewed as its complement. Small scale system maps produced with the Regional Constellation provide the base graphic for at one of the T-Line Index user views. Customized photomaps could be produced directly from the T-Line if digital imagery is processed to accept linework from the T-Line graphic. Up to date photomaps indicating access and current conditions could be used in turn by survey crews along line retrofits and for additional site work. Resulting new mile-maps from the Digital Hardshell provides a large scale view of at least portions of corridors under examination for new projects, which in turn use the regional database to generalize existing transmission lines into the system map.

The inner cycle can be thought of as integration benefits that directly contribute to the Plan - Design - Operate - Maintain project life cycle. The outer cycle constitutes a reverse feedback for updating and engineering redesign support.

**SUPPORTING ACTIONS**

- Provide GIS output and other environmental assessment data useful to Reconnaissance Engineering.
- Promote use of CAD workstations for Reconnaissance Engineering output.
- Convert strip map production from analog to digital at uniform 1:24,000 scale.
- Tie digital photomap production into T-Line process, making the T-Line Index a production, as well as an inventory tool.
Figure 4-5: Integrative function of the 1:24,000 scale map/image product. At this scale Environmental Impact Analysis outputs could be used by reconnaissance engineering prior to survey of approximate alignments. Line design is generalized into strip maps which can be used to develop the T-Line index. In turn the index is consulted as a guide for environmental assessments on subsequent retrofits or new construction.
IV. ORGANIZATIONAL STRATEGIES FOR SYSTEMS INTEGRATION

Technical strategies for systems integration and modernization address the use and design of technology and databases for more efficient and effective realization of Branch objectives. Once a course of action is decided, key questions remain concerning how best to optimize human and organizational resources to accomplish the tasks ahead. This chapter presents several strategies concerning how the organizational structure of Facilities Planning can be used and/or modified to accomplish the tasks of systems integration and modernization.

LOCATION OF IMAGE PROCESSING

From the beginning of consultations for formulating the recommendations and strategic plan, the role and organizational location of the image processing system has been a key issue. An IPS task force was convened and met to discuss the contributions of image processing technology to digital orthophotography, GIS input, and whether to disperse or centralize IPS within the Branch. As noted in the technical strategies above, a precise and full delineation of the long term role of this information technology in the Branch is still incomplete but a few organizational implications can be drawn concerning actions which have been taken and discussions about planned work and resources for image processing.

**Strategy** Centralize IPS functions in a unit closely aligned with GIS and other geographic information production and applications development

As has been noted, image processing has important contributions to make toward each of the geographic data processing constellations. Technical capacity exists to spread this function out among separate systems, (Intergraph Imager, Arc/INFO-ERDAS). Some production image integration might be supported this way, for example, design renderings with image backdrop done within the CAD system. However, the most efficient initial processing and enhancement of aerial and satellite imagery can be accomplished by concentrating the expertise and system tools at one place in the organization. IPS personnel would need to be well informed of user requirements, but this strategy will conserve development effort while maximizing quality assurance standards for image processing and the products that rely on this increasingly prevalent technology.

The centralized IPS mission is to provide rectified imagery at small, medium and large scales for image backdrop, vector/raster integration for image map products and other visual displays, and to provide additional interpretation and digitizing services to the Branch GIS. Under the technical strategy section of this report some supporting actions are recommended to optimize the benefits derived from IPS.
Some organizational supporting recommendations are suggested in this section. They are intended to be viewed as complementing and facilitating the technical recommendations.

Image processing has not evolved to directly develop and produce an information system product. Equipment deficiencies and lack of programming support has lengthened the development process and production has not been achieved. Production and research development, programming, and planning have been too concentrated in the workload of a single individual. After a period of rapid production of analog photomaps eliminates the current backlog, and once adequate input/output devices exist to put digital photomap production on line, the separation of development and production tasks will be critical. A key recommendation here is for Branch management to consider the level of FTE allocation necessary to sustain the IPS mission.

**SUPPORTING ACTIONS**

- Provide IPS access to upgraded processing and output technology.
- Keep location of I2S and related systems within a geographic information production unit.
- Allocate trained FTE at sufficient levels for simultaneous photomap production and assistance to GIS and CAD systems.
- IPS system research to concentrate initially on smooth interface with Arc/Info and MGE environments.
- Separate R&D and production functions and expectations.

