SAN FRANCISCO INTERNATIONAL AIRPORT: EYE ON PROGRESS[1]

With an eye on airport safety and future expansion, San Francisco International Airport has been investing in state-of-the-art computer technology to improve facilities maintenance, speed construction projects, and reduce operation costs. Since the San Francisco Chamber of Commerce purchased the 100 acres off Old Bayshore Highway at the edge of South San Francisco in 1927, the Airport has been continuously expanding and increasing in complexity with each decade. With every expansion and increase in passenger load, more and more tools are required to maintain the Airport and keep it functioning. Therefore, when the Airport started preparing for another expansion, the elements were already in place for the development of a geographical information system (GIS). The GIS will be the foundation for other systems, such as automated facilities management or computer aided dispatch to eventually create an overall computerized information model of the airport properties including a three-dimensional electronic model of the airfield and facilities. The decision to computerize was designed to increase the efficiency and safety of the Airport in a broad range of functions.

HISTORY BEHIND PROGRESS

In October 1986, the Airports Commission retained consulting firms to provide services related to the preparation of the Airport Master Plan. The Master Plan provided the Airport with a comprehensive set of plans, guidelines, policies and conditions that will serve as a framework for decision-making and implementation of landside facilities over the next 15 years. The implementation of the Master Plan will increase the square footage of the terminal areas, cargo areas, airline support and maintenance areas, general aviation, and other educational and commercial facilities from 4.5 million sq. ft. to approximately 6.5 million sq. ft. This increase and reconfiguration in airport leasable area has greatly complicated the process of leasing property to new tenants and the relocation and expansion of the existing tenant spaces. Since the late 1970s the Property Management section of the Business and Finance Department has been requesting a better leased area and data management system. Responsibilities of the Property Management section includes tracking and modifying lease agreement drawings, tenant delineation, lease disputes,

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upgrades, termination, ownership and liability. They needed a system that could easily manipulate vast amounts of data quickly. Furthermore, the system had to be easily adaptable, accessible and manageable. From this request, the Facilities, Operations and Maintenance Department (FOM) started to research and develop a GIS. Initially, this came in the form of "Spaceman," a rudimentary computer-aided drafting system. Unfortunately, the system was so slow and the software so difficult to manage that they had to abandon the project. FOM continued to seek new computer systems. As time passed and computer technology advanced, FOM realized its own need for a spatial database to facilitate modifications and drawing management.

By 1986, the scope of the research expanded to include management of accurate architectural and engineering drawings and specifications as well as leased line data. However, this meant that the electronic production of spatial data had to carry vector accuracy and object intelligence. Further research revealed other advantages of an electronic storage system with "intelligent" spatial data. First, this system could provide immediately reusable, as-built information for all facility improvement projects. Second, it could support other facility operations computer systems including maintenance, parts inventory, property management, general administration, communication, hazardous waste identification, and security. Third, the improved electronic accessibility would reduce the demand for physical storage space and filing of contract documents. Finally, it would facilitate the design and scheduling of the Master Plan, the dispatching for emergency response situations, and the general spatial identification and analysis process. Therefore, the system had to have the capability to draft high-quality design and construction documents such as floor plans, elevations and sections and to link relational databases, do three dimensional modeling, and fulfill general presentation and mapping needs.

CREATING A GIS

With these goals in mind, FOM located two companies that did similar work, McDonnell Douglas' GDS and Generation5's MunMap which eventually became Geo/SQL. The first was a tried and true system McDonnell Douglas had developed and used for their facilities. The second was a budding software company that linked AutoDesk's AutoCAD to a relational database to produce a GIS. Due to McDonnell Douglas' inability to sign certain San Francisco contractual requirements, Generation5's Geo/SQL was chosen as the backbone for the new database linking. With AutoCAD as the interface program where information is entered and displayed and Geo/SQL as the linking mechanism, Oracle was ultimately selected as the engine for the relational database because it was the standard software for the City and County of San Francisco at the time. As time passed and software improved, two additional software products were integrated into this system by the Airport to streamline its data retrieval and improve user interface. First, ADE (AutoCAD Data Extension), AutoDesk's limited version of a graphical-to-relational database association software, was added to assist Geo/SQL in graphical data retrieval and relational database association. Second, several of Softdesk's customized design tools for architectural and engineering systems were added to ease extensive computer aided drafting (CAD) training and to standardize graphical data creation.

Over the past 16 years, FOM has invested close to $5 million in computer systems and in creating an AutoCAD-based graphical and Oracle textual database. The first half of this investment was for computer hardware, software, technical support staff and personnel retraining. For the second half, FOM acquired a complete set of digitized photogrammetric survey maps of airport property, three dimensional as-built models of the terminal buildings and boarding areas, and a partial conversion of remodeling projects' document and management information.

