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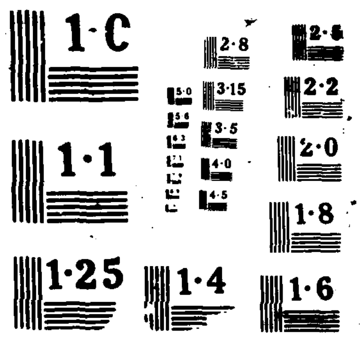
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AN ANALYSIS OF METHODS FOR MAXIMIZING
THE UTILIZATION OF SPACE
IN USAF FACILITIES

THESIS

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Squadron Leader, RAAF

AFIT/GEM/DEM/87S-19

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AN ANALYSIS OF METHODS FOR MAXIMIZING THE UTILIZATION OF SPACE IN USAF FACILITIES

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Engineering Management

John P. Quinn, B.E.

Squadron Leader, RAAF

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Thanks seem inappropriate for my wife, Rhonda, and daughter, Rebecca. I regret the time not spent with them, and appreciate their patience, understanding, sacrifice, and assistance, especially in the production of this thesis. They were very much a part of this effort and I shall have to find some way to repay them.

John P. Quinn

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Abstract

New facilities are expensive. Before new construction is chosen by an organization as the solution to a facility space deficiency, every effort should be made to satisfy the requirement within existing facilities. This may require rearranging interior layouts, reassessing the actual space needs of users, reallocating space, and making building alterations to permit more effective space utilization.

If new construction is necessary, the interior layout should be systematically designed with functional relationships and long term flexibility in mind. This study examines methods used by the United States Air Force (USAF) and Royal Australian Air Force (RAAF) to 'manage' facility space and to 'plan' facility space. It compares the general effectiveness of methods used by the USAF, and determines what effect the quality and accessibility of building information and space utilization data has on a base's effectiveness in utilizing its facility space. The practices of Base Civil Engineering (BCE) Design and Real Property Sections in the planning and management of facility space were solicited from key BCE personnel.

The use of the computer as both a space management and interior design tool is explored. Computer algorithms, programs, and systems developed and used by private US

organizations for space planning and management, are examined for potential use in Air Force Civil Engineering (AFCE).

Recommendations are made for both the RAAF and USAF to improve their utilization of existing facility space. Specific design tools, rather than intuition, should be used to plan floorspace layouts. Utilization studies should be conducted periodically, not only when a deficiency arises. Databases should be examined and updated constantly to ensure facility managers and designers have the best information possible on which to base decisions on how building space can be best used.

AN ANALYSIS OF METHODS FOR MAXIMIZING THE UTILIZATION OF SPACE IN USAF FACILITIES

I. Introduction

General Issue

Each year the United States Air Force (USAF) spends many millions of dollars on the design and construction of new buildings to accommodate its personnel and equipment. Facility construction and maintenance costs increase each year due to such factors as: inflationary effects on the costs of labor and building materials; generally improving standards for accommodating personnel; and, the maintenance complexity and environmental control requirements of new 'state of the art' equipment.

There will always be a need to construct new facilities to accommodate new equipment, and to make the most of potential cost and time savings when operating and maintenance procedures for existing functions change significantly. There will also be a continual need to replace facilities which have either reached their intended design life, or which can no longer support their intended functions and cannot be modified economically to do so.

There are usually many alternative courses of action available for consideration when planning the accommodation of a single user's, or an entire installation's, functions.

Constructing new facilities to accommodate new or changing functions is expensive, and other alternatives should also be considered as part of the facilities planning and design process. Some of these alternatives could be: 1) redistribution of activities within or between buildings; 2) compression of some functions which no longer require so much space; 3) extension of a facility to reduce the requirement for duplication of essential services and activities; 4) internal modifications to lay out functions in a more efficient working arrangement and thus reduce or obviate the need for additional space.

Are there existing facilities that have space that is surplus to the user's requirements? Are there facilities which are not being used effectively by users? Are functions so badly distributed througout some buildings that circulation problems are created, that space is being wasted by excessive allocations to some functions, or that some space is unusable by virtue of its position or lack of essential utlities? Is there some surplus space that is being closely guarded by users for possible future expansion? Is space being underutilized through the use of inefficient operating procedures? In this case, could a study of the user(s) work methods free space for allocation to other functions which require accommodation?

These are just a sample of the questions that could be asked and researched as part of a long term facilities planning exercise, in the justification phase for the construction of a new building, or when facility modifications or extensions are envisaged. In any event, consideration of all the possible alternative courses of action requires an extensive knowledge of the functions and activities of users, their space requirements, and the facilities which house them. Convenient access to this information in a usable, reliable database should increase the quality of accommodation planning and design decisions.

These principles are not peculiar to the USAF. All organizations must somehow monitor and plan its use of facility space, whether it owns or leases those facilities. Doing more with less is a universal business goal. Keeping down costs is desirable for private businesses as it should result in increased profits. Government organizations, although not profit motivated, have an obligation to taxpayers to get the best possible value for money.

In order to make the most of valuable real estate, to reduce travelling distances (and travelling time) for user's and customers, and to limit the requirement for new construction to that which is essential to support the user's and installation's mission, an organization's existing building space should be utilized as fully as possible. Maximizing the utilization of space in facilities would:

1. minimize the overall requirement for new construction by satisfying a greater number of requirements

from within existing building space, and

2. maximize the value of each dollar spent constructing new facilities, and on modifying those existing.

The Royal Australian Air Force (RAAF), although not possessing facilities on the same scale as the USAF, constructs and operates its own installations. Budget limits similarly constrain the extent of new construction that is desirable. New facilities must be designed and constructed to ensure long-term functionality, and the use of building space must be monitored and managed to ensure that as many requirements as possible can be satisfied from existing assets.

Statement of Problem

It was not assumed, before this study was performed, that the USAF has a problem with facility space utilization. This study aimed to identify and analyze methods which are used by USAF installations (and others which could be used) to layout facility space and to manage its utilization, in order to determine if there is a problem.

This study examines the extent of usage of these methods in Air Force Civil Engineering (AFCE), how appropriate they are, and their general effectiveness. It identifies those factors which constrain planners and designers in their performance of this task, and determines if there is a relationship between the comprehensiveness, accessibility, and accuracy of the available planning data-base and the capacity to maximize the usage of building space.

A secondary purpose of this study is to develop some conclusions and recommendations on space planning and space management methods that can be applied within the RAAF Facilities organization to help alleviate the accommodation shortfalls currently being experienced.

Research Objectives

In order to achieve these goals, the following objectives were used to guide the research:

1. Determine what methods are currently being used by facility planners and architects in AFCE, RAAF, and civilian organizations, to design efficient building layouts and to manage a facility's space throughout its design life;

2. Determine the effectiveness of such methods, and make recommendations to assist AFCE in making the most of its building space resources;

3. Gather perceptions of AFCE facilities design and real property planning personnel on the comprehensiveness, accuracy, and accessibility of the data that is collected to manage the utilization of building space, and determine if there is a relationship between these factors and the effectiveness of their efforts;

4. Determine who actually controls the utilization of building space on USAF installations. What roles do the Base Civil Engineer (BCE) and the Facilities Board (FB) have in this task? Do Unit Commanders manage the use of space within

their own allocated buildings, or is this function also performed centrally to coordinate all base requirements?

5. Determine what constraints there are to the effective management of building space;

6. Construct a list of planning factors involved in the redistribution of building space; and,

7. Determine what effort is actually made to consider the possible reallocation and/or rehabilitation of existing building space as an alternative to new construction.

Scope and Limitations

This study examines the process of interior facilitiy design from the conceptual, architectural layout standpoint. It examines the approaches, some methodical and some seemingly intuitive, taken by planners and architects in deciding how a building should be laid out, and the criteria used to evaluate the efficiency of layouts. It also establishes the types of data available to real property planners and space managers, collection practices being employed, their perceptions of the accuracy of the data, and problems they face when using this data to plan the redistribution of space.

While literature from non-military sources is examined, no attempt has been made to solicit views and practices from civilian organizations, due to the time constraints of this study. The interior design and space management methods of some practicing Architect-Engineer firms are studied, particularly with reference to the use of computer technology and to space studies conducted within Base Comprehensive Planning (BCP) contracts with the Air Force.

The potential for new construction cost savings which could be generated by maximizing space utilization in existing facilities by using layout design and space redistribution methodology is unknown, and this study does not attempt to quantify this. However, it is assumed that if a reduction in gross building floor area were possible using one method over another, then the cost of that facility would decrease somewhat in proportion to the area saved. It is not suggested that expenditure on new facilities could be reduced but rather that more facilities could be constructed for the same budget.

It is also assumed that a more functional, flexible facility design would: 1) enhance mission accomplishment by saving the time and energies of the users; 2) satisfy the mission requirement for a longer time frame; 3) permit easier and lower cost modification to fit a user's changing requirements, or to fit a different set of requirements should the space be reallocated to other users. The long term need for replacement facilities could be minimized by such short term action. This stresses the need for BCP procedures to include space management studies for all existing and proposed facilities.

The Royal Australian Air Force (RAAF) has facilities regulations which infer the need to maximize the usage of existing facility space. Although this study will not extend to the collection of data from RAAF sources, it will examine RAAF real property regulations, common practices of data collection and space allocation (as experienced by the writer), and make recommendations on how the RAAF could benefit by adopting alternative practices.

Background

Space management is a long term function aimed both at keeping all available space occupied, and having the flexibility to reorganize facility layouts and redistribute space in reaction to mission changes, technological developments, and changing accommodation priorities. It entails the development of a comprehensive database to include spaces available within real property assets, functions and personnel accommodated, unsatisfied space requirements, and methodologies and criteria for space allocation.

Space management of facilities on a USAF installation can be viewed from two levels; 1) centralized management of the utilization of all base real property assets by all users, and 2) management of space within a specific facility. Space Planning is a subset of the latter level of Space Management, and can be applied to the layout of a facility once its functions and space needs have been researched and set. Space Management also includes such tasks as allocating existing facilities to specific organizations, allocating areas within a facility to specific users, tracking and co-ordinating the changing usage of areas within a facility, keeping accurate account of personnel and equipment accommodated, and recording or forecasting future requirements for space.

As all these activities are data intensive, the use of computers has made a large contribution to current capabilities and expertise in all areas. Although optimal solutions for facility layout are perhaps not achievable, the development of Computer Aided Architectural Design (CAAD) systems over the past 30 years has greatly enhanced the architect's and facility manager's abilities to generate and evaluate many alternative layouts for a specific problem. This may be required in the initial design process for both design and remodelling projects, or for altering working arrangements to achieve greater efficiency or to accommodate additional personnel and functions.

II. Review of Literature

Chapter Overview

This chapter examines literature dealing with methods and practices used by the USAF, RAAF, academic, and civilian organizations to maximize facility space usage. Two perspectives are taken; first, that high utilization can be 'designed into' a facility (Space Planning), and second, that in order to maintain high utilization data must be acquired and updated and space must be 'managed' (Space Management).

The various USAF regulations and manuals which provide guidance for: 1) the design of facilities, and 2) their long term utilization, are examined first, followed by RAAF regulations and parallel guidelines. Their emphases and inherent problems are highlighted.

Literature which outlines general space management principles will then be reviewed. Space Planning will be introduced and defined. The development of techniques for space planning in facility layout design will be presented at the end of the chapter. The concepts of flexibility and growth, and the development of the Open Planning concept for administrative and production work areas, will also be examined.

Some of the documented USAF space studies which have being carried out, mainly as part of Base Comprehensive Planning (BCP) exercises, will be presented. The role of the

Work Information Management System (WIMS) in facility space management, will be briefly discussed.

Finally, some of the characteristics and capabilities of computer systems currently in use by A-E firms and space planning consultants, other systems and programs developed by organizations and academics, and commercially available space planning software, will be presented.

USAF Regulations

Design Guidelines. The major facility design guidelines stressed by the USAF Force are economy, functionality, flexibility, and standardization.

Economy and Functionality. The need for economy in the construction of new facilities is recognized in Air Force Regulations (AFRs) and Air Force Manuals (AFMs). AFR 88-15, Criteria and Standards for Air Force Construction, states in paragraph 1-15 that:

> A primary objective in military construction is to provide facilities with low construction costs and low maintenance costs consistent with the anticipated duration of the military requirement (14).

However, paragraph 1-5 states that the functions which a new or modified building is intended to accommodate should not be compromised:

> All military facility planning shall employ economical, functional architectural and engineering design, closely tailored to the actual requirements of the project, with particular attention to ... the type and extent of services and equipment to be provided. Designs shall be governed by functional requirements, shall conform to existing Air Force standards and criteria, and shall be

consistent with applicable Congressional cost limitations (14).

These standards and criteria are given in three publications. AFR 88-15, paragraph 1-1, gives the design and construction criteria to be applied to all new construction, reconstruction, rehabilitation, alteration, modification and maintenance and repair of existing facilities (14). AFM 86-2, Standard Facility Requirements, establishes the basic criteria that define the size, type, and number of facilities required for mission support (15). This system provides allowable building spaces for a wide variety of functions and activities. The size of a facility is generally determined by the number of personnel to be accommodated, with some addition for known equipment and production requirements.

Although AFM 86-2 does not outline design methods, it lists in paragraph 1-6 the basic steps in developing facility requirements, one of which is to

> Translate design and planning criteria into design proposals and drawings to determine the needed size, type, and number of facilities and their configuration and functional layout (15).

This study examines methods of both establishing design requirements, and for translating them to functional layouts.

Flexibility. The third major facility design requirement recognized by AFR 88-15, Criteria and Standards for Air Force Construction, is flexibility. Flexibility is defined in paragraph 1-6 as "the ability of an existing structure to accommodate a change in use with minimum expenditure of resources" (15). AFR 88-15 also acknowledges the trend for facilities to accommodate changes in usage throughout their design lives:

> In such a long tenure of use it is inevitable that the functional requirements of a building will change, often drastically. For this reason, flexibility is a major design requirement for all buildings except for those with highly specialized functions which are precluded for economic reasons (15).

AFM 86-2 gives general guidance for the design of office spaces in paragraph 13-4: "In designing administrative facilities open bay design is preferred for economy of construction and flexibility of layout" (15). The concept and design principles of open office planning, and other design and construction techniques for enhancing flexibility, will be reviewed later in this chapter.

Standardization. Standardization of facility design has been an Air Force goal since the early 1950's, when the first Definitive Designs for Air Force Structures was developed by the Air Force using the Department of Defence manual 4270.1. A study by Basham (6) traced the history of this first effort to standardize facility design through to the development and refinement of the AFM 88-2, Air Force Design Manual - Definitive Design of Air Force Structures (13). These designs are in the form of line drawings detailing the gross dimensions, layout, and content of various types of facilities including proposed building materials and construction methods.

The aim of this product was to reduce costs in the building delivery process (6:13). The use of standard designs has not been successful and in the early 1980's AFM 88-2 was removed from distribution pending the resolution of some inherent problems. These problems were "misinterpretation, overbuilding, loss of flexibility, poor communication ability, costs [of production], and the lack of an effective updating and evaluation process" (6:16).

Guidelines for the use of AFM 88-2, in view of design guidelines in other AFMs and AFRs, were confusing. For instance, AFM 88-15 states in paragraph 1-5, that "AFM 88-2 establishes architectural requirements, space allowances, and arrangements" whereas paragraph 1-6 says:

> the architectural design must 1) reflect careful consideration of the type and arrangement of fenestration and entrances, and 2) provide high quality architectural layout and treatment through the expert use of economical basic design concepts (14).

Overbuilding is "the construction of a facility that exceeds the requirements and may mean wasted time, effort, money, and space" (6:18). The average number of different size designs for the standard designs at AFM 88-2 is less than two, and half of them have only one size plan (6:18). Thus, there was no flexibility in determining the size of many facilities if the definitives were used blindly without consideration of AFM 86-2's space allowances.

A small survey of air staff, command, and base level engineers attending AFIT courses showed that all thought that the use of standard designs was mandatory. Two thirds thought that variation was encouraged, and the other one third thought that they were to be used with a minimum amount of variation (6:17). If this perception was in any way indicative of the general impression of AFCE design personnel, then there was a real possibility of overbuilding and space wastage.