**DATABASE ADMINISTRATION**

The major reorganization of Branch work flows and mapping processes into the database constellations recommended by this study requires organizational strategies appropriate for building and maintaining large integrated databases that undergo constant modification and updating as planning and construction projects proceed. Existing Branch and Section management has primary responsibility for ordering and overseeing the production of maps and other information products. A specialized intermediate responsibility exists to direct the development of the databases themselves, and to provide direction and oversight to the technical system managers and other personnel who use these data.

This is the role of a database administrator. The Branch has not relied upon such a position before this point because the flow and maintenance of geographic and image information has been project and/or product oriented. Responsibility for its organization and currency has been divided between system managers and Section chiefs. With a greater emphasis on the quality and format of the intermediate geographic data used by multiple systems within the Branch, the database administrator becomes an essential role for the management of information as a Division asset.
Strategy Database administrators with responsibility for each constellation

The database administrator must be close to the data. That is, the position requires familiarity with the components of the various systems used in the Branch, knowledge of database design and data modelling considerations, and a sensitivity for data gathering procedures and quality issues. Because these conditions vary between the three proposed constellation clusters, this study recommends three database administrators for the Branch, one each for the Regional Constellation, the Digital Hardshell and the T-Line Index. Because database administrators should be in close physical and organizational proximity to the principal systems and personnel which rely upon their administrative support and planning skills, database administrators should be a part of the Branch Sections in which these production activities take place.

The degree to which database administration is a full-time position may vary between the constellations, or over time throughout the life cycle of designing, building, testing, and maintaining them. In the initial phase of Branch systems integration and database development, the three database administrators each can be positions assigned less than 1.0 FTE. Subsequently, a database administrator may also be occupied with some technical system managing responsibilities, but in no case should an individual have database administration responsibilities for two or more of the principal constellations. Coordination and inter-constellation integration should be handled by regular consultation between administrators, technical system managers, and Branch management.

SUPPORTING ACTIONS

- Regional Constellation administrator familiar with GIS and IPS data structures and procedures to be located in Geographic Analysis Section.
- Digital Hardshell administrator with CAD, photogrammetric, and survey knowledge to be located in Geographic Analysis Section.
- T-Line Index administrator with CAD/ GIS skills and familiarity with a broad range of user groups and customer requirements to be located in the Land and Cadastral Section.

DATABASE CONSTELLATION AND THE BRANCH MEO

Proceeding alongside this systems integration study has been a Branch Productivity Review. Part of the Productivity Review task has been to formulate a Most Efficient Organization (MEO) proposal for the Branch. The scope of that effort has been broader than the systems integration study, considering, as it has, detailed descriptions of current production, FTE staffing, and workload and budget projections. Consultation between the two studies has taken place at regular
Intervals. Integration and modernization approaches and technical options were developed independently of developing versions of the Branch MEO. The recommendations and strategies in the current report were prepared in conjunction with deliberations on the final version of the MEO and are not considered by the authors of either study to be incompatible.

In the interest of fleshing out some of the details of the MEO, however, some comments can be presented as a part of this study, to indicate where certain initiatives and strategies fit with respect to the MEO.

**Comment**  On the location of database constellations within the Branch

In the preceding section, this report has proposed the locations of database administrators for the various constellations within specific Sections. At the time of preparing this report, FTE levels and exact names of Sections are not finalized but will resemble the preliminary chart as given in Figure 4-6 (reproduced from the Branch Productivity Review MEO). While database administrators, system managers and technical production personnel must necessarily belong within specific Branch Sections, to some degree the constellations themselves can be seen as clusters of data exchange and work flows that cross and unite sections in different ways.

The majority of the Branch's technical expertise, system development, mapping production, and geographical analysis is organized within a large section, to be known as the "Geographical Information Section". Within this section will reside most personnel and technical management devoted to photogrammetry, CAD, GIS, and image processing systems. General responsibilities include mile-map production from the Hardshell, planimetric and topographic photogrammetric surveys, danger tree analysis, photomap production, GIS analysis and project work, and a variety of auxiliary photo and map preparation and data handling tasks.

The Regional Constellation can be considered almost entirely contained within this Section. [EFBH] Residing primarily on the GIS and to some degree within the I2S environment of the IPS, production work can be located in a proposed Geographic analysis unit within the Section. Currently this work is split between two Sections; the GIS contained within the existing Environmental Section [EFBG]. With the reorganization of Branch Sections, EFBG will still rely on the GIS for environmental assessment, corridor analysis and other mapping data. To a certain extent therefore, the Regional Constellation can be considered to have some participation from that Section. Within EFBG also resides the Desktop Publishing System, DTP, on Macintosh computers. Due to its report publishing requirements, this system, and the role of Graphics Coordinator, is proposed to be left to this Section.

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4 Although Section names may be changed, this report assumes BPA mail codes will remain for the Branch: Environmental EFBG, Geographic Analysis and Photogrammetry EFBH, Survey EFBI, and Land and Cadastral Section EFBJ.
Figure 4.6: Proposed MEO for Facilities Planning Branch.
The Digital Hardshell database administrator will also reside in the Geographic Analysis Section [EFBH]. Mile-map compilation and much of the work involving preliminary versions of the hardshell will take place within the CAD system which will also be managed in EFBH. In addition, important inputs into the hardshell process will come from the new analytical stereoplotter and possibly from IPS, also located in this Section. However, key decisions regarding survey planning and data gathering, and ultimate responsibility for the precision and accuracy of Digital Hardshell coordinates will be the responsibility of the Survey and of the Land Cadastral Sections, [EFBJ & EFBJ]. Both should accordingly be allocated one or more Intergraph workstations. In Survey, this can post process GPS and theodolite data, produce cross sections, TIN, contour and other topographic models for the digital engineering requirements of the Division and plot out preliminary versions of the hardshell for field use. In Land Cadastral, the workstation will be the interface with the T-Line Index, for query, editing, and management of that database.

This introduces a fine distinction between database administration and quality assurance. In general, database administrators are responsible for the currency and reliability of databases. Responsibility for the accuracy of content data in them remains a part of normal Branch production and quality assurance procedures.

In contrast to the logic of establishing database administration close to the technical management Regional and Hardshell constellation systems, the T-Line Index administration is placed within the Land Cadastral Section, EFBJ. It is within this section where current coordination of map and drawing catalog and inventory takes place and it is here where the proposed MEO assigns the important distribution and library functions associated with the Facilities Planning Branch. Since the T-Line is considered a primary tool for exactly these functions, its administration should lie within that Section. However, to an even greater degree than the other database constellations, the T-Line index is inherently a cross-organizational information system. Important links to the GIS, IPS, and CAD systems will necessarily involve the T-Line database administrator working closely with the technical system managers located in the Geographic Analysis and Photogrammetry Section.

**Comment: On systems integration and the management support staff**

The proposed MEO specifies a Management Support Staff to assist with a variety of functions that coordinate production, planning, and systems integration tasks.

Current Section level ADP planning will become the responsibility of a Branch ADP coordinator working closely with Section Chiefs as well as database administrators and technical system managers in determining equipment outlays and benefits.

A guiding principle for the MEO is the logical separation of R&D from production. Geographic Analysis and Photogrammetry Section contains the production
personnel associated with the geographic data processing systems. Additional staff engaged in research and development may be located here, or in other Sections but will be coordinated by a Branch R&D administrator. Early R&D efforts might well consider the coordination of the 1:24,000 scale map-image integrated product and how it could serve the needs of the constellations and of outside Branch customers. Additional R&D work in user interfaces and image processing will also greatly benefit the development of the database constellations, especially the T-Line.

Emerging technologies, such as softcopy analytical stereoplotters, video imaging, high definition television and the use of CD ROM for drawing storage will also involve R&D administration and the coordination of database administrators.

A special position in the Branch Management Support Staff has been created with the title of Project Management: System Integration. This position chiefly will be responsible for implementing this study and take other actions to ensure the success of systems integration while continuing to enable Sections to meet production goals. In doing so, he or she will coordinate the three database administrators as well as the system managers. Although the draft MEO defines this as a temporary position, perhaps dissolving after the incremental constellation development is well underway, the need to coordinate this committee of Database Administrators, Sections Chiefs, and Systems Managers may be ongoing. Fulfiling this need with either a permanent position or a with a rotating chair should be considered.

Comment  On constituents and customers for facilities planning Sections

The MEO process has raised issues concerning the relationship between individual Sections in the Branch. As indicated in Figure 4-6, the proposal renames one section (Land Cadastral) and greatly restructures another (Geographic/Engineering becomes Geographic Information). Although the initial thrust of the A-76 process was directed at survey and mapping activities directly supporting other Branch products and services, the focus was expanded in the productivity review process in recognition that these essential services are integral to the Branch mission.

By considering the Branch and BPA mission statements, this study has pointed out that customers for Branch products, and constituents for its information base, exist throughout the Agency. Some work done within a Section directly supports another Facilities Planning Section. An example is IPS support for GIS. The proposed organization can streamline a number of these flows by concentrating technical ADP systems primarily within the Geographic Information Section, although satellite CAD stations will exist in Survey and Land/Cadastral as well.

The Sections, and the Branch as a whole, provide information to reconnaissance engineering, project estimating, and structural and right-of-way design which are all functions of other Branches with the Facilities Engineering Division.
Still other customers of Branch products and services lie outside the Division. For example, Branch support of customers in Operations, Maintenance, and Construction, in the form of photomaps, constitute part of the valuable role the Facilities Engineering Division contributes to wider BPA activities. Seen in this light, a number of MEO objectives, consolidation of ADP systems, the management support staff with centralized systems administration, and the establishment of a computerized records service center within the Land Cadastral Section are all initiatives that recognize the broad nature of the Branch’s constituency.

**TAKING ACTION ON THE STRATEGIC PLAN**

Implementation of strategies recommended here requires a hands-on approach. Basic concepts have been examined and it is left to Branch personnel to begin accomplishing systems integration. The role of the outside technical consultant changes at this point, from proposing solutions, to commenting on their internal interpretation and assisting with efforts at database design and data transfer.

This implementation will take place in a changing systems and organizational environment. The acquisition of a new analytical stereoplotter is imminent and newer GIS workstations and some expanded electrostatic output capability are already installed. The MEO process is moving forward and some realignment of systems in Sections will be occurring. With these factors in mind, a scenario for implementation is developed below.

**Strategy**

Integration project management and constellation design teams

The need for database administrators to manage the day-to-day availability and evolution of constellation databases has been discussed, above. Special mention was made of the role of the Project Manager for Systems Integration in coordinating and monitoring this development. This function is paramount for the initial phases of establishing priorities, database development, and pilot demonstrations.

Each of the database constellations require more detailed design. A design team of system managers and key individuals with production or technical knowledge should be assembled to address the implementation of each of the three principal constellations. These teams will prioritize tasks for implementation, layout detailed database design specifications and establish data sharing practices within the constellation using existing network configurations and a standard data format.

Project Management will consult with Branch and Section managers to determine an overall priority for integration work. While design proceeds incrementally on all three, one constellation might be given extra resources to produce quicker results. Reasonable arguments can be stated for putting the initial emphasis on any of the three databases. The Regional Constellation is closest to being realized. The
T-Line Index is fundamental to integration and can make use of several efforts already at varying stages of completion. The Digital Hardshell is central to transmission design and requires the most development since it involves the interaction of several Branch systems, some of which will be recently installed and requiring additional application development and translation. At this stage, the determination of whether to use a .DXF or similar ASCII file transfer standard for inter-constellation data exchange should also be addressed.

As pilot project work is completed, or as databases and networking are put into place, day to day management of the effort is passed to the database administrators, who are appointed at this time. Project Management then shifts priority to accelerating the effort of design and testing for the next constellation, and so on until each of the three database administrators are overseeing a working, transaction- based information processing environment and application development is in a working state. When the third constellation is contributing toward its range of digital and map products, priority shifts again toward the 1:24,000 product design cycle. At this time, the photomap backlog has presumably been made up and that process is once more available to be digitally linked to the 1:24,000 product.

SUPPORTING ACTIONS

- Project Management forms design teams for each database constellation to consider detailed design and data flows.
- Teams adopt an approach to inter-constellation transfer standard
- Teams prioritize tasks for each constellation. Project Management prioritizes pilot project for T-Line.
- As teams finalize constellation design, management of databases is passed to a database administrator. Project Management focuses on next level priority.
- As all three constellations come "on line" priority shifts to implementing the 1:24,000 product cycle. Project management continues coordinating the efforts of the database administrators and system managers.
V. SUMMARY OF RECOMMENDATIONS

The purpose of the Task 4 Recommendations and Strategic Plan report has been to summarize the findings of the integration study and present a series of actions that will support a modern computing environment for efficient and effective survey and mapping operations supporting Branch and BPA goals.

These recommendations are an outgrowth of extensive discussion and participation. Implementation of individual strategies suggested in this report will be incremental and, perhaps, selective. Responsibility for carrying out a program of systems integration and modernization falls to Branch management, particularly through the Systems Integration Manager on the support staff. Specific implementation decisions must be held accountable to available resources and project schedules. This report acknowledges these requirements and has presented suggestions and recommendations formulated with the best available knowledge about current and projected workload and FTE levels.

The report has presented a series of strategic recommendations, organized as either technical or organizational in nature but of course, actions taken in one sphere influence those to be taken in the other. Within the technical recommendations chapter, the discussion has been organized by major database/product constellation, an approach consistent with the previous Task 3 Alternatives Identification Study. The following summary briefly recaps these recommendations in the context of "Strategic Framework", "Application and Database Development", "ADP Planning", "Marketing", and "Staffing".

Strategic Framework

The demand for more efficiently produced maps is not sufficient to invest the capital and energy required for systems integration. The future of the mapping function in organizations such as BPA lies not the production of maps as end products, but in managing the organization's geographic data. Effective management of this important organizational asset will not only lead to efficiencies in mapping, but to more flexible provision of information for a variety of engineering, maintenance, operations, land acquisition, environmental, and public notification requirements. To this end, the systems integration study developed a framework for integration and modernization that consolidates existing and intermediate products while also providing a pathway for growth into the emerging digital engineering and image/map integrated design and analysis environment.

This framework has been dubbed the Database Constellation approach (Task 3) and serves as a convenient means to organize otherwise piecemeal and scattered integration efforts involving isolated systems and products. The constellations are
described for the most part as clusters of interlocking data processes at similar input and analysis scales. These clusters are found to support key Branch objectives:

- geographic analysis and planning
- siting and engineering design
- inventory and access to geographic and facilities engineering data

Accordingly, the Regional Constellation, the Digital Hardshell, and the T-Line Index have been proposed as the principal constellations of Branch data processing and mapping activities. Within these clusters, integration should proceed by building common databases for access by several data processing systems required to produce geographic information products. Depending on convenience and efficiency there may be several "databases" within constellations, but the design of each one should conform to a model of data that is appropriate to the constellation's objectives. In addition, databases are not considered static and unchanging. Particularly with the Digital Hardshell, versions of right-of-way design and mapping must be available periodically as projects proceed, for field use and provisional design.

These constellations are directed toward traditional "markets" for Branch services but do not exist completely independently. Each of them can be placed along an infrastructure project life cycle (Fig. 4-1) and therefore require shared inputs and outputs. Consequently, data exchanges between constellations will not be supported by direct database queries since different, or complementary models of data may be involved. In particular, integration around a series of intermediary products at the 1:24,000 scale involves data inputs from the various constellation processes. In this case, file transfers, well documented, and making use of standardized translation software and ASCII formats can be adopted.

Application and Database Development

Implementing this strategic plan will involve continuing database development and application development. The Branch has acquired expertise over the years with exactly this kind of development and the recommendations in this report leverage existing integration efforts and expertise.

With regional and environmental data at intermediate and small scales, a fairly consolidated database already exists as a core around which to structure the Regional Constellation. Future environmental project data can be integrated into this constellation in an incremental fashion. General emphasis should be given to substituting data obtained from 1:24,000 scale sources, for those data from smaller scales. A particular need exists for a larger scale, and more up-to-date land use/land cover data layer for corridor and site environmental analysis. In addition, this layer and others in the regional constellation might be integrated with digital elevation model data available for the region as a whole (from USGS) to be supplemented by more highly accurate terrain modeling obtained from the Branch Survey Section along BPA rights-of-way. Along with these data, imagery from the Branch IPS can
be integrated for planning and public notification viewing. IPS capability is also essential from obtaining certain GIS, regional database inputs such as land use from aerial photography. In this case, image warping and rectification applications currently under development should be maintained.

Effective production of digital terrain, plan and profile mapping and other data for engineering design, requires an integrated process of hardshell, photogrammetry, and cadastral survey inputs. This is the objective of the Digital Hardshell, a process involving the interlocking access by CAD, Stereoplotting, COGO, and other software to databases storing accurate coordinates and elevations of point, line, and area features and facilities. Specifically, this involves converting the coordinate database into a digital, CAD operation earlier in the process than now occurs, to be accomplished by providing the Survey Section with at least one CAD workstation and PC software with workstation compatibility for field use. In addition, digital editing capability is an essential requirement for the Branch's new stereoplotter, in order to store what was formerly photogrammetric manuscript data directly into the CAD formatted database. Finally, elevation data from the hardshell process, can be provided as rectangular point files (DEM) or triangulated irregular networks (TIN) to project and design engineering. This may necessitate some accuracy requirements analysis and application development in the CAD environment, but some capability already exists to do this modeling within the Survey Section, and Intergraph provides modules to accomplish it with little in-house development.

Perhaps the most application and database development work will occur in establishing the T-Line Index. The benefit of doing this lies in eliminating similar efforts in several other areas which now must be independently maintained and cross-referenced. This report discussed at some length the user interface and design requirements of such an index. The primary recommendations are:

1) Establish an attribute database with a standard database management system such as ORACLE,
2) Use existing spatial databases (regional database, system grid, hardshell) as a base graphic for user interface with the index.
3) Support at least two applications initially, on separate platforms, to support the requirements of large scale, vs. regional user views.
4) Use the T-Line as a graphical tool for scanned image and digital data retrieval.

In addition to providing an inventory and index tool to available sources of Branch and Division facility data, the T-Line graphic itself can be generalized, or customized to support the generation of a number of products at the 1:24,000 scale level.

**ADP Planning**

The proposed MEO provides Branch level integration of ADP planning efforts and establishes an ADP coordinator as part of the management support staff. This
person will work closely with Branch database administrators and technical systems managers for implementing a modernization and upgrade plan consistent with the strategies outlined in this report.

The strategic recommendations in this report are primarily based on existing Branch data processing capabilities and assume no new purchases of major data processing systems. Even the most extensive application development and database design effort involving the T-Line Index can leverage existing hardware and software to achieve its objective incrementally. At least in the short run, the existing ADP plan for acquisition and maintenance can be accommodated. In terms of hardware, the major expenditures that apply to this strategic plan are already approved, a new analytical stereoplotter with digital editing capability, improved workstations and input and output devices for the IPS, and additional CAD workstations for the Land and Cadastral, and Survey Sections.

Some software purchases will be required. Chief among them are digital terrain modeling software, additional capability in the Intergraph environment, and dynamic segmentation upgrades to existing Arc/Info and MGE software. At least in the Arc/Info case, this capability is provided in the next upgrade version, which the Branch receives as part of its software maintenance agreement with ESRI.

**Marketing**

A recent study into the effectiveness of Branch-produced photomaps found widespread acceptance and enthusiasm for this product. While many users apparently do not depend on this imagery for precise measurement, the comments and suggestions they contributed to the study indicate a number of enhancements to be designed into the photomap series and booklets. (Cimmery and Butcher 1991)

Similarly in the course of interviewing BPA personnel in other Branches, the Systems Integration Study has noted support for a geographic index of facility data, digital terrain model data, and GIS site analysis maps and 3-D graphics.