DATA ACQUISITION

Airfield

In 1991, a San Francisco-based surveying and mapping firm was hired to transpose the above ground features into AutoCAD format. The scope of work was designed to provide 1" = 40' planimetric base maps that included survey monuments, surface utility features, building roof outlines, curblines, fences, walls, shorelines, runways, property boundaries and state plane coordinates annotated at 400' intervals. The utilities were paneled for easy visibility from the air. Photogrammetric control surveys were performed with point locations on the control map. The horizontal coordinates were referenced to NAD 83 and the vertical to NGVD 1929. The photography was obtained by an aerial mission performed with a Cessna 206. A series of overlapping 9" x 9" black and white photographs were taken at 1" = 400' scale. Six flight lines with 47 exposures were completed. A single photograph at 1" = 2300' was also taken to cover the entire Airport property. This photograph was scanned, rectified and georeferenced for AutoCAD overlays.

Computer driven instruments were then used to square the measurements between points on the photographs and the same points on the ground. An augmented system of control points was established on the photographs, then two adjacent photographs aligned to make a cohesive model. The adjacent models then formed a continuous strip and were adjusted using the coordinates given by the ground control. At this point, if any errors were discovered in the ground control, a secondary field survey was performed for further verification. Further digitization of the digital planimetric maps was compiled using a WILD BC-2 analytical stereoplotter interfaced to an AutoCAD workstation. During this process, the digital maps were made from the photographs. Through the analytical stereoplotter, the two contiguous photos form a stereo pair, enabling the compiler to see the photo area in three dimensions and digitize the features to be extracted for the map. The stereoplotter computer recorded the digitized data consisting of x, y, and z coordinates as well as coded features. The entire airport was subdivided into a total of 125 map sheets and AutoCAD drawing files as shown in Figure 1.

Using the map sheets as a basemap, the GIS was able to retrieve graphical information for the development of construction documents for runway and taxiway paving and stripping, road construction, sewer and drainage upgrading, etc. Field surveys were performed on a project by project basis and corrections were made electronically so that the data generated from each project incrementally enhanced the accuracy of the basemap. On another level, the basemap was an invaluable tool to track the logistics of the Master Plan as the plans and schedules developed and were later modified. It provided an accurate reflection of the Airport during its different phases of transformation. Furthermore, because the basemap can be quickly changed and updated, information and construction documents became easier to develop. This allowed more time for design development. No additional time was required for preparing the base plan and location maps.

Building Interiors

As the airfield graphical database was being created, database development on the terminal buildings was in progress. A Request for Qualifications (RFQ) was advertised in April 1993 to solicit consultants to produce complete three-dimensional as-built models on AutoCAD to include all architectural, structural, electrical, mechanical, plumbing and fire protection elements to the Airport CAD standards. Of the 41