In terms of flexibility, the use of hardline drawings in AFM 88-2 implied a fixed spatial arrangement, a solution to a design problem rather than a design guide (6:19). In terms of costs, the document was 400 pages long and design development costs alone amounted to around $6,000 per sheet. Costs for printing, distribution, design updating (as problems became evident), and re-distribution were also high (6:21-22). In view of the other inherent problems, the costs could not be justified.

Real Property Regulations. Paragraph 1-3 of AFM 86-2, Standard Facility Requirements, states two purposes of the facility requirements system:

a. To make maximum use of the existing facilities, and

b. To acquire and maintain, through continuous study of functional requirements, solid justifications for building new facilities and occupying existing facilities (15).

Real Property Management regulations refer specifically to the need for constant monitoring of existing facility usage. AFR 87-2, Use of Real Property Facilities, requires that current and accurate data must be kept by BCEs on accommodation requirements and facility usage, and states in paragraph 2 that "if such data reveal that one or more facilities are not being put to maximum use, a management analysis of the use will be made" (16).

Furthermore, a BCE must make an annual presentation to the Base Facilities Board on facilities usage versus requirements, both satisfied and unsatisfied. He must detail where space shortages and surpluses exist and propose methods of best using the available space (16). This responsibility is extended to Major Commands (MAJCOMs) as well. Paragraph 2 of AFR 87-2 states that MAJCOMs

> should continually validate and evaluate assets and requirement data developed by bases, and ensure maximum effective use of all existing assets, through periodic base facility use surveys or other available means. [They should] make every effort to compress space assigned to activities, to ensure maximum effective use and conformity with criteria in AFM 86-2 (16).

This paragraph also states that all departures from AFM 86-2 allowable space criteria must be approved by either the MAJCOM or Headquarters United States Air Force (HQ USAF).

AFR 87-22, Utilization and Retention of Real Property, paragraph 6, requires that each installation must "develop and maintain a current 5-year plan for the optimum use of all assigned real property" (17). Procedures are also outlined for the reporting of Air Force Real Property which are not and cannot be utilized effectively.

These design and real property regulations all stress the importance of utilizing existing building space effectively, but none deal with practical methods. How does one modify buildings for optimal space usage, compress the space requirements of functions, or reallocate space from one user to another to ensure that the highest priorities are satisfied? These questions will be examined in the succeeding chapters.

The RAAF Facilities Organization

This section describes the structure of the RAAF Facilities organization, regulations governing the management of building space from both the design and real property perspectives, and observed deficiencies in the RAAF's real property data collection practices. Data on RAAF methods for managing the utilization of building space will not be collected and analyzed as part of this study, and the following is submitted as an accurate account of current RAAF practices.

Organizational Overview. Design and construction of all facilities for the Australian Department of Defence (DOD) and all other Federal Government Departments is performed by, or arranged through, the Department of Housing and Construction (DHC). While DOD is responsible for the management of its own facility construction and maintenance programs, all designs for Air Force and Navy facilities (and most major Army facilities) are produced by DHC architects, engineers, and draftsmen, or by consultants contracted to DHC. All facility construction is performed by contractors but the production of plans and specifications, all contract negotiation and administration, and quality assurance, are the responsibility of DHC.

RAAF interests are preserved by the Director General of Facilities - Air Force (DGF-AF) and his staff of RAAF and Public Service engineers and planners. The organization of the Facilities Branch and a summary of the duties and responsibilities of DGF-AF are in Appendix A (3). Within the Department of Defence - Air Force Office (AFO), DGF-AF has a dual responsibility to the Chief of Air Force Development (CAFD) and to the First Assistant Secretary Facilities (FASF). Administratively, the Branch is located within the Facilities Division of the Department of Defence (Central), but physically, within the AFO building area.

The two RAAF Commands, Operational Command (HQOC) and Support Command (HQSC), have small Facilities staffs and most RAAF installations have one or two positions for Facilities Officers. Most Facilities Officers have Bachelor of Engineering (BE) degrees. Their expertise in facility planning, layout, programming, and management is acquired through experience.

Design Guidelines. The RAAF requirements for a new facility or modification to an existing facility which is anticipated to cost in excess of A$ 0.07 m are broadly defined in an Air Force Works Requirement (AFWR). This document is an in-house justification of the need for a new facility or major facility modification, and is usually written by the proposed user or his Command or HQ controlling Directorate. A copy of the AFWR format is in Appendix B.

RAAF regulations are in the form of Defence Instructions (Air Force), or DI(AF)s. DI(AF) AAP 3300.001 is entitled RAAF Facilities Manual (or FACMAN) and contains, amongst other things, all instructions, guidelines and procedures which RAAF facilities personnel must follow in the provision, maintenance, and management of RAAF real property assets (3).

Another publication, the Services Scales and Standards of Accommodation (SSSA), details space entitlements for certain facility types on all DOD military installations (4). Floor areas of community, single person accommodation, military family housing, administrative, and ablution facilities are carefully regulated and space is usually allocated on a troop strength basis. Operational, maintenance, production, and technical workshop areas are not regulated, but such requirements (in the form of an AFWR) must be justified and pass scrutiny by Base Facilities Officers, Command Facilities Officers, DGF-AF staff officers, and the Air Force Requirements Committee (AFRC).

If endorsed by the AFRC, the requirement will be considered by the Air Force Works Priorities Committee (WPC) for inclusion into Air Force submissions for upcoming capital works programs. These submissions are combined with similar submissions from the other Armed Services and DOD organizations and pass before various DOD committees before the actual programs are developed.

Before a programmed works item can be passed to DHC for design, a Functional Design Brief (FDB) must be prepared by DGF-AF staff officers and approved by FASF. It must also be referred to the Department of Finance (DOF) if the initial DGF-AF cost estimate exceeds A$ 0.1 m. The FDB is

> A brief which comprises a detailed statement of the design features, engineering and architectural requirements necessary for DHC to complete design and documentation to the stage of letting contracts for the proposed works (3: Annex A to AFTI(FAC) 8/85).

It "provides DHC with . design concept" and "supplies all the necessary information to DHC to meet the functional requirement as stated in the AFWR" (3: Section 8-4, para 425). A copy of the FDB format, taken from the <u>RAAF Facilities Manual</u> (3), is in Appendix C.

<u>AFWR and FDB Space Controls</u>. Information for mandatory inclusion in the AFWR is listed in the AFWR format in Appendix B. This information includes:

1. activities to be accommodated,
2. the number of personnel to be accommodated,
3. division of personnel between sections,
4. expected duration of requirement,
5. anticipated and/or possible future activities to be accommodated,
6. whether the area entitlements of the SSSA apply, or whether there are overriding reasons why they should be exceeded,

7. existing facilities that are currently being used to accommodate the activities (if applicable), and their deficiencies, and

8. an analysis of alternative ways of satisfying the requirement, including modification to, or extension of, existing buildings (3: Section 8-4, Annexes A and B).

The production, passage of the document through the AFWR approvals process, and ultimate AFRC endorsement is the responsibility of the sponsor (the user's representative at AFO level). However, Facilities officers at all levels act as consultants, providing advice on alternatives, and real property and facilities programming information.

After assessing the true needs of the user in relation to the existing facility resources of the installation, DGF-AF must decide if a new facility is warranted or if building space can be made available, modified, or extended. This process is largely subjective, and depends on the accuracy of the AFWR's research, the experience of the DGF-AF Plans section staff, communications with Command, base and regional DHC personnel, and their personal familiarity with the Base's existing facilities and operations. The desires of the user, base management, and specialist officers at Command and AFO levels, can also introduce political factors which can influence the scope of work and whether existing space (if available) is modified or a new facility is constructed.

The FDB is currently written by the DGF-AF staff officer responsible for facility development at that base, although consideration has been given for some time to the delegation of some of this responsibility to Command Facilities Officers. The Staff Officer will usually have been involved with all aspects of the proposal from its inception, and will be reasonably familiar with the base. The information he must supply on the FDB includes:

1. approved activities, in the form of a room-by-room list,

2. personnel numbers for each room, and whether they occupy that room on a permanent or temporary basis,

3. whether future extension is envisaged (the same Officer is usually responsible for Master Planning of that base's long term facility requirements),

4. whether permanent or temporary, pre-fabricated and/or modular construction is required,

5. a Functional Relationship Diagram detailing the interrelationships of all activities and key personnel, and

6. any special criteria which should be used to evaluate alternative floor layouts, such as the number of visitors expected, foyer requirements, minimum corridor widths, and any restrictions on access to certain parts of the facility (3: Section 8-4, Annex E).

Functional Relationship diagrams provide a description of the interplay of activities within a facility, and is vital to acquaint DHC architects with the operations of the user. This technique will be described in more detail later in this chapter. A standard clause in all FDBs is:

> The final design must take best advantage of the site and incorporate all economies possible with regard to floor area and construction, yet still retain the necessary functional requirements and work flow pattern (3: Section 8-4,Annex E).

DHC has its own comprehensive design guidelines. Minimization of construction costs and underutilized space for all Federal Government buildings are also its stated objectives.

Real Property Regulations. DGF-AF is responsible for the approval of any changes in the functional usage of facilities, subject to agreement by the specialist AFO Directorate overseeing the operations accommodated by the facilities in question (3: Section 5-9, para 906). Each RAAF installation has a Facility Usage Schedule which is a one line summary of each facility's user, broad usage, RAAF building number, and DHC building number. An annual update of this document is required.

The Property Assets Register (PAR) for each installation holds the building data for all facilities. In many cases, this data is the only building data held by the RAAF on a facility. It includes details on the gross floor area, number of rooms, construction materials, internal engineering services, fixtures and fittings, and items of fixed electrical and mechanical plant. DGF-AF is currently attempting to have final design drawings for new facilities transferred to microfiche once construction of the facility is complete. The backlog of plans yet to be processed by the responsible Government agency is enormous, and hardcopy storage room in the DGF-AF offices has been exceeded, resulting in loss or forced disposal.

The RAAF holds no engineering services or floorplan drawings for the majority of its existing facilities.

Hardcopy, full size drawings are sometimes available from DHC on request, but DHC does not make a practice of securing 'as-built' drawings from construction contractors nor do they update drawings when minor modifications are carried out later in the life of a facility.

Successful management of the space within facilities and throughout an installation is difficult when so little data is available on existing building layouts, and when the decisions on how to satisfy requirements are made remote from the base. Base Facilities Boards are a relatively recent phenomena on most RAAF bases. Historically, once a building is allocated to a user (with the approval of DGF-AF), that user arranges the usage of that facility to fit his particular requirements.

Space utilization studies are usually undertaken only if their is a perceived space deficiency due to increased mission requirements, modified maintenance responsibilities and/or procedures, or equipment acquisition or updating. DHC or consultant architects have never, to the writer's knowledge, been engaged specifically to study the utilization of space in an existing facility or group of facilities.

Such a study may be done as part of an AFWR justification for new works, but this is usually done by the facility user. A bias towards new construction is usual by users, and DGF-AF is responsible for establishing the authenticity of the claimed space deficiencies and suggesting alternative courses of action, before the AFWR is examined by the approving authority. If the deficiency is acknowledged and a project approved, DGF-AF will decide the best course of action after DHC and design consultant advice (if necessary) has been evaluated.

While base Master Planning is a coordinated effort by RAAF and DHC personnel, data input on available existing building space to satisfy additional long-term requirements is largely a function of the planners' familiarity with base facilities. Two exceptions of note are single living-in accommodation and military family housing requirements, for which excesses and shortages can be estimated with reasonable accuracy from base personnel records and on-base living accommodation records.

Comparison of USAF and RAAF Guidelines

The emphases in USAF facility design guidelines are: 1) support for mission accomplishment by ensuring the functionality of facilities, 2) costs, and 3) minimizing the size of facilities by placing maximum limits on activity spaces. The emphases in real property guidelines are: 1) accounting for Air Force assets, and 2) maximizing the use of facility space. The regulations provide guidelines for the design of Air Force facilities and define the documentation requirements for monitoring the usage of facilities but they do not detail methods of designing facility layouts or establish how the real property data should be used to manage space.

While RAAF facility design guidelines stress similar objectives, they also mandate methodical layout planning to ensure that the interrelationships of activities to be housed by a facility are considered. USAF action to introduce similar requirements into the AFM 88-2, Air Force Design Manual-Definitive Design of Air Force Structures, will be outlined in Chapter 3.

RAAF real property accounting does not provide decision makers with sufficient data to adequately plan facility needs or to evaluate facility proposals. Records are entirely manual and are updated infrequently. Drawings for newly constructed facilities are available but overload problems are preventing their accessibility by Facilities Officers when required. Accurate drawings for most existing facilities are not, for practical purposes, available. Assistance is usually sought from DHC architects and engineers to provide data and drawings for existing facilities and engineering services, and to produce costs for several alternative courses of action. In many situations more accurate indicative costs, for the purposes of comparing alternatives and developing facilities programs, could be established by Facilities Officers if accurate drawings of facilities and engineering services were available.

Facilities Space Management Literature

The available literature dealing with the tracking of activities and allocated space within real property facilities, managing its usage, and improving its utilization, deals exclusively with the use of computerized Database Management Systems (DBMS) and 'spreadsheet' software. As is presented later in this chapter, many computer systems interface DBMS and spreadsheets directly with floor plan layout programs. In many cases, area take-offs to the database and spreadsheet are made automatically when any changes are made to final floor plan layout drawings.

Although such space management systems can be used effectively to store information and report usage in whatever format is desired by the designer or client, the effective utilization of space within individual rooms and open plan areas requires much hand collection and subjective analysis of data to determine work flows, workstation and equipment area needs, privacy requirements, and utility requirements, in order to determine activity space needs.

In order to manage facility space, there must be a clear definition by the user (or client) of the activities to be accommodated, the work processes to be performed, the relationships between each pair of activities and between each pair of discernable activity groups, and the areas required for each activity. For a new facility, this definition and analysis of needs must be accomplished before the facility is designed, to provide design criteria to architects and planners. For an existing facility, these needs and relationships must be re-assessed prior to any remodelling design. Moreover, in order to effectively manage the facility's space throughout its design life, these needs and relationships should be re-assessed on a regular basis in order to identify space surpluses, deficiencies, or inefficient layout of activities or workstations.

As organizational roles and missions (in the military sense) change with time, so do the needs for certain activities and the space required to perform those activities. How often is a user's utilization of a facility re-assessed (either by the user or by the BCE)? If the answer is never, or even seldom, then it is highly likely that the facility does not properly fulfil that user's needs.

Identification of this 'gap' could be followed by a planning exercise to generate alternative reorganization or remodelling layouts. If functionality is of prime concern then possibly the best solution, based on proximity relationships between activities, would be chosen even if the cost is high. If cost is of prime concern then the exercise would still be worthwhile.

As is discussed later in the facility layout design methods section of this chapter, most space planning computer software incorporates the capability to fix certain spaces in the layout for certain activities. If some activities would be too costly to relocate within a facility due to special environmental control requirements, floor load capacity, special lighting, or essential proximity to utilities or external access points, then they can be fixed and only the other spaces and activities be re-assessed. If the building construction is inflexible (eg; if walls are load bearing and not easily removable, ceiling and roof levels are staggered), then these factors should also be incorporated to find the most practical and acceptable solution to the space problem.

Such a planning exercise could also be the starting point for the justification of a new facility, or a facility extension or major modification. Should part or all of a facility be vacated, due to its inability to support the organization's current mission, then this process of assessing space needs, as well as layout planning, would be required for potential new users of that space. If a number of space requirements exist on the installation, and one or more must be selected to occupy the space, then this selection should be methodical. The following criteria could be used for selection:

1. Highest priority, in terms of mission essentiality and/or necessity to meet time constraints over which the installation has little or no control (system acquisition, for example).

2. Area required. If a high priority requirement would either not fit into the space available or would leave excessive space over, then a lower priority requirement may be preferred.

3. Suitability of type of construction with regard to the type of work to be carried out inside the facility. For example, electro-magnetic screening, floor loading capacities, physical security and fire requirements.

4. Suitability of facility location with respect to other on-base facilities, especially those operated by the same user, airfield pavements, and major support facilities.

5. Commonality of work-type with other building users, and the ability of all users to co-exist without the loss of efficiency or the disruption of operations.

6. Cost of remodelling or modifications necessary to make the facility comply with functional requirements.

Determination of Space Needs. Pulgram and Stonis, in Designing the Automated Office: A Guide for Architects, Interior Designers, Space Planners, and Facility Managers (47), recommend a four-phase process for determining the spatial needs of an office-type facility. The process can equally be applied to most facility types, and comprises 1) data collection, 2) analysis and synthesis of collected data, 3) definition of hard criteria, and 4) preliminary and final reporting. Each phase will be discussed.

Phase I - Data Collection. Information on work procedures, workstation requirements, personnel job descriptions, activity dependencies, existing facility inadequacies and deficiencies, functional descriptions, personnel numbers, equipment types and quantities, storage requirements, and utility requirements, must all be obtained.

There are usually three types of information source; facility users, specialists such as management consultants and/or facility managers, and the organization's management

(47:22). There are four primary techniques available to collect this data; observation, questionnaires, interviews, and applied experience and research (47:23). Most readers will be familiar with the first three techniques. Research includes extraction of relevant data from organizational records, standard operating procedures, regulations, and work standards.

The information must include individual task demands, group task demands, and organizational task demands. This information

> forms the nucleus of the organizational structure. It provides the basis for understanding equipment needs, for developing space layouts patterned around functional relationships, for designing appropriately furnished workstations, and for providing sufficient building systems support (47:24).

<u>Phase II - Analysis and Synthesis of Collected Data</u>. This involves "identifying patterns and clusters of similar requirements around which standards or conclusions can be developed" (47:27). Previously collected data is disassembled, patterns found, relationships identified, and design direction and standards formulated. Synthesis entails assembling the data pertinent to the tasks (such as specific design criteria) that will guide the generation of design alternatives and permit their evaluation, as well as enable space standards to be established based on known and anticipated requirements (47:27).

The 'data bank' can be broken into 10 categories (47:27-38), as follows:

1. Functional Unit Profiles. What will they be doing? How will they operate? Which will be most heavily affected by anticipated changes?

2. Personnel listings and ancillary support spaces, such as rest rooms, conference rooms, and stationery storage.

3. Growth projections for personnel numbers and ancillary functions. In particular, areas where there is heavy growth, extensive storage requirements, and extensive conference and briefing requirements, should be noted.

4. Ancillary functions that support group and organizational tasks, such as libraries, computer rooms, canteens, reproduction, central typist word-processing pools.

5. Technological requirements including equipment: sizes, combinations, shared usage, quantities, special location criteria such as external building access, venting, utility, and environmental controls.

6. Base building requirements - the type and character of the space to be occupied. Will it be rehabilitated existing space, some hypothetical office space (facility yet to be nominated), or a new facility? Architectural features, building systems, and optimal interior zoning data, should also be identified to set constraints on the design. The need for subsequent flexibility should be defined: How often do functions change? How often do equipment, workstation configurations, and personnel allocations change? What is the population density, or space allowance range per person?

7. Communications. How does paperwork and material flow? Which activities and staff have heavy personal or telephone contact, write to each other extensively, develop plans and policies together, perform similar tasks, or perform tasks requiring co-ordination? Who has heavy storage requirements and/or a need for frequent access to storage areas?

8. Adjacency requirements. This type of data is synthesized from all data types mentioned above, and refers to the perceived need for any two activities to be located next to each other. Adjacencies can be determined by volume of material passing between activities, the need for extensive communication or coordination between activities, minimization of total daily travel time or walking distance between activities. It could also be determined by technical requirements, such as the need to minimize utility runs from central building utility cores in order to minimize costs, or by noise dampening requirements such as the need to separate classroom areas from plant rooms and heavy workshop areas.

9. Special requirements such as lighting, power, acoustics, plumbing, excessive floor loading, security, abnormal working hours, windowless space, HVAC, audio-visual, computer terminals.

10. Space standards for entire facilities and/or individual activities. These may have already been determined by the organization or left open, to be dictated by the particular need and justification. Space standards may exist for:

a. Tasks (per person, or per group) such as writing, conferencing, filing, storage, telephone usage, production workstations, reproduction, word processing, typewriter, computer terminal.

b. Individual offices, multiple occupancy offices, open plan offices, and workshops. Personnel may be allocated a type of office or workstation based on their organizational status or level, their trade or profession, or the kind of work performed.

c. Access requirements to work areas (circulation space, hallways), expressed as a width or as a percentage of total gross or net floor area.

d. Mechanical and electrical plant space. If the design requirements are not known, then a percentage of the gross or net floor area may be applicable.

e. Buffer space for unknown future space requirements, or for future layout flexibility if relationships change or functions are redistributed.

f. Qualitative requirements such as access to window views, space for plants, wall hangings, visitor comfort, and aesthetics.

g. Staff facilities such as canteens and rest rooms. If such standards do not exist, they should be created at this point in order to make future space management workable.

Phase III - Definition of Hard Criteria. Pulgram and Stonis explain this phase as "Obtain owner review comments, add circulation and layout factors, tabulate quantities, and summarize the qualitative program" (47:38). This phase comprises (47:44):

1. Finalization of space standards,

2. Personnel tabulation,

3. Space requirements tabulation,

4. Tabulation of area calculations, and addition of circulation and layout factors, expressed as percentages of the total tabulated area.

5. Tabulation of total square footages by functional unit for personnel, storage, and other requirements.

6. Tabulation of total square footage for special areas.

7. Summary of grand total square footage.

8. Summary of qualitative requirements.

9. Summary of adjacency diagrams.

Phase IV - Preliminary and Final Reporting.

Although this phase is critical in commercial practice for presentation of findings and recommendations to the client, it is not always as essential a requirement for USAF in-house facility design and space management tasks. It would, however, be required of a management consultant or Architect/Engineer (A-E) firm if contracted by the Government to provide a space needs analysis, base comprehensive planning, or design service where user requirements had not been formulated.

The final report should be similar to the preliminary, but would incorporate client review comments and amendments. It would outline all tabulations from the previous phase, and include: the terms of reference for the study; the methodology; the adjacency diagrams; quantitative and descriptive information about functional, personnel, and equipment projections; the need for flexibility of design and buffer space; maybe an initial possible block floor plan layout; and recommendations such as restrictions on area shapes, and space quality.

Models for Determining Space Needs. In Computer-Aided Architectural Design (39), Mitchell examines methods of analyzing quantitative data on space needs to determine relationships and area requirements for activities. He states that

> Computer-based techniques are beginning to revolutionize this phase of design, since they make possible the efficient manipulation of large volumes of data, and the performance of much more extensive and sophisticated analyses than had been possible in the past (39:399).

Methods reviewed are simple empirical methods, timetable models, queuing models, simulation models, and normalization of space needs. Mitchell cautions the use of computers in this task, in that they

> tend to require a great deal of accurate and detailed input data, which is rarely readily available, and which may be difficult and expensive to collect. Furthermore, the modelling effort itself is quite a lengthy and expensive process (39:410).

Empirical Models. These models are simple heuristic formulae produced through experience. Mitchell gives the example of such a formula for determining the number of seats in a lecture hall as a function of the average number of hours of teaching per student per week, a frequency factor, an occupancy factor, and the length of teaching week (39:399). The area of the hall would then be based on the number of seats required.

Mitchell cites an example of the application of empirical models in generating lists of spaces to be provided in generic facility types, based on the number of occupants.

His main criticism is that mistakes of the past will be carried forward into the future, as this method takes no notice of changes in policy. Also, it "provides no firm basis for optimization of space usage, or for examining the sensitivity of space and facility needs to variations in activity patterns and space use policy" (39:400).

Timetable Models. Timetable models are used widely for assessing the classroom requirements of educational facilities. They involve examining the number of students enrolled in each course and the schedule of classes for each course, to determine the number of rooms of different sizes that would be required to accommodate all classes. It is used not only in facility design but in timetable formulation to ensure that class scheduling does not exceed the capacity of classroom space available.

Queuing Models. Where customer service is of great importance in facility design, for example in supermarkets, cafeterias, and department stores, queuing models can be useful in determining minimum space needs for projected customer numbers, available staff numbers, and desirable maximum customer waiting times.

Simulation Models. Simulation can be used to assess space needs in customer service facilities where the movement of personnel through a facility is more complex, and where servicing is in multiple phases. Most simulation of this kind is concerned with input and output to spaces in the system, such as arrivals and departures of people, but not with the details of individual behavior within spaces (39:405). Computer simulation programs have been written to simulate traffic flow through multi-story vehicle parking stations, cafeterias, and air terminals, as well as for the flow of goods and personnel through warehouses and production facilities (39:405).

Normalization of Identified Space Needs. Once the required activities and their areas are known, there may be cases where it would be more cost effective (for both initial construction and remodelling situations) to consider having a limited range of standard shape and size modules to choose from. For example, take the construction of modular buildings, where room areas must be in multiples of standard sized modules - say 8 feet square, or 64 square feet (SF). Economies of scale may be possible by constructing a large number of a few different size spaces than a vast array of different sizes to exactly meet the identified space requirements. Construction costs might be minimized by constructing 10 spaces, each of area 192 SF, rather than 8 spaces of 192 SF and 2 of 128 SF. A simple problem of this nature could be solved by hand.

If many different standard size modules were available and many activities with differing space requirements must be accommodated, the optimum selection of sizes and quantities to minimize costs requires the application of dynamic programming techniques, which are best handled by computer (39:407-409).

Space Planning - Facility Layout Design

The concept of space planning and some basic principles will now be examined. Literature dealing with both manual and computer aided methods of floor plan layout is discussed in depth towards the end of this chapter.

Whether the internal space of a building is laid out by hand, or with the aid of a computer, the architectural principles used to compile and evaluate the alternative arrangements are similar. In order to effectively utilize the computer to: 1) process the designer's input, 2) produce a layout, and 3) evaluate it in terms of performance against specified criteria, the required procedures are algorithmic, highly mathematical, and commonly consist of complex manipulations of matrices.

Definitions. According to Grant, in A Partially Annotated Bibliography on Space Planning Methods for Architects and Space Planners, space planning is "the placement of elements being designed or planned in a given space or environment" (26:2). He gives a more narrow, but incomplete, definition as "the complete filling of a space by the elements being designed, as in the filling of a hospital floor, with no floor space left unoccupied" (26:2).

Eastman, in Automated Space Planning and Theory and Design: A Review, defines space planning as "the arrangement of a set of elements, where distances, adjacencies and other functions of the arrangement are objective" (21:2).

Friedmann et al, in Interior Design: An Introduction to Architectural Interiors, defines a space planner as one concerned with "the analysis of spatial requirements, the programming of needs for clients, the preliminary space layouts, and ultimately the final planning" (24:476).

Space planning is as much a part of the design of modifications and renovations of existing facilities as it is a part of the initial facility design process. When a facility is being designed, space needs of the users and activities are gathered and analyzed in order to provide a structure which meets the functional requirements. When planning an internal modification where the available overall area is considered adequate but in need of rearrangement to accommodate new or changed activities, spaces have to be placed within a given area. In such cases space planning is referred to by some authors as 'space-filling'. Miller, in Computer Aided Space Planning: An Introduction, defines it as "the act of positioning a set of elements in some predefined space such that they satisfy a given set of constraints" (38:6). Grason, in A Dual Linear Graph Representation for Space-Filling Location Problems of the Floor Plan Type, defines space-filling location problems as

> the placement of a set of subspaces in a particular larger space, subject both to a class of location requirements and to the constraint that the subspaces must entirely fill the larger space (27, in 36:170).

Grant states that in all space planning definitions,

> the emphasis is on the placement of elements with regard to relational-proximity criteria; that is, the relations among the elements being placed, in terms of adjacency, contiguousness, distances apart, and the consequent costs or utility in terms of total traffic distances or conflicts (26:2).

Space planning in architecture refers both to the selection of sites for individual facilities (location planning) and to the location of individual activities within a single facility (layout planning). Facility location planning is practiced by city and town planners, master planners, and base comprehensive planners and is not dealt with in by this research. Facility layout planning is practiced mainly by architects, facility managers, and real property managers, and is the subject here. Techniques for layout design are examined after the following review of literature dealing with AFCE practices.

<u>USAF Methods for Facility Space Planning and Management</u>.

The only literature available to the author that deals with specific USAF space management or space planning exercises are documentation of a get-well program run in HQ USAFE in the 1970's, recent Base Comprehensive Planning studies, and some planning criteria statements. The two latter address the long term effective utilization of an installation's facilities and have endeavored to consolidate existing space, establish planning criteria and philosophies for the orderly development of future facilities, and to establish current deficiencies and expected future space requirements. Some have also established which existing base facilities should be renovated or modified and the functions for which they should be used.

No literature could be found which dealt with the use of space planning principles, methods, or techniques by AFCE when designing or modifying facilities.

<u>HQ USAFE</u> HQ USAFE identified several problems with space utilization in facilities on bases within its command in the early 1970's. With 31 major air bases or air stations and 480 supporting installations including communications, housing, and ammunition storage sites, control of an increasing inventory of facilities had become thin. General David C. Jones wrote, in a letter to Wing and Base Commanders in March 1972:

> Inadequate control of facility use has become a matter of increasing concern to me. Actual use of facilities often differs from reported use. Existing requirements regarding approval and documentation of canges in use are ignored. As a consequence, our total facility programming effort continues to be adversely affected by unreliable source data. ... Facility use should remain as stable as possible consistent with your mission. Arbitrary changes must be avoided. Any proposed changes in use must be supported by your civil engineer's facility use study. Required approvals must be obtained before the changes are made. The objective is maximum effective use of all existing facilities under your control (29:1).

A Facility Use Study was undertaken in 1972

> to implement a command-wide program with the objective of insuring maximum effective use of all existing real property facilities under USAFE jurisdiction, control, and accountability (29:1).

A Facility Use Team was formed and tasked to visit major USAFE installations to (1:2-3):

1. develop space requirements based on an installation's mission and standard facility criteria;
2. validate the base real property survey, and find out what facilities were actually being used for;
3. compare known requirements against existing assets, by category code; and to
4. initiate change in use requests, approve or disapprove, initiate disposal action where required.

The team noted that in many cases the base's mission was not clearly defined, and thus facility requirements had not been accurately assessed. Also, it found that space management on bases tended to be left to one individual in the BCE organization with no support for his activities from the BCE, the FB, or Commanders. Finally, it judged that the FB was not acting as a corporate decision-making body on space use, and that decisions were largely oriented to changing operational requirements rather than to a base program or objective.

The team was disbanded in the mid-1970's due to a lack of funding and manpower. The Planning Assistance Teams which were set up in the early 1980's to assist bases in comprehensive planning of base layouts took over this role of overseeing base facility utilization. However, this was done as a once only project for input to the Base Comprehensive Plan rather than as an on-going program. USAFE's current stated methodolgy for achieving maximum effective use of its facility space is in Appendix J.

Space Management in USAF Base Comprehensive Planning. The USAF Base Comprehensive Planning (BCP) process is used to plan for the future of USAF installations (9:586). Clark, in his article "Base Comprehensive Planning: Leading the Air Force into the 21st Century," states that Air Force Engineering and Services has the responsibility of stewardship for the real property assets entrusted to the Air Force by the American taxpayer (9:586). This involves

> the economical and environmentally sensitive care and maintenance of 11 million acres of land and all the facilities and systems that we build on it. These include 66,000 buildings .... (9:586).

BCPs are carried out under HQ USAF funded contracts by A-E firms. Phase 1 of the process involves the

> identification of where we want to go (what are the future goals and objectives for developing the base as a community?), what we have now (an inventory), and what the current deficiencies are (9:587).

As part of this phase A-E firms have produced, with the aid of BCE staff and facility users, complete inventories of space usage for all buildings on an installation. Such studies may be all inclusive, or divided into functionally discrete base areas each having its own Master Plan. Studies undertaken at Scott AFB, Illinois, and the United States Air Force Academy in Colorado Springs, Colorado, are discussed as examples of each type.

The BCP for Scott AFB, conducted by Harland Bartholomew and Associates, Inc. from St. Louis, included a Space Requirements Study for all categories of building space. The scope of the Administrative Space Requirements Study was

> to determine how much administrative space will be required to accommodate each organization or unit, and where that space should be located to carry out mission and functional requirements (5:1).

The report tabulates all existing space quantitatively according to building number and user organization, giving category and condition codes. It tabulates, on the same table, the future space requirements anticipated by organizations as a function of personnel numbers, an allowance of 135 SF per person gross building area, and individually listed special purpose areas covering such things as EDP, drafting, reception, and contractor space.

Requirements were gathered from users by survey of unit and squadron commanders. The survey requested information about each unit's mission, organizational and functional relationships, number of authorized administrative personnel, contractor and special purpose space requirements, and space deficiencies (5:2-12). Serious deficiencies were noted, and much of the existing space assessed as unsuitable for renovation or continued long-term use.

The study was able to identify the amount of new construction required, those existing inadequate facilities which could be renovated, and non-administrative space which could be converted for administrative use. These recommendations became part of the BCP. A sample of the final tabulations, functional relationship diagrams, and user survey, are in Appendix D.

At the United States Air Force Academy, Master Plans were created for each discrete area, and space requirements studies were conducted simultaneously for all space types within an area. Skidmore, Owings, and Merrill (SOM), a large nation wide A-E firm, was engaged. In preparing the Community Center Master Plan, a two-phase assessment of the existing facility conditions was undertaken. An inventory of all usable spaces including physical dimensions, broken down by user and space type, was performed and existing building layout plans were generated by computer. Then the functional and operational characteristics of all departments and programs using the facilities were determined (50:A-0).

The first phase required visiting each room in every building and recording dimensions, user, space type, and function, then comparing these records with as-built drawings held by the BCE. The second phase consisted of interviewing users to assess missions, goals, and functional relationships within and between organizations. Deficiencies were not recorded unless "they impacted the Master Planning effort" (50:A-7).

The Cadet Area Master Plan study dealt similarly with the identification of all spaces, their users, their suitability for conversion for other functions in terms of their condition and location within the area, and with the identification of deficiencies. Out of 11 area types including classroom, lecture, laboratory, office, dining, and housing, only dining was found to have no deficit in space. The total space deficit was about 15 per cent of the existing space available.

Recommendations were made, as a result of computer intensive space planning studies, on the short and long term requirements for new construction and conversion, and relocation of functions. Due to limitations of available land, development of site was to be minimized. This meant that maximizing the utilization of existing facilities was a goal of the study. The study states:

> By surveying each of [the] Academy programs, an operational base of information was established to determine present facility utilization and to understand the characteristics which may direct future utilization. Decisions to consolidate, reassign, or build additional space are based on an assessment of the use and magnitude of existing facilities (49:11).

Facility Design Criteria in Base Comprehensive Planning. Brooks AFB has identified design and planning criteria for the long term requirements of its research and development (R&D) facilities. In a report entitled Advanced Air Base Planning Prototype, Brooks AFB, San Antonio Texas, it was recognized that the base's program requirements exceeded both the capacity and adaptability of its R&D facilities. The report stated,

As projects begin and end, processes and thus facility support systems, spacial configurations, and environmental controls can change. For this reason, state-of-the-art facilities are designed to accommodate change. Three criteria for R&D facilities should be applied to Brooks AFB:
- Flexibility
- Adaptability
- Maintainability (28:3.15).

It further developed the following planning considerations to implement these criteria (28:3.15-3.16):

1. a modular approach to space planning;

2. zoning areas as wet/dry - keep offices out of wet areas;

3. place all mechanical equipment at ground level to enhance accessibility for maintenance and to reduce vibrations and loads on structures;

4. place people-oriented spaces on the outer edges of buildings to maximize the use of daylight;

5. use movable equipment and partitions;

6. use materials that provide for low maintenance and longevity; and

7. select systems that permit these facilities criteria to work.

Such definition of criteria and planning guidelines give the architectural development of an installation direction, and forces building designers, real property space managers, and facility managers to monitor and plan the use of each facility's space.

1 Lt J.P. Mitnik, in Computer-Aided System Needs for the Technical Design Section of the Base Level Civil Engineering Squadron, surveyed commissioned officers in BCE design sections on a variety of issues relating to their duties (40). Of the 306 design personnel surveyed using a random

sampling technique, 65 were architects. The entire sample was asked to rank a list of design activities in order of time spent accomplishing them. Of the architects, 20 reported thet they spent more time in architectural layout (eg; space layout, circulation, flow, functionality, bubble diagrams, user needs) than anyother technical activity, and 22 spent more time allocating space, computing square footages, determining requirements and space utilization than any other technical activity (40:5.8).

<u>Computers in AFCE Space Planning and Management</u>

The WIMS system is an integrated computer Decision Support System whose objective is

> to provide Air Force Civil Engineering at all levels with data automation tools and equipment that are easy to use, flexible, accessible, and operable by Civil Engineering personnel and responsive to management and mission requirements (10:3).

WIMS will eventually be implemented in throughout the AFCE organization worldwide. The intent is to give "key managers the ability to fully automate--in the form they choose--the data required to do their jobs" (10:2). Data input and program execution is performed interactively at individual mini-computer terminals.

Real Property records are integrated with the Long-range Planning module, one of 14 modules contained within the system. The real property personnel have at their disposal a customized database of facility areas, with category codes, condition, user organizations, and functional activities.

Data will be transferred into the WIMS databases direct from the Base Civil Engineer Automated Management System (BEAMS).

The accessibility of building information, building usage data, ease of use, and ease of updating records, are all greatly improved from BEAMS. An added feature is that the database files can be modified to include additional fields and to produce output in whatever format is required (10:4). With WIMS real property data can be accessed quickly and directly by designers and real property space managers at their desks, without the need for generating and searching through hardcopy reports.

The WIMS also has the capability of running 'canned' software and high-level programming languages. WANG, who manufacture all of the WIMS hardware, has produced a special adaptation of AutoCAD which will run on the hardware as a stand alone package without interfacing with WIMS. AutoCAD is perhaps the most extensive, versatile, and popular Computer Aided Design (CAD) software packages available. It has a space planning capability, with 'blocking' and 'stacking' features only usually found on more sophisticated space planning programs, to improve layouts of activities on one or more vertical levels. WIMS can be configured with high resolution graphics to support CAD.

With its integrated databases, wide accessibility, ease of use, and the WANG AutoCAD option, both space management and space planning by BCE real property and design personnel respectively, will be aided.

Mitnik's study (40) asked BCE design personnel if they had any CAD experience, and what would they use CAD for if they had access to it in the workplace. From the sample of 306 designers, 40 had used CAD, a further 19 had used computers for data analysis, and 15 more had some computer language experience but had not used computers in design or analysis. Generalizing this data to the entire population of BCE designers, a surprisingly small proportion (approximately 24 percent) have had computer exposure. This is especially surprising as 61 percent were Lieutenants, 60 percent had been commissioned for less than four years, and for 55 percent their current assignment was their first as a commissioned officer (40:4.4).

Desirable uses for CAD were solicited by an open-ended question. The most relevent responses to this author's study are in Table I below. Respondents were free to include as many uses as they wished.

Although this data is aggregated for all designers and not just architects, it does indicate that there is some interest in achieving better design and having better access to accurate building data for design purposes. However, these levels of interest (4.9 and 3.9 percent respectively) were no greater than the percentage of designers who felt that CAD was not warranted for thier purposes (4.9 percent).

Perhaps, as WIMS implementation introduces more design personnel to the computer, designers may discover the possible applications of CAD to architectural design in AFCE.

Table I.

Possible Uses for CAD in a BCE Technical Design Section - Survey by Mitnik, 1986

Response	Number	% of sample
Alternative/detailed design analysis	54	17.6
Calculations	53	17.3
Decrease drafting time	52	17.0
Update as-builts (better)	47	15.4
Modify drawings quicker	43	14.1
Reduce design time (quality)	31	10.1
Concept/schematic	16	5.2
Better design	15	4.9
CAD not warranted	15	4.9
Intelligent/accessible database	12	3.9

Facility Layout Planning Techniques

This section is an in-depth review of space planning methods and techniques involving some technical discussion. It may be of particular interest to architects and other personnel involved in interior facility design.

Grant states that most traditional facility layout methods are "implicit or intuitive, based on education, experience, sensitivity, and taste" (26:4). When pressed for reasons for favoring one alternative layout to another, or for reasons for making specific room adjacency decisions, designers who use intuitive methods have usually either admitted to basing their decision on one criterion to the exclusion of all others, or have declared that a more systematic approach would threaten their creative potential (26:5).

Systematic methods have been developing since the early 1960's (26:5). Reasons for favoring systematic methods have been proposed by many authors, and include:

1. It enhances communication of ideas between members of design teams, and between designers and the potential users of the facility (26:5);

2. It enhances the teaching of design and planning (26:5);

3. It encourages or enforces thoroughness (21); and

4. It allows the average designer to emulate the successful efforts of the ingenious (26:5);

5. It makes design decisions more understandable, recordable, and retraceable (21).

Grant feels that perhaps professional accountability and objective analysis are the primary reasons for space planning methods to be systematic:

> The nature of design itself - an activity aiming at altering a situation to bring it closer to somebody's image of what ought to be - makes it incumbent on he who exercises delegated authority, as does the architect and planner, to always stand prepared to explain and justify the basis of his decisions. If his decisions are based only on unexplained intuitive or implicit processes, it is difficult to defend them or even explain them on any basis other than experience, genius, or a plea of 'trust me, I know the way'. If decisions are systematized and

explicitly described, the decisions may not be better, but at least they are open to argumentation and analysis (26:6).

For these reasons, the development of systematic methods has been slow and resisted by the profession in general, as most cling to intuitive methods for fear that individual creativity will otherwise be eliminated from design (26:7).

Lee, in his book Computer Aided Space Planning, analyzes the steps that most architect/planners take intuitively when designing space layouts. They are as follows:

1. Identifies each element involved and defines the relationships between each pair of elements.

2. Establishes for each element the required area, and any specific configurations desired.

3. Diagrams element relationships by relating various elements to each other graphically as bubble diagrams.

4. Transforms bubble diagrams into a *space relationship* layout by incorporating the area required for each element. The layout becomes a scaled drawing.

5. Evaluates alternative arrangements according to program constraints, such as functional requirements, project budget and aesthetic consideration (33:19).

Bubble diagrams will be further discussed later in this chapter.

Steadman, in Architectural Morphology (54), divides all systematic methods broadly into two groups, heuristic and exhaustive. A heuristic method might be intended to generate just one, or a few plans, in which certain stated requirements of adjacency between rooms, and perhaps also constraints on the dimensions and shapes of rooms, are optimally satisfied. Exhaustive methods are designed to produce all possible plans conforming to the given requirements. Heuristic methods can be employed both by hand and by use of computers but have a serious drawback. These methods commonly attempt to optimize the plan by applying one evaluative criterion alone - that of circulation. No other planning criteria such as aesthetics, structure (the skeleton of the building), heating, and lighting, are considered. Steadman describes the process:

> For every pair of rooms or 'zones' in the building, a figure would be worked out - perhaps derived from surveys - for the typical frequency of journeys made between those rooms per day or per week. In any actual layout, this figure could be multiplied by the distance separating the rooms in question. Then the total of all such products could be summed for all pairs of rooms. These design methods were intended to find arrangements in which this sum was minimized (54:141).

Exhaustive methods are better handled by computers. Neither the computer program nor the technique itself exercises a choice, beyond the constraints initially fixed by the designer:

> The architect [or designer] is presented with the entire set of feasible alternatives under the specified definition, and can then apply further criteria of his own for selection within this range. Or else he can, as a result of seeing the possibilities, go back and change the initial constraints so as to generate some different set (54:140).

Grant believes that there are three groups of criteria for formulating and evaluating spatial plans such as floor layouts:

Intrinsic physical or situational characteristics such as access to views, the existence of in-floor or in-ceiling utilities, and load bearing capacity of floors at different locations; and social, economic, and aesthetic conditions such as the cost of floor space rental, historical associations, prestige, or negative prestige value;

Relational-proximity, such as -

a. Relation to existing features (distance to exit, stairway, elevator, utilities)

b. Relation to new elements being located as part of the subject design (distance between a nurse's station and patient ward, volume of traffic between a facility's front entrance and an information or serving counter)

'Gestalt' or wholistic characteristics. This group involves the facility as being more than the sum of its individual elements. It involves overall effectiveness of the layout in achieving its functional objectives.

Most of the literature deals with space allocation models focusing on relational criteria, mainly with respect to minimizing distances and circulation (traffic flows) between spaces. This classification includes such techniques as SLP and Dual Graph floorplan generation models, and require the input of areas and relationship data in the form of a relationship matrix which are converted to two dimensional layout plans or data matrices which can be read as plans. Most computer applications are based on relational criteria.

Another classification of space allocation model is the overlay type, in which multiple maps of the floor plan envelope are shaded to "indicate value judgments about suitability and desirability, and then stacking the several shaded maps on a light table to obtain a composite evaluation" (26:7). One plan is shaded for each criterion.

This technique has the capability of combining intrinsic, situational criteria with relational-proximity criteria, by allowing the designer to view and consider the effects of many such criteria acting at once (26:8).

Mitchell, in Computer Aided Architectural Design, classifies space planning techniques into assignment, dual graph, and overlay (39). Dudnik and Krawczyk, in An Evaluation of Space Planning Methodologies classify techniques similarly, and single out the assignment type as having the most objectivity. They define assignment techniques as an approach which

> considers the space planning problem as a combinatorial problem of assigning the various required spatial elements to discrete locations or modules in the available space in such a way as to satisfy a given set of constraints and to optimize some objective function (20:415).

Grant explains that the objective function is

> generally some function of distance and interaction among the elements being located, with the interaction function usually dealing with cost of traffic, volume of traffic, relative importance, or some hierarchy of priorities among traffic types (26:38).

This definition could include both relational-proximity techniques and linear/non-linear programming models.

Eastman states that the objective of space planning exercises, and the conditions under which they are undertaken, are not always the same. One such objective, but not necessarily the most important one, is to fit a set of activities into as small a space as possible without overriding adjacencies (21).

Eastman recognizes there being two major classifications of space planning models or algorithms - 'heuristic' and 'optimizing'. His definition of heuristic is not quite the same as Steadman's cited earlier (54). It and includes methods of generating a few alternative layouts or an exhaustive number, the objective being to evaluate each alternative numerically according to specified criteria and selecting the one with the greatest compared worth. Optimizing algorithms take the form of linear and non-linear programming problems, the equivalent of Mitchell's assignment problems. Some practical examples of their use are drawn from Mitchell later in this Chapter (39:468-474).

Lee favors heuristic methods of space planning. He states that as the requirements become more complex,

> the task of arriving at an optimum solution or generating alternatives for evaluation becomes less manageable as well as [more] time-consuming. ... no solution can possibly satisfy all criteria. Optimum solutions are compromises where the conflicts are minimized (33:19).

He advocates the use of computers to generate solutions to space allocation problems - "With its large, accurate memory and low computation time, the computer can be used to generate as well as evaluate solutions" (33:20).

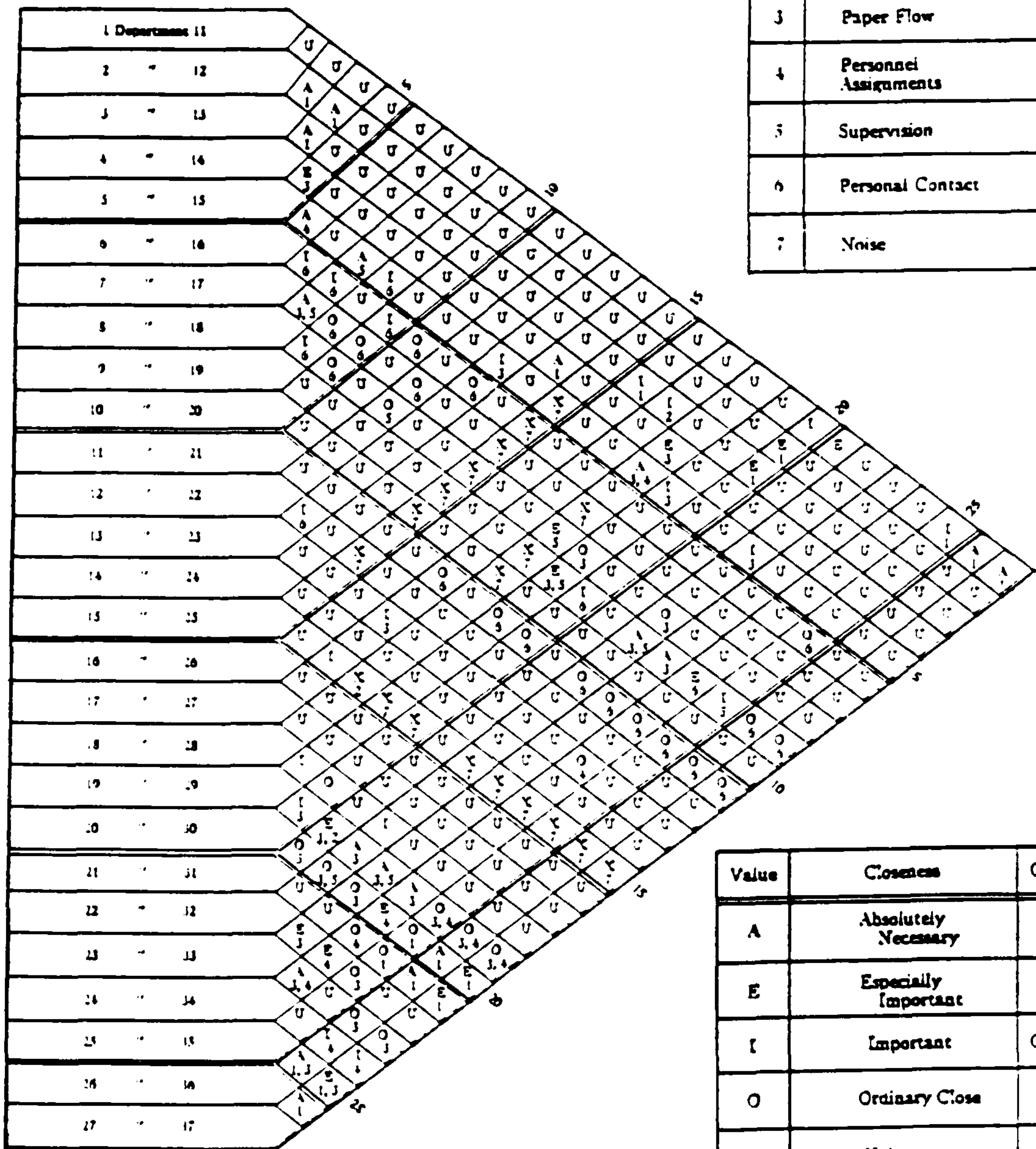
Each of these techniques, relational-proximity, overlay, heuristic, and assignment, will now be examined. Some conceptually different design methods of minimizing construction costs while improving layout flexibility, such as Open Office Planning, will also be discussed. Computer applications of these layout techniques have been developed by practicing architectural firms, organizations, academic researchers, and commercial interests, and will finalize this discussion of design methods.

Relational Proximity Methods. This type is documented extensively and, in its simplest form, is the one most easily applied by hand. The most common technique, and that which most popular computer applications seek to automate, is known as SLP. This was first documented by Muther in Systematic Layout Planning in 1961 (35). The technique is also documented by Pulgram and Stonis in Designing the Automated Office (47:46-50), by Gaither in Production and Operational Management: A Problem Solving and Decision Making Approach (25:342-346), and by Francis and White in Facility Layout and Location: An Analytical Approach (23). It is essentially a six-step process:

Step 1. Compile a list of activities to be placed in the overall space. This may consist of individual rooms to which activities will be assigned, or could comprise various administrative or production operations to be arranged within a large open space. Areas are also required for each activity.

Step 2. Graph on a chart (or matrix) the interrelationships of all pairs of activities or rooms in terms of their need for adjacency. Muther designed the original chart at Figure 1 with six levels of proximity, from

Code	Reason
1	Material Flow
2	Service Flow
3	Paper Flow
4	Personnel Assignments
5	Supervision
6	Personal Contact
7	Noise



Value	Closeness	Color
A	Absolutely Necessary	Red
E	Especially Important	Org. Yel.
I	Important	Green
O	Ordinary Close	Blue
U	Unimportant	U
X	Undesirable	Brown

Figure 1. Muther's Original Functional Relationship Chart (35)

'absolutely necessary' to 'undesirable' (43; 35:197-198), although two or three level scales and color codes have all been used for this purpose (47:30-32). Pulgram and Stonis state that

> Requirements for adjacency are born out of relationships that exist within functional unit (intragroup) and between functional units (intergroup). Typical relationships include:
>
> Intragroup - user(s) to user(s)
> - user(s) to group items and spaces, eg; equipment, storage, conference spaces.
>
> Intergroup - group to group
> - group to ancillary, eg; conference, central computer, word processing.
> - specific user(s) to user(s)
> - specific user(s) to group(s) (47:29-30).

Figure 2 is an example of a three-level relationship chart. As shown at Figure 1, the original Relationship Chart of Muther also included a number coded reason for the relationship chosen, such as material flow, supervision, personal contact, or noise (45:7).

Step 3. Convert the completed Relationship Chart into a 'Bubble Diagram'. A bubble diagram is a graphical means of

> relating the various activities to each other visually and geographically to form the basic pattern of the layout ... the object being to work out on paper the arrangement of activities that will place those with higher closeness ratings nearest each other, and those with lower closeness ratings progressively further away (45:8).

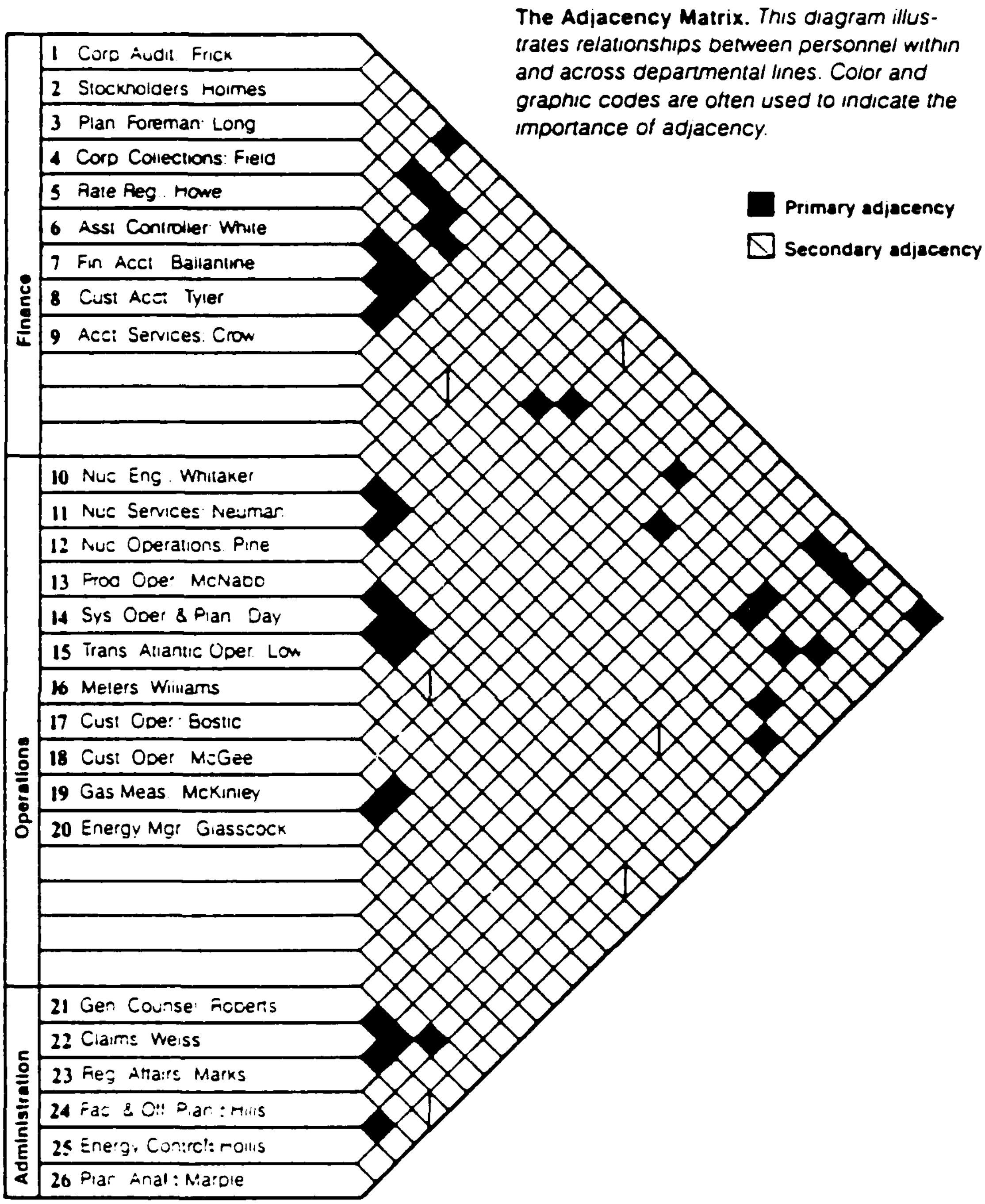
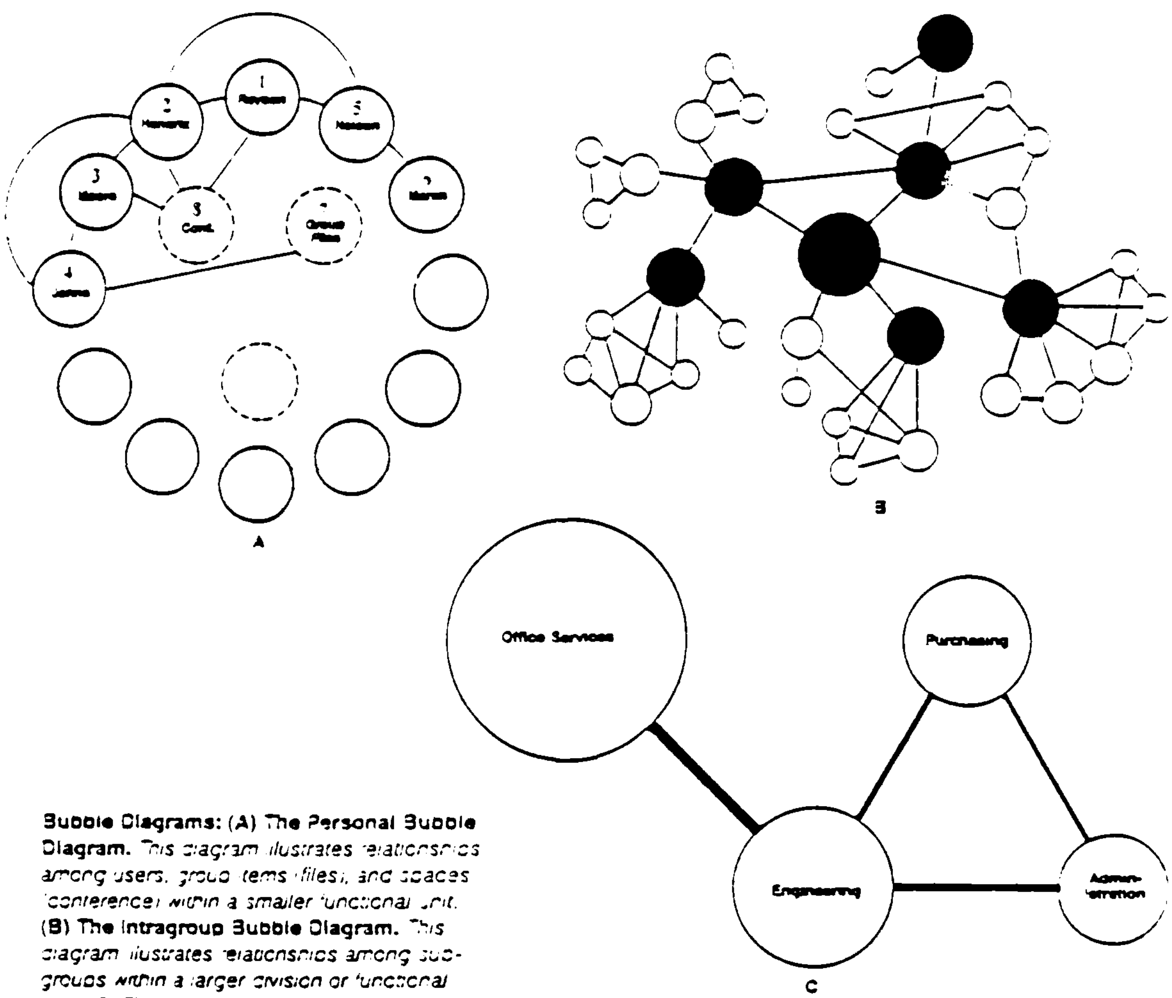


Figure 2. Three level Relationship Chart (47)

The `bubbles' represent activities and the lines joining them indicate the strength of the relationship as indicated on the Relationship Chart. At Figure 3 (47:31) are examples of such diagrams. Once the relationships have been represented correctly, usually by varying the thickness, number, or color



Bubble Diagrams: (A) The Personal Bubble Diagram. *This diagram illustrates relationships among users, group items (files), and spaces (conferences) within a smaller functional unit.* **(B) The Intragroup Bubble Diagram.** *This diagram illustrates relationships among subgroups within a larger division or functional unit.* **(C) The Intergroup Bubble Diagram.** *This diagram illustrates relationships among total groups or divisions within an organization.*

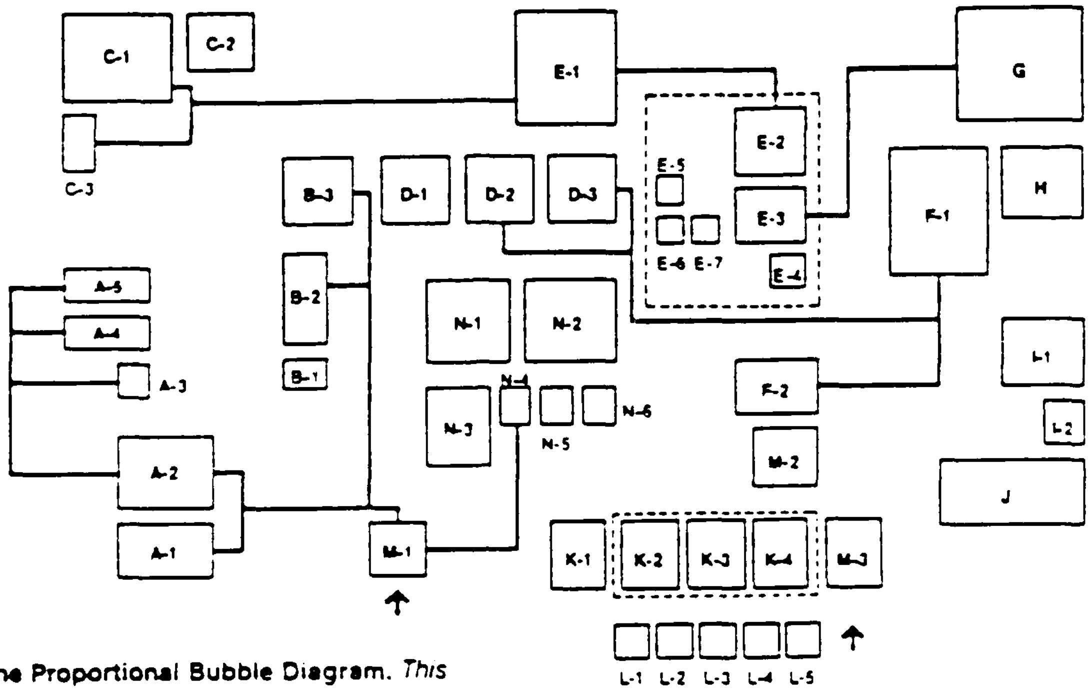
Figure 3. Examples of Bubble Diagrams (47)

coding of lines joining each pair of activities according to the number of levels on the Relationship Chart, the activities are moved further apart or closer together depending on the strength of the relationship. Activities are then rearranged such that they will fit into whatever facility shape the designer has envisaged, on the basis of construction costs, site restrictions, or aesthetic appeal. If the designer is concerned mainly with the functionality and efficiency of operations within the facility, then he may not wish to confine the design to any preconceived shape. In military construction both construction costs and function are of concern, so a balance must be struck.

Step 4. Incorporate the area requirements of each activity to create a Proportional Bubble Diagram with each activity space represented as a square reflecting its proportional size. Figure 4 is an example of this.

Step 5. Mold the proportional bubble diagram into a Block Diagram, which fits individual spaces together according to relationship strengths by adjusting the shapes but preserving the areas. Figures 5 and 6 show the stages involved.

If there are constraints on length to width proportions for each space or for the overall floor plan, then these are included in this step. Many such block diagrams are possible from any proportional bubble diagram. If the objective is to fit a set of activities into a building space, then this step must also include consideration of situational criteria such as the floor load capacities at different positions, structural support locations, window locations, stairs, and



The Proportional Bubble Diagram. *This scaled diagram illustrates relationships among specific departments and services within an organization according to size. Legend: A, administrative; B, legal affairs; C, accounting; D, computer services; E, corporate planning; F, engineering and consulting; G, systems engineering; H, energy; I, customer operations; J, nuclear operations; K, corporate records; L, storage; M, public space; N, employee services.*

Figure 4. Proportional Bubble Diagram (47)

major utility services. These existing features are often too expensive to relocate, and would only be moved as a last resort and only if funds permitted. If available modification funds are very limited then existing non-load bearing walls, electrical distribution, domestic plumbing, and lighting arrangements may also be considerations in the formulation of feasible block diagrams.

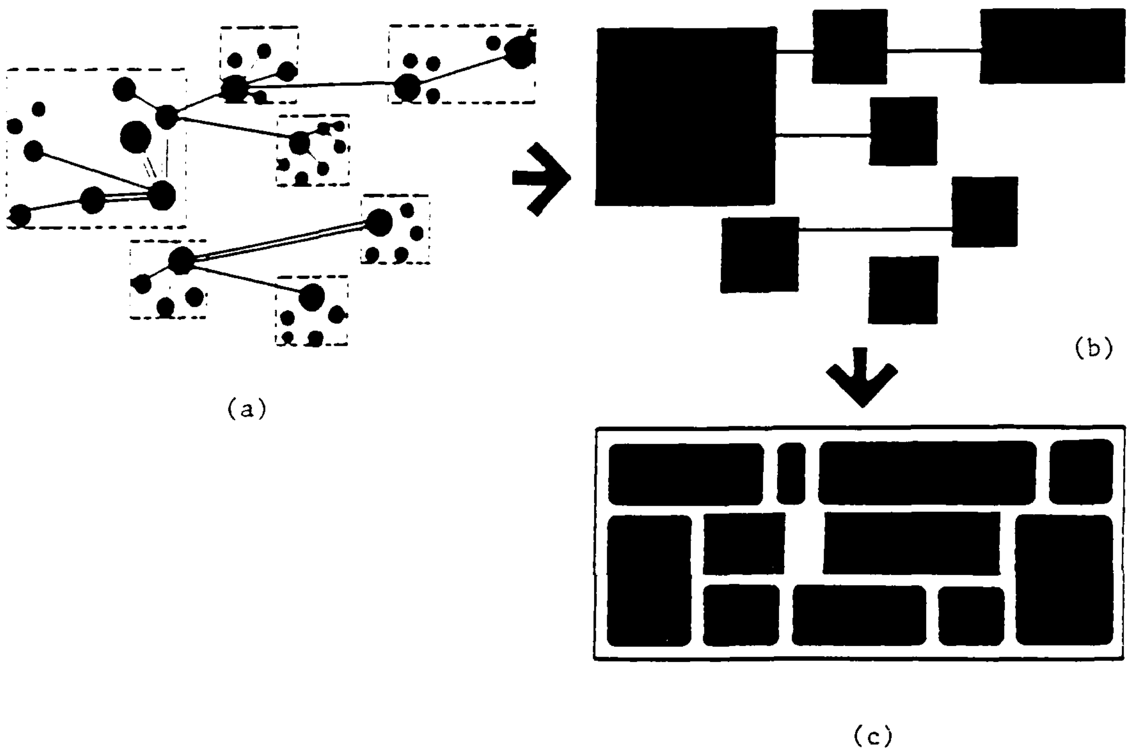


Figure 5. Conceptual Use of Block Diagrams. (a) Block diagrams developed by space determinations, (b) Proportional Block Diagrams showing space and adjacency requirements, and (c) Block space allocations and adjacencies considering building constraints. (47)

Block diagrams are also a means of planning and evaluating the required vertical and horizontal relationships of these elements within a space or a builuing. .... In any office, conventional or automated, this step is important to the organizational logic of the office (47:48).

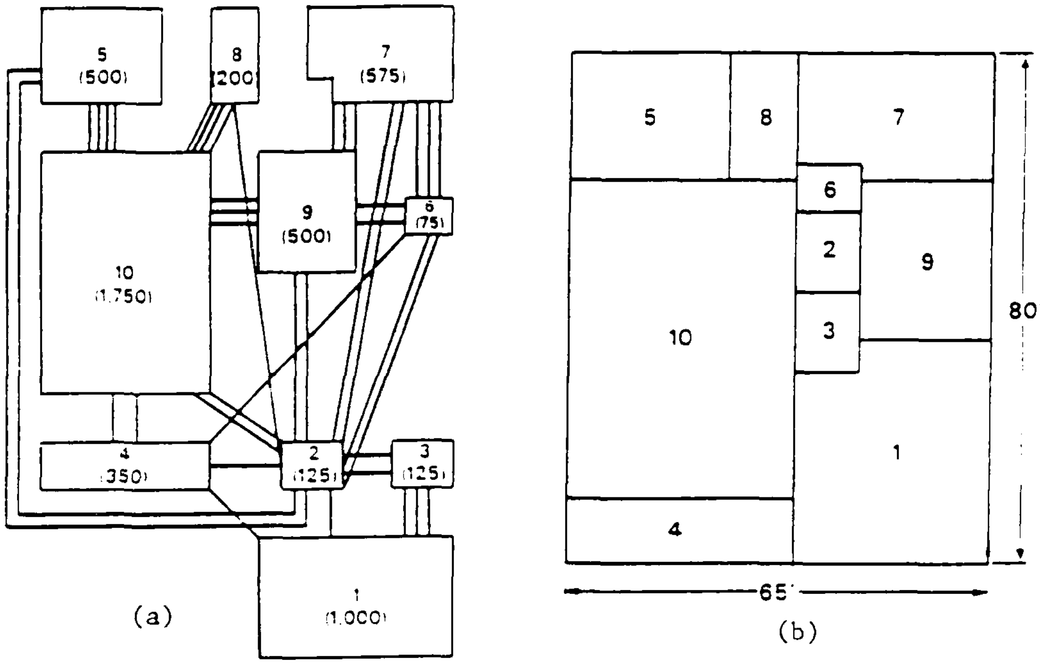


Figure 6. Molded Proportional Bubble Diagram and Resulting Block Diagram (23)

Step 6. Evaluate the feasible block diagrams.

There are three basic methods of evaluation (45:12):

Balancing advantages against disadvantages. It may be possible to screen out some alternatives initially as not in compliance with high priority criteria, such as conformity to security and fire regulations, irregular shapes that could not be effectively utilized by the intended functions, and small pockets of unallocated space that cannot be effectively distributed to those activities having the greatest need for additional space.

Factor Analysis Rating. This comprises making a list of organizational objectives (factors) related to the configuration of the activities in the space, assigning a numerical scale weighting to each objective in terms of priority for achievement, rating each alternative block layout against each factor, multiplying the weight of each factor by the rating for each alternative, and summing to produce a score for each alternative. The plan with the highest total score is selected.

Cost Comparison. All alternatives can be costed to include planning, installation, operating, and maintenance costs. Also, projected and hypothetical costs for modifying and/or expanding the layout at some future time could be considered. The alternative with the lowest costs would be selected. This method of evaluation introduces the concept of layout flexibility into design. This concept is of vital importance in the design of facilities for organizations with changing missions, where the market for products or services is constantly changing, or where new technologies lead to rapid growth of the organization or to restructuring of administrative procedures, processes, and production techniques. Flexibility and growth will be treated in more detail later in this chapter.

Dudnik and Krawczyk (20) and Eastman (21) classify relational-proximity techniques as either 'constructive' (or build-up or generative) or 'improvement' (or hill-climbing). Mitchell acknowledges this classification as well (39:440-452). They are algorithmic, or procedural, in nature and require much iteration before approaching optimality. They are well suited to, and extensively used in, computer applications.

Constructive Techniques. These begin with an empty layout (no activities allocated) and a relationship matrix. Each element is located in accordance with whichever of the following four algorithms is chosen:

Random Generation. Mitchell explains the concept:

> A random sampling strategy, in conjunction with some simple assembly rules, is employed to very rapidly and cheaply generate plans for consideration. Each plan that is produced is scored by summing the importance weightings of the adjacency requirements that are met. The plans for which the score exceeds a specified minimum value are printed out (39:441).

Polymino Assembly method. The element placed next is the one having the highest interaction with the last placed element.

Ordered Score method. The elements are placed in the building space in the order of decreasing total interaction scores from a relationship chart.

The Nuclear Growth approach. The choice of element to be placed next is based on the total interaction score of an individual element not yet placed, with all those elements placed previously (20).

Improvement Techniques. These "start with an initial layout and a matrix, and a attempt to alter the layout in such a way as to improve the measure of performance produced by the objective function" (26:37). Four different algorithms are commonly employed to define the process by which elements are selected for re-configuration (26,20):

Random Switching method. Switch the location of any two elements and reassess the value of the objective function. If the value increases keep that arrangement; if it decreases then reverse the switch. Keep switching pairs of elements until it seems that the value of the objective function will not increase.

Ordered Score and Alternative Checking method. Each element is switched in order of its total interaction score with all other elements. The layout is re-evaluated after each switch is made, until the best layout for those elements placed is found.

Single Switch method. This procedure is the same as for random switching, except that the switch order is systematic.

Greatest Improvement methods. All possible switches of pairs of elements are considered but only the one resulting in the greatest single improvement in the value of the objective function is executed. The process continues until no further improvements are possible.

Mitchell (39) and Eastman (21) each explain improvement techniques with the analogy of climbing a hill at night when the summit os not visible. One can take a step in any direction and, if it results in an upward movement, stay there and take another step. If not, one would step back and try again. After many steps, a peak would eventually be reached although it may be only a local one and not the summit. Alternatively, one could test every possible direction with one foot and only execute a move to the position that one knows is the highest.

This method would guarantee the most direct route to a peak, although that peak may similarly not be the summit (39:443-448). Both authors believe that the ability of improvement methods to achieve optimality depends on which starting layout is chosen, and how many steps (or how much computer time) the designer is willing to invest.

The Dual Graph approach is also a Relational-Proximity technique, but is more graphically and mathematically rooted. Bubble diagrams are called dual graphs. Whereas block diagrams are planar representations of spaces and can be dimensionned shaped in a variety of ways, dual graphs are non-planar representations of activities or processes, and not spaces. Both are used to generate and evaluate alternative floor layouts.

Relational-Proximity methods have been criticized for their over emphasis on two criteria; circulation, and traffic flow between spaces. Grant criticizes the 'triviality' of their application -

> They incorporate too little input, merely a relationship matrix and traffic flows, and yield too much output: an entire floor plan layout.... They attempt to determine building layout as only one criterion, that is, proximity among the designed elements and the implication of a given layout in terms of the total cost of movement in a typical working day (26:8).

This criticism is true if Steps 5 and 6 of the SLP process reviewed earlier do not attempt to; 1) incorporate physical and situational constraints in the formulation of alternative feasible block diagrams, and 2) evaluate these alternatives with the organization's objectives clearly in focus.

Another criticism is that, if performed manually rather than using one of the many computer applications that have been developed, the physical arrangement of the bubble and block diagrams is highly subjective and the selection of the 'best' alternative is a function purely of the time allocated by, and the imagination of, the designer. Even though optimality will probably never be reached using these techniques, the computer will generate many more alternatives and can evaluate them according to programmed instructions or permit the designer to do so interactively.

Buffa and Armour were two pioneers in the use of computers in space planning. They developed a program called CRAFT in 1964 for evaluating layouts for production facilities. Evaluation was based on minimizing the distances that materials and goods moved between areas during production. In their initial published documentation of the process, Allocating Facilities with CRAFT, Buffa, Armour, and Vollmann wrote:

> Ordinarily, the bulk of a manufacturing company's assets is tied up in plant and equipment. The operating effectiveness of these facilities depends in considerable measure on the effectiveness of the layout. A poorly conceived layout can result in congestion and prohibitive material-handling costs, and, on the other hand, an effective layout can provide an environment for efficient production. How can a manager evaluate the effectiveness of a layout for a complex production system? Is this important? Of course it is, for the basic layout used sets the design of the entire production system for some time to come, and it cannot be changed without considerable cost (8:136).

The CRAFT technique is still used today and has been modified to use other evaluative criteria besides traffic flow. It is reviewed along with other computer aided space planning packages later in this chapter.

Overlay Techniques. Overlay techniques are used mainly in facility siting, highway routing, urban planning, and area Master Planning, but is mentioned briefly here because of its potential ability to consider more than one criterion when laying out facilities. Overlay techniques have been developed and used over the past 20 years by McHarg. In Design with Nature (37) he outlines a model he has applied to regional planning and landscape design. The technician superimposes maps shaded to indicate value judgments by the designer on the suitability of various sites as a facility location. One map is required for each criteria. The heavier the shading of a certain area, the more unacceptable it is as a potential site. When overlaid, the darker the spot the more unacceptable.

This technique can be used for locating a particular activity within a facility or within an installation, but is not so readily applicable to designing a layout involving locating many related and unrelated activities within a building envelope. In such a case a map would be required for each activity with respect to each criteria. With 20 activities and 10 criteria, 200 maps would be required. McHarg believes that the technique permits the designer to objectively ascertain the best location for each activity. He describes it as "a method whereby the values [are] explicit, where the selection method [is] explicit -where any man, assembling the same evidence, would come to the same conclusions" (37:35).

While computers can effectively discern shading levels and apply weights, the human eye has difficulty. Grant sees many problems in the manual application of this "McHarg Technique" (26:67) -

> Each added parameter map, with its judgmental shading, increases the overall trend toward a uniformly dark gray or black outcome space, with resultant difficulty in discriminating the implied patterns. One result might be a hesitancy to increase the number of parameter maps considered (26:67).

Also, because the inputs are judgmental, "it seems desirable to be able to re-iterate at a low cost, with changed judgments, in some cases many times" (26:68). Unfortunately, the more parameters and the more differing judgments by the different people participating in the design, the more expensive the process if performed by hand, and the darker and less discernable the final product.

Heuristic Search Procedures. Mitchell states that this class of methods "is characterized by solution-generation in a sequence of stages, with evaluations based on the partially specified state of the data structure being made at each step" (39:454). Because it is heavily reliant on exhaustive enumeration of potential solutions, this type of method is best handled by computer.

Mitchell gives a simple example of a heuristic search, based around several decision rules. He points out that, in most situations, there can be many 'reasonable' decision rules, and that the purpose of these rules is to eliminate large portions of possible activity allocations.

The method appears to be similar to the Ordered Score and Nuclear Growth methods detailed by Dudnik and Krawczyk (20) but that a more rigorous set of decision rules is applied to satisfy as many adjacency requirements as possible. As with Relational-Proximity techniques, a relationship chart or matrix is required.

Mitchell's example is the creation of a floor plan within a 25 by 25 square modular grid. The dimensions of each module (grid square) is set to the minimum common denominator of all activity space requirements, say 5 feet square (25 square feet). The decision rules are:

1. Select the space which has the highest number of adjacency relations with other spaces.

2. Place the first module in the center of the grid.

3. For placement of subsequent modules for this activity;

   a. List all empty grid locations which are directly adjacent to located modules.
   b. If there is only one location, select it, else
   c. For each such empty grid location, count the number (between 1 and 8) of adjacent located modules.
   d. Select the grid location with the highest number.
   e. If there is a tie for selection, break it arbitrarily.

4. To select subsequent activities for placement, select the unlocated activity having the highest total number of adjacency relations with activities that have already been located.

5. To 'grow' these subsequent activity spaces, a variation of Rule 3 might be used;

   a. List all empty grid locations which are directly adjacent to located modules.

   b. If there is only one location, select it, else

   c. For each remaining potential location, count the number (between 1 and 8) of adjacent located modules <u>of the current activity</u>, and eliminate all locations which have a lower number of adjacencies than the maximum which occurs.

   d. If there is now only one location, select it, else

   e. For each remaining potential location, count the number (between 1 and 8) of adjacent located modules <u>of any other activities adjacency-related to the current activity</u>, and eliminate all locations which have a lower number of adjacencies than the maximum which occurs.

   f. If there is only one location, select it, else make an arbitrary selection (39:459-460).

This method, says Mitchell,

> grows spaces which fairly closely approximate a square in shape, and which are located so as to simultaneously satisfy as many adjacency requirements as

> possible....Numerous floor plan layout programs which employ plausible selection rules of this type to locate modules within a square grid have been developed. The best of them are computationaly very efficient, capable of locating thousands of modules in a few seconds, and produce results of excellent quality (39:460).

As with SLP, the relationship matrix need not be based solely on circulation/traffic flow between spaces, but on a wide range of criteria, both quantitative and qualitative.

Assignment Techniques. The common thread in this class of methods is the use os mathematical techniques to optimize the space allocation, by maximizing or minimizing some objective function rather than merely reporting its value. Three methods will be reviewed - quadratic assignment, linear and non-linear programming problem formulation, and analytical (or algebraic) procedures.

Quadratic Assignment. This type of problem formulation was first done in 1957. The purpose is to assign a set of activities with known space requirements to a set of possible locations, in such a way that the following objective function is minimized:

$$\text{Total Circulation Cost} = \sum_{i=1}^{n} \sum_{j=1}^{n} G_{ij} \, C_{ij} \qquad (1)$$

where

n = the number of activities to be assigned
G_{ij} = a measure of distance between pairs of located activities i and j
C_{ij} = a measure of circulation cost per unit distance between i and j

The set of locations is usually taken as the set of modules (or cells) in a square grid. The individual cells can be any shape or size desired. "The floor plan layout is represented as a problem of assigning integers to locations in a two dimensional array" (39:426). Values for C_{ij} and G_{ij} must be input by the designer. An arbitrarily high interaction value between modules of the same activity can be given to prevent activity spaces being 'split'. Mitchell explains:

> If the circulation data is in terms of numbers of trips per week [or day], the objective minimized is total distance traveled by building users. If values are given in terms of travel time or cost per unit distance, then either time spent in circulation or the total cost of that time respectively is minimized (39:427).

The problem can be modified to preset locations for some activities. If cost is to minimized then a fixed cost (say Fij) would be associated with each such module *i, preset* to location j. An example of this would be to "reflect a preference of high status employees for corner locations in an office floor layout" (39:427) or for such spaces as entrance halls, loading bays, and plant rooms to be located on an external wall, at ground level, for external access purposes. If spaces are pre-assigned, they serve as the starting point, or nucleus for the assignment process.

This method is efficiently handled by computers and is similar in principle to the Nuclear Growth method. Mitchell cautions its use, saying that it is "appropriate only in situations where circulation efficiency or some directly analogous objective is regarded as <u>the</u> primary determinant of the plan" (39:428). Other limitations are that:

1. It takes no account of shape constraints on spaces.

2. It does not recognize any difference between circulation space and other types of space, and may produce splitting of activity spaces in the plan.

3. The collection of necessary circulation and cost data may be difficult and expensive, if not impossible. For this reason, experience and professional judgment is commonly used in place of actual circulation and cost data (39:428).

4. There is no known solution procedure for this type of problem, "nor is there a direct way of computing the optimum value of the objective. Enumeration and search procedures of various kinds must be employed" (39:429).

Linear Programming. Standard linear programming is applicable when the objective function and space dimension constraints can be formulated in linear form. Mitchell says:

> Typical linear objectives are maximization or minimization of overall plan length, width, perimeter, or proportion ratio. Typical linear constraints are upper and lower bounds on allowable lengths, widths, perimeters, and proportion ratios of individual rooms and of the overall envelope..... An immediate obvious limitation of the linear programming approach is that area constraints are non-linear, and thus cannot be incorporated... (39:470).

Also, properties such as construction costs and heat loss are functions of area and cannot be included as constraints or objectives. However, by setting one dimension for each space, and setting an allowable range for each area (min, max), the optimum value for each other room dimension, and hence the optimum area, can be determined. The limitation here is that area adjacency relationships cannot be used to determine the best arrangement of spaces. A rough block diagram must be obtained prior to this application.

Mitchell cites an example where linear programming is particularly applicable. For the layout of a trailer or a building with severe site restrictions, where the total width of the facility is preset, linear programming can efficiently optimize the length of each room and overall length of the facility, given suitable area ranges for each room and pre-set room widths as follows:

Room		Minimum Area (square feet)	Maximum Area (square feet)
1.	Bath 1	75.0	80.0
2.	Bedroom 2	160.0	180.0
3.	Utility	50.0	80.0
4.	Kitchen	150.0	200.0
5.	Dining	100.0	125.0
6.	Bedroom 1	180.0	200.0
7.	Hall	-	60.0
8.	Living	180.0	200.0
9.	Bath 2	60.0	80.0
10.	Family room	100.0	125.0

Circulation space such as hallways must also be input as activities and given similar area and dimension constraints. Room lengths are input to the objective function and constraints as variables a to g. These variables are represented in Figure 7. The objective function and constraints are as follows:

$$\text{Minimize } (a + b + c + d + e + f + g)$$

$$\begin{array}{ll}
\text{subject to:} & g \leqslant 10\cdot 42 \\
a \geqslant 6\cdot 25 & (a + b) \geqslant 15\cdot 0 \\
a \leqslant 6\cdot 67 & (a + b) \leqslant 16\cdot 67 \\
(b + c) \geqslant 13\cdot 33 & (c + d + e) \leqslant 20\cdot 0 \\
(b + c) \leqslant 15\cdot 0 & (f + g) \geqslant 15\cdot 0 \\
d \geqslant 4\cdot 17 & (f + g) \leqslant 16\cdot 67 \\
d \leqslant 6\cdot 67 & c \geqslant 6\cdot 67 \\
(e + f) \geqslant 12\cdot 5 & c \leqslant 8\cdot 89 \\
(e + f) \leqslant 16\cdot 67 & (d + e) \geqslant 11\cdot 11 \\
g \geqslant 8\cdot 33 & (d + e) \leqslant 13\cdot 89
\end{array}$$

The initial block diagram and final plan showing optimal dimension, for Mitchell's trailer example, are shown at Figure 7.

<u>Non-Linear Programming</u>. Non-linear programming overcomes some of the limitations of linear programming, and "has been used in conjunction with dimensionless representations of floor plans to generate optimum dimensioned layouts with respect to some cost criterion and subject to certain functional constraints" (39:468). A block diagram showing the required space arrangement is necessary, as well as maximum and minimum room lengths, widths, and areas, and a maximum proportion ratio for each room if

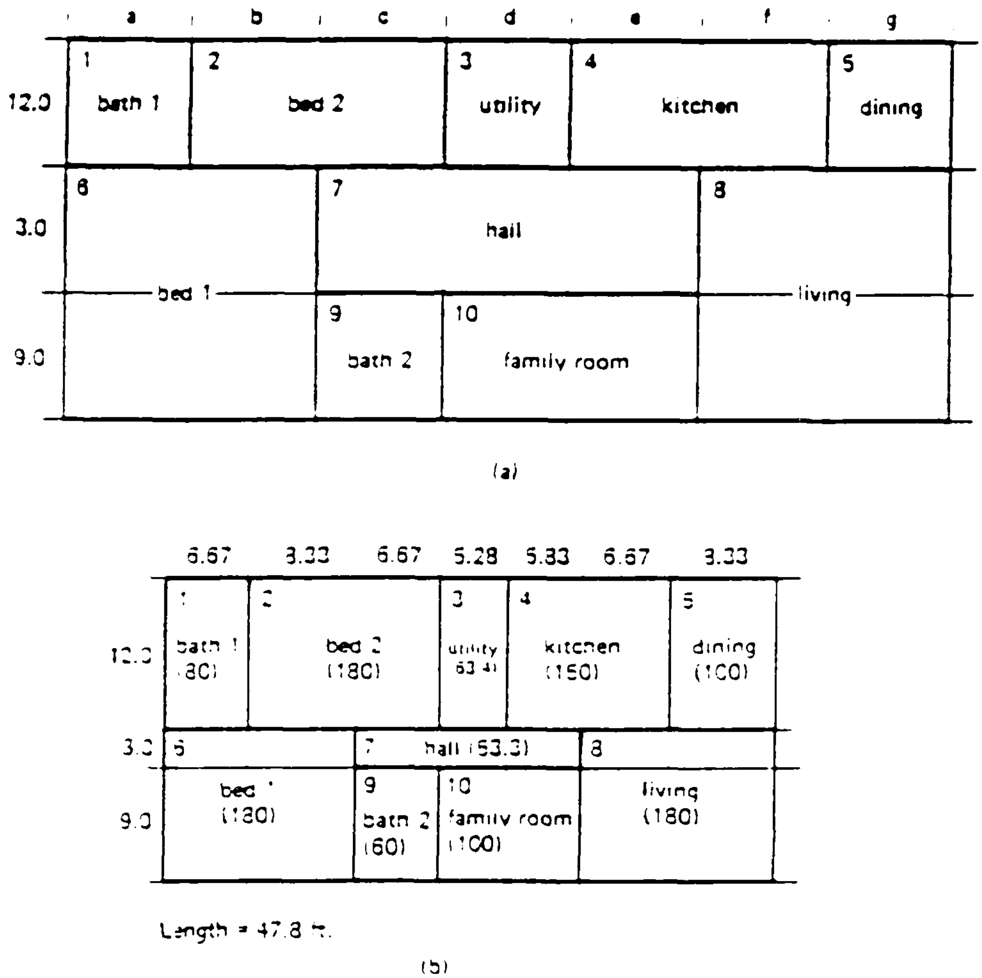


Figure 7. Application of Linear Programming to Floorplan Layout. (a) Initial Dimensionless Block Plan for a 24 ft Wide Trailer with Short Side Dimensions Fixed. (b) Final Optimum Dimensionned Layout Using Linear Programming (39)

desirable. This type of problem can handle area constraints. The objective function could be to minimize costs, as follows:

$$\text{Minimize} \quad \sum_{i=1}^{n} a_i \, c_i \qquad (2)$$

where

n = the number of rooms or activities to be fit into the facility,
a_i = the total floor area of room or activity i, and
c_i = the construction cost per square foot for room i.

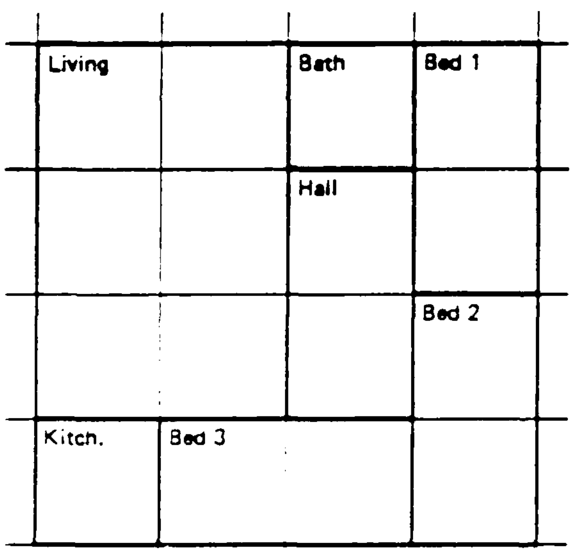
Simple problems, such as the one following, could be solved by hand. The objective function and constraints are not stated but can be deduced from the table. The primary difference between this and the previous linear programming example is that no room dimensions are fixed. Hand solution of even this relatively simple problem is tedious and time consuming and there are many low cost computer packages available which make this unnecessary. Figure 8 shows the table of requirements and a computer solution.

Mitchell qualifies the effectiveness of this method - "They cannot absolutely guarantee to generate the optimum solution, but experience has shown them to be extremely reliable and efficient" (39:470). One limitation of SLP is that the final dimensioning of rooms within a facility is subject to the designer's innate ability to dimension rooms according to some constraints such as building and room proportion, and shape regularity. Non-linear programming is directly applicable to this phase of SLP.

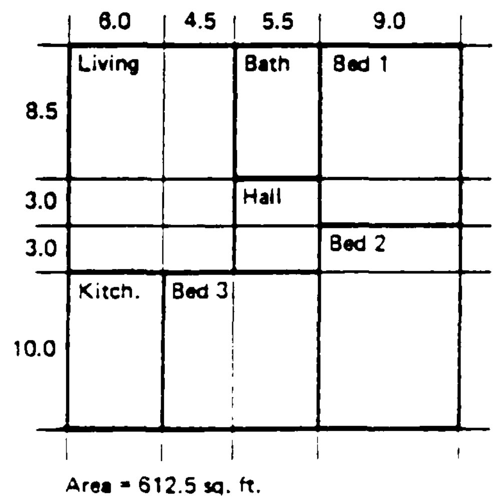
<u>Algebraic Procedures</u>. Simultaneous equations can be found to describe desirable relationships between different room areas and dimensions, overall building area and dimensions, and building and room proportions. However,

Room	Minimum length (ft)	Maximum length (ft)	Minimum width (ft)	Maximum width (ft)	Minimum area (ft²)	Maximum area (ft²)	Maximum proportion ratio
1 living room	8·0	20·0	8·0	20·0	150·0	300·0	1·5:1
2 kitchen	6·0	18·0	6·0	18·0	50·0	120·0	
3 bathroom	5·5	5·5	8·5	8·5			
4 hall	0	15·0	3·5	6·0	0	72·0	
5 bedroom 1	9·0	20·0	9·0	20·0	100·0	180·0	1·5:1
6 bedroom 2	8·0	18·0	8·0	18·0	100·0	180·0	1·5:1
7 bedroom 3	10·0	17·0	10·0	17·0	100·0	180·0	1·5:1

(a)



(b)

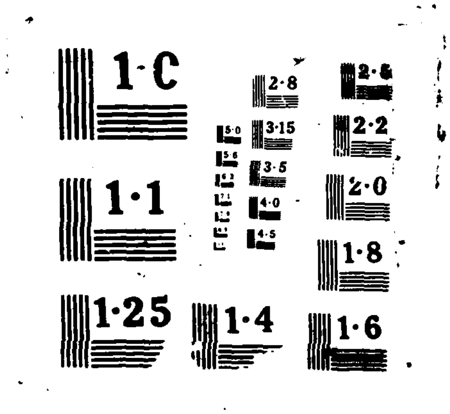


(c)

Figure 8. Application of Non-linear Programming to Floorplan Layout. (a) Table of requirements, (b) Dimensionless Representation of Layout, and (c) Optimum Dimensionned Solution. (39)

AD-A188 273 AN ANALYSIS OF METHODS FOR MAXIMIZING THE UTILIZATION OF SPACE IN USAF FACILITIES(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST J P QUINN 2/4

UNCLASSIFIED SEP 87 AFIT/GEM/DEM/87S-19 F/G 13/13 NL


1.0
2.8
2.5
3.2
3.6
2.2
4.0
2.0
1.1
1.8
1.25
1.4
1.6

the number of possible combinations of simultaneous equations becomes immense as the number of rooms increases. There are 2^n different sets of equations, where n is the number of rooms in the plan (39:472). For small buildings, it may be possible to list and solve all sets by hand, but computer programs have been (and can be) developed to handle linear and non-linear combinations of variables.

Flexibility in Layout

Flexibility was defined in Chapter 1. Floorplans, according to Pulgram and Stonis should be designed to incorporate room for growth - "Space planning efforts that allow for growth ensure a floor plan that can be expanded, contracted, shifted, or changed. Present space allocations must be able to be tailored to future usage requirements" (47:51). Efforts to maximize this level of flexibility have only recently become popular and effectively used. Modular construction, office landscaping (or Büro - Landschaft), workstations and systems furniture, and modular partitions, have been introduced widely into administrative facilities since about 1960.

Modular Construction. Many companies now specialize in producing and assembling kit buildings composed of pre-engineered building components. This type of construction is termed modular due to its building block approach. Facilities can be designed to provide a range of ceiling heights, internal lighting levels and arrangements, and areas which are multiples of a standard size module. They are utilized predominantly as interim accommodation during construction of new facilities, remodelling of existing facilities, or as overflow accommodation for expanding functions pending the provision of additional building space.

Foundations can be permanent or temporary, strip or pad footings. Power, water, sewerage, and other utilities can be permanently fixed or temporary junctions. Internal walls can be relocated to vary the number and arrangement of internal spaces. Security, fire, computer, and high floor loading requirements can all be met using modular construction.

Remodelling, extension, and utility flexibility are all enhanced, and can be carried out at lower cost due to the use of pre-engineered floor, ceiling, and wall panels, and roofing systems. Facilities can be relocated and components re-used in different configurations to support different mission requirements.

Transportable cabins are a form of modular building and, if capable of being mated together, can provide a measure of flexibility in configuring emergency use, mobile, and deployable facilities.

Office Landscaping. Otherwise known as Open Office Planning, or simply Open Planning, this concept of office layout design was developed in Hamburg, West Germany, during the early 1960's by a firm of office management consultants. Pile, in Open Office Planning (1984), states that

> The dominant trend in office design is toward more use of open planning. More than half of the office space currently being planned and constructed is said to be, in some way or other 'open' although an exact measure is hard to establish. ... The open office is clearly here to stay and demands only the best, the most thoughtful, and most flexible thinking to make it maximally useful (46:16-17).

Mogelescu, in Profit Through Design:Rx for Effective Office Space Planning, describes the general principle of the concept as that

> office planning should not be based upon the traditional organization chart of command structure, but rather on the groupings of personnel in open space along the lines of interpersonal relationships and communications (41:103).

Friedmann et al, in Interior Design: An Introduction to Architectural Interiors, add that all other values such as appearance, status recognition, tradition, privacy, acoustics, are either ignored or given very minor status (24:187; 46:8). In open planning, there are no fixed walls and private offices, all workstations, furniture, screens and plants are movable and are usually arranged to create functional work groups (41:103).

Mogelescu says that "With the elimination of fixed walls or partitions, a maximum degree of long term flexibility can be achieved ...." (41:103), but adds that several technical problems are produced as a result. These include the provision of telephones, power, lighting, air conditioning, air conditioning and heating, and noise controls (41:103). These can all be all be solved to produce a satisfactory work environment.

Pile, in Open Office Space (46), lists some of the benefits of, and objections to, open office planning.

Benefits include:

1. Workers achieve better communications than in conventional partitioned offices. People can talk directly to each other, use visual signals, and pass papers to one another.

2. Groups working together develop a better sense of teamwork and cooperation.

3. Managers can direct and supervise more naturally, as they are not isolated from the rest of the team. "They will be seen as mentors rather than as task masters" (46:13).

4. Changes in the arrangement of work stations, to react to changing workflows and procedures, are relatively easy to make. Furniture and equipment can be relocated easily.

5. Provided that main utility runs are initially designed for flexibility (whether ducted in-floor, or in-ceiling with drops to each workstation grouping), wiring for electrical, telephone, and communications requirements can be changed more easily to fit changing work arrangements and consequent equipment relocations.

6. Large open spaces are easier and cheaper to light, heat, and cool than the equivalent area of separated offices. Pile does not consider, however, that with separate offices all may not be in use simultaneously and some services could be switched off.

7. With proper acoustical floor and ceiling treatment (and possibly background music), the noise problem normally associated with the lack of individual privacy can be avoided. It can, in fact, create a less distracting work environment than will total silence with conversations leaking through walls and service ducts.

8. Initial cost savings are possible due to the absence of internal walls and doors. Pile stresses that this should not be a major criterion for using open planning.

9. Major changes can be carried out overnight with little or no remodelling costs and lost working time. For areas subject to frequent user and mission changes, savings in time and money in this area can be significant.

10. There may be a saving in total floor space, leading to a saving in construction costs. However, in many cases this space would best be constructed as a cushion for future construction. In military applications, this may or may not be justifiable and would depend on forecast requirements based on possible future mission changes and historical precedence.

11. Friedmann et al assert that "given good planning and equipment, users like open offices better than warrens of closed cubicles, ... [leading to] improved morale, a reduction in absenteeism and worker turnover, and to improvement in total office productivity" (24:13).

Objections to the open planning concept include:

1. Loss of privacy. There are many situation which do not lend themselves to this type of layout, especially where confidentiality and individual customer relations are important. In any open office there should be conventional partitioned areas for such activities as conferences, private interviews, counselling, and reception for clients.

2. Noise. As mentioned earlier, proper acoustical treatment can create a deadening or damping of noise to acceptable background levels. If silence is required, this type of general office planning is inadequate.

3. Absence of status recognition that private offices provide. This type of objection has little to do with productivity or functionality. Many open plan offices incorporate strategically placed partitioned offices for some managers.

4. Some poorly designed open offices can be depersonalizing if workstations are arranged too symmetrically. This need not be so. European open offices have been criticized by US architects and interior designers for their random appearance, although this would permit each worker a greater personal identification with his own space.

Ease of communication is the key principle of open planning. This principle relates well to relational-proximity space planning techniques such as SLP, which are rooted deeply in activity interrelationships and the need for adjacency. Bubble diagrams show activities arranged in their most satisfactory pattern according to specified criteria. Whereas block diagrams restructure these patterns to fit a more regular building envelope with relatively straight corridors linking activities, open planning preserves these 'optimal' bubble diagram activity arrangements with minimal compromise for building shape (46:15).

In terms of saving space, Friedmann et al list as a benefit, that "in an office space without subdivision there is a saving of space resulting from the sharing of circulation space that would otherwise have to be duplicated in each private space" (24:189). Pile submits that a common expectation among clients is that this form of office planning will save money. He says that,

> if the plan involves saving money by 'compacting' to reduce floor area, a sense of crowding may develop with related acoustical problems and a resultant loss in the hoped-for flexibility of layout (46:47).

The biggest savings in money are realized with time, and are reflected in reduced costs of cleaning, making changes to working arrangements, and in renovation work (46:48).

AFM 86-2 promotes the use of open planning in Air Force administrative facilities, as referenced in Chapter 1, for reasons of layout flexibility.

In terms of overall space allowances per person, paragraph 13-2 of AFM 86-2 provides definitions and allowances for gross building area, net office area, net floor area, administrative support space, and special purpose space. At paragraph 13-3, net floor area per building occupant is restricted to 115 SF minimum and 130 SF maximum. This includes administrative support areas such as conference rooms, file storage, supplies storage, mail handling, and reproduction. The actual usable net office area dedicated for each individual office or workstation is restricted to 80 SF minimum and 90 SF maximum.

Paragraph 13-4 of AFM 86-2 gives guidance to designers on this issue:

> Project planners and facility designers should make an analysis of the types and numbers of personnel to be housed, and determine the desirable minimum net office area per person. This should be followed by an analysis of administrative support space requirements, taking into account the types of activities being housed (15).

However, it also states that these requirements must not exceed the maximum allowances quoted above. Thus, while promoting the open planning concept and recognizing its inherent flexibility and space-saving potential, there is no policy to reduce space allowances to below that for conventional partitioned offices. However, Major Commands, BCEs, and individual designers may feel that particular situations warrant restriction to the lower end of the space allowance range.

Workstations. Workstations are individual working areas, and are usually clustered in functional arrangements along lines of communications and workflow. Mogelescu states the results of an unreferenced survey of executives conducted in the late 1960's. In the survey,

> The workstation concept was ranked high among the ten most significant post-World War II office developments, largely because of its importance in the utilization of space and the offsetting of spiralling costs (41:105).

Systems furniture is a recent term given to describe complex workstation furniture designed to improve the functionality, decor, privacy, and flexibility of workstations. Systems furniture is usually composed of the following interlocking components : movable screens or panels, to offer some visual privacy for personnel when seated and some acoustical damping; shelving for books; drawers; working surface, including space for a computer terminal; and integral task lighting, electrical and communications wiring, and power outlets.

Much of today's systems furniture is modular with many optional accessories and variations of arrangement to suit individual preferences and workflow requirements. Workstations utilizing systems furniture can also be clustered together in many different arrangements, to suit group activity needs.

Pile, in <u>Open Office Planning</u>, reviews 13 of the several hundred office furniture systems now in production (46:18-45). His main observation on the use of systems furniture is that, for any single facility, "Dedication to a particular system - all of whose components are fully interchangeable - furthers flexibility..." (46:18). Pile presents 12 case studies where open planning has been used, primarily to show that there are many ways of effectively using and arranging systems furniture, lighting, carpeting, file storage, and computer systems in an open plan office, to maximize the functionality of the space and yet provide an attractive, enjoyable working environment.

Pile issues a warning on the use of privacy screening in open planning;

> The use of systems furniture has a tendency to limit the openness of open planning, replacing truly open areas with clusters of screened units that often seem to approach the cubicles of a partitioned office. An excessive use of screen enclosures is probably the most common mistake in current open planning...[however] Even when you an 'open' plan seems to be drifting toward total enclosure, it still retains the virtues of easy flexibility, a flexibility that no conventionally partitioned office space can approach (46:16).

Demountable Wall Partitioning. Floor plans for large office functions can be designed as essentially open plan offices but partitioned into individual and small group offices using floor to ceiling wall partitions which either fix or slide into covered floor and ceiling tracks. Flexibility is still enhanced in that a number of redundant tracks are installed with the initial construction, and the users privacy and noise requirements can also be satisfied.

Air conditioning, heating, and lighting are all either in-ceiling or in-wall, electrical and communications wiring is usually floor and external fixed wall ducted. No electrical or other services are integral to the demountable walls.

In such offices the walls tend to be semi-permanent. Removal and installation usually require semi-skilled labor, and creation of additional doorways requires skilled carpentry.

For those organizations skeptical of the open planning concept but desirous of greater flexibility and reduced remodelling disruptions and costs, this type of design and construction may be an effective compromise.

Computers in Space Planning and Management.

For all but the most straight forward methods of space planning reviewed earlier in this chapter, computers are used almost exclusively because of their capacity to handle large amounts of data, generate many alternative layouts quickly and at low unit cost. Programs utilize algorithms or heuristic rules and procedures. The earlier discussion on systematic versus intuitive space planning methods highlighted the need for objectivity and thoroughness to ensure all functions, activity relationships, locational criteria, and space constraints are considered in designing or redesigning a floor plan layout. Grant states

> Systematization of approaches to design and planning has been encouraged by the development of the computer, and the temptation to try and develop computer-assisted design techniques. The computer is a harsh critic with regard to detail, thoroughness, and explicit process description; it simply does not function if these characteristics are not satisfied (26:5).

In many organizations computers are utilized effectively as drafting tools but not as design tools. Some organizations which are exceptions to this, particularly in space planning, are listed in the review of applications to follow.

The following extract from an article by Buffa, Armour, and Vollmann, entitled Allocating Facilities with CRAFT, highlights the advantages of computerized techniques in space planning. CRAFT does not generate alternatives; it only evaluates them. However, despite being developed in 1963, it is still used in conjunction with layout generator programs. Although directed at manufacturing plant application, it is equally true of the design of most facility-types:

> How can management evaluate the effectiveness of the layouts which come in from the company's industrial engineering department or from an outside engineering and architectural firm? Usually, there are only a few alternate plant layouts for management to study, although the number possible is staggering. Of the two or three alternate layouts, it may be fairly obvious which is the most effective. But what of the thousands of possibilities not presented? Management assumes that the analysts have disposed of them in their analysis, but have they? The answer in the past has been no, because it would have been too expensive to attempt to analyze any large fraction of the possible alternate layouts (8:136).

Programming languages that enable designers to translate building descriptions (including spatial arrangements) into a format capable of being transformed by computer, displayed in visual form, and evaluated in terms of some input criteria, have been under development for some 25-30 years. Computer hardware and software have been developed to utilize these capabilities. Mitchell (39) cites a study, by Hoskins made in 1973, of the requirements for the development of such systems. It concluded that the following are required for full realization of the benefits of such a system:

1. A manageable database of components whose performance standards are known and assembly conditions pre-defined, and a database structure for ease of accessing and storage;

2. Design rules for locating components;

3. Design rules for arranging spaces;

4. Activity data for specification of spaces, fittings, and finishings; and

5. Establishment of criteria for evaluation and optimization.

There exist today many programs that handle such data and act as effective design tools. Some of these have been reviewed and are presented in Appendix E. Some are systems developed by organizations for their specific use, some by academic researchers, and others for commercial purposes. Only those which available literature indicates incorporate automated space planning, evaluation, or space management packages, are included.

III. Methodology

Chapter Overview

This chapter describes the methodology used to investigate the research objectives stated in Chapter I. It describes the development of the instruments by which data on AFCE practices and perceptions was obtained, and how this data was analyzed to answer the research objectives.

General Method

Data was obtained from HQ USAF, MAJCOM, and BCE personnel, and from a review of literature. Three different means of collecting data from personnel were used. First, HQ USAF experts in Base Comprehensive Planning and Real Property Accounting were interviewed. Second, MAJCOMs were sent a letter requesting details of space planning and management policies for bases under their control. Finally, BCE Real Property and Design chiefs were surveyed for actual space planning and space management practices used at base level and for their perceptions on various related issues.

Justification of Approach

Interviews. HQ USAF/LEEVX BCP expert, Mr Phil Clark, and HQ USAF/LEERV Real Property leaders, Mr Dick Jonkers and Mr Bill Edwards, were interviewed in person for the following purposes:

1. to provide initial guidance for this research, assist in the refinement of its scope, and to provide sources for the review of literature;

2. to gain an overall appreciation of the USAF's design, planning, and real property policies dealing with facility space management issues;

3. to produce a list of planning criteria seen as important considerations when designing and managing building space;

4. to obtain background material on factors that constrain AFCE personnel from achieving high facility utilization; and

5. to construct a measure for assessing the effectiveness of methods used by base personnel to manage the use of facility space.

Being a foreign Officer, the author was unfamiliar with AFCE Design and Real Property regulations, policies, and procedures. The interviews provided a good perspective of the AFCE organization. Data produced from these interviews and follow up conversations were qualitative only and were not analyzed statistically.

Letter to MAJCOMS. A letter was sent to all MAJCOM/DEs to determine their policies on space usage issues other than that found in AFRs and AFMs. The letter also aimed to determine if MAJCOMS monitored the utilization of space on bases as directed by AFRs, and how they were able to assess whether a base was utilizing its available facilities as well as it could. A copy of the letter is in Appendix F.

Their perceptions of how base personnel designed facilities and managed existing space were also canvassed, for comparison with actual practices learned from the BCE survey.

Survey Questionnaire. Civil Engineering personnel at Air Force bases provided data on actual space management practices and perceptions via a mail survey. No similar study has previously been made, thus no database existed. A copy of the questionnaire used is in Appendix G.

The advantages and disadvantages of conducting surveys are acknowledged. Dominowski, in his book Research Methods, states that "the survey method draws the researcher's attention to the use of getting a representative sample of subjects" (