In both cases, many of the products that these users require can be provided easily within the Branch's evolving technical systems and integrated data environment. The stated Branch mission is to provide high-quality comprehensive services in the areas of geographic analysis, surveying and mapping. This study has recommended that research and development of new products and procedures should continue to contribute to survey, analysis and mapping improvements. An important part of that research effort involves marketing Branch products and services in the Agency. Accordingly, an extension to the photomap product study mentioned above has been suggested to investigate the demand for integrated image and mapping products which could have a broad base of support in BPA maintenance, operations, and environmental enhancement work. Units involved in those efforts need to be sufficiently informed of the usefulness and availability of these products.
Staffing

For the foreseeable future, the current level of Division staffing is assumed to be static, or at best, very slowly increasing. A key constraint on implementation therefore will be the level of FTE which can be allocated to any of the incremental recommendations of this study. In general, while some additional staff hours must be invested in database and application development, the FTE to be assigned to regular production in the Branch should remain steady, or perhaps slightly decline as a better integrated geographical data processing environment is built. Initially, however, this requires some shift of FTE from production to research and development positions. In the long term, it also requires personnel to manage database constellations and facilitate system integration on an ongoing basis.

Data and application development will take place in three areas as systems integration begins. T-Line index development on ORACLE, Arc/Info, and/or Intergraph platforms will require a design team to coordinate design, technical assistance, and programming. In addition, improvements to image processing capabilities has increasing relevance for GIS input, and the future resumption of digital photomaps will require sufficient staffing to achieve the recommended separation of research and production. An important recommendation is for Branch management to consider the level of FTE allocation necessary to sustain the IPS mission. Finally, conversion to a digital editing environment for stereoplotting, and in particular, modernizing and integrating the danger tree analysis programs into the CAD environment will require additional development FTE.

In modern computing environments, database administration becomes critical as applications require integration and data sharing. The burden of maintaining data content standards falls, as always, to Section Chiefs and Branch Quality Control. Maintaining current, well designed databases, supporting file transfers and graphics compatibility, and brokering the competing demands of data users is the role of the database administrator. This study considers three such positions to be essential in the dynamic, on-going effort to organize production around the geographic analysis, engineering design, and data inventorying functions.

While database administration may not always occupy a full-time position, some combination database administration-technical systems manager FTE will certainly always be required. The success of integration depends on some management and responsibility for the design and implementation of integrated databases and it is therefore recommended that database administration roles in the three constellations areas should not be combined in one position.

Inevitably, staffing becomes a matter of internal organization. This study did not focus on this issue but several implications for the Branch have been discussed.
The establishment of database administration positions should be within the Geographic Analysis and Photogrammetry, and Land and Cadastral Sections. This places this important function close to data users and technical systems managers. The coordination and development of these positions is overseen by a Systems Integration Manager assigned to a support staff at the Branch level.

CAD expertise will be required in the Survey Section when a workstation is devoted there for post processing coordinate data and preparing preliminary hardshells. This could involve a transfer of one or more persons between sections.

In Conclusion

Modernization and systems integration at the Facilities Planning Branch is an ongoing effort designed to provide effective geographic analysis, survey, and mapping support for engineering, maintenance and construction, and environmental enhancement programs at BPA. This strategic plan has provided an organizing framework for carrying out the necessary integration of systems, data flows, and products. This will require the development of file exchange standards, integrated databases, and some additional application programming. Some of the benefit from this implementation will be to reduce the current redundant efforts involved in multiple data indexing and reformattting for file transfers. Additional benefits of the integrated environment lie in enabling the Branch to adapt to new product demand from an expanded customer base at BPA.

Each of the strategic initiatives presented in this report have been described in terms of an incremental approach to design and implementation. Especially in the initial stages, Branch systems integration should be recognized as a process which consolidates and conserves resources, the better to serve a varied user base at later stages with new products and information services. An integration Project management position and the establishment of working groups in the form of constellation design teams has been recommended to carry forward these tasks.

In the emerging digital engineering environment, the Facilities Planning Branch faces outstanding opportunities for providing modern analysis, survey, and mapping services to BPA. Integrating technical systems and data flows with sound database administration and adequate ADP planning is an investment in the future capacity to efficiently provide effective support for the BPA mission.
REFERENCES