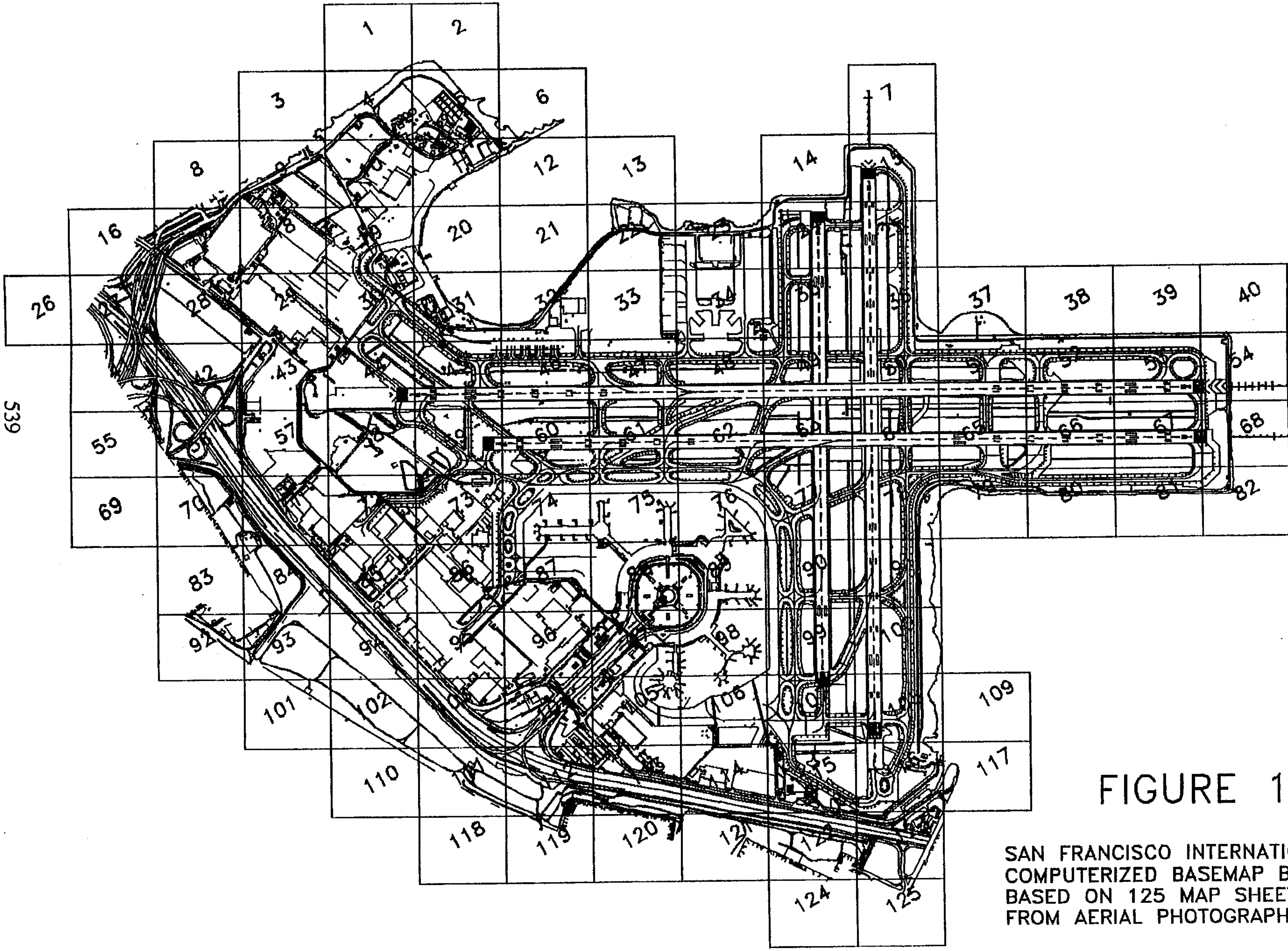

FIGURE 1

SAN FRANCISCO INTERNATIONAL AIRPORT COMPUTERIZED BASEMAP BREAKDOWN BASED ON 125 MAP SHEETS DIGITIZED FROM AERIAL PHOTOGRAPHS.

companies who responded to the RFQ, only nine were selected to respond to a Request for Proposal (RFP). Three separate contracts were awarded, one for each existing terminal building and its attached boarding areas. In this instance, these three projects produced graphical and textual data which became the foundation for a variety of other airport systems. It created a geographical database for property/lease management, telecommunication management, emergency response situations, general administration and facilities maintenance. This became the basemap for the building interiors.

DEVELOPING THE APPLICATION

In order to create the graphical database to support the different systems, the building information was to be separated into two types of data: restricted and general. Restricted information is the information used strictly by specific departments. For example, tenant lease payment information is restricted information used only by the property management section for the collection of rent or the accounting department for payment processing. General information is the data that is shared among all of the departments. For example, the airfield basemap information is shared among all the departments for general location mapping or dispatching. The advantages of this system are the ability to protect and secure proprietary information from parties who need not have access while maintaining the accessibility of information essential to all. Moreover, this assigns the burden of data entry and maintenance to the departments that use the information most and that very frequently have the most accurate information.

Furthermore, the building systems had to be broken down into individual data units and represented in AutoCAD. Encoding all the data units with unique identification tags was not only an impossible task, but also useless. Not all of the spatial entities will have relational database links. Therefore, core units were developed to identify those fundamental elements that linked to other information, such as text, photographs, other drawings, and/or other software. These units have to be rudimentary enough for multifunctional tasks, from general planning to individual design. Therefore, the units had to be broad enough to be comprehensive yet reasonable enough to encode since the ever-changing graphical database will require constant coding and/or recoding. For example, an identified core unit was used to regionalize the spatial data into collective elements for easy retrieval. As a result, the closed polygon outline of a room was established. Room outlines are used as the basic geographical unit in which to relate other building information. Each room outline was then systematically coded and indexed based on its room number. The relational database used the room number as the unique identifier for its connection to the graphical database. For instance, property lease information retrieval is based on the tenant document database linked to the building basemap. To retrieve all the leased areas for a specific tenant, the software will search the sql (structured query language) database for the tenant, then all of the room numbers leased to that tenant. Using those room numbers, the software can retrieve the linked room outlines and display it on the screen. If additional information such as the building elements are required, more queries can be done to produce those elements.

Another fundamental unit used to break down building information is the detail symbol. Because it is not feasible to model an entire building down to the details in AutoCAD, the detail symbol is used as the key to accessing scanned detail drawing information. Each detail symbol is encoded with the electronic name and location of the original scanned contract drawing. Therefore, to access the scanned detail, the software will grab all of the encoded information from the detail symbol to locate the scanned file. Once the scanned file has been identified, the software will start the viewing mechanism to display the scanned image.

FUTURE APPLICATIONS

Altogether, the development of the GIS is still in its infancy. There has been a marked decrease in the architectural and engineering design costs to FOM using the limited applications provided by the GIS, the full cost reductions, however, have yet to be realized. Future applications are being developed and data is still being collected and entered. An immediate goal is to associate the airfield and building databases to other systems such as emergency dispatching, data and telephone communications, and facilities maintenance so FOM can pass on the savings to other departments. As the Master Plan is implemented, many new buildings are in the process of design development and construction document preparation. Many are coordinating the standards in which the documents and data are created for an easier transferal from design and construction to facility maintenance; however, construction does not stand still for computer technology to solve its many idiosyncrasies. Therefore, even with the information that has already been processed, a tremendous amount of data still is waiting to be entered into the system. So, together with the need to train hundreds of additional airport personnel, it will take some time for the overall airport computer information system to reach its fullest potential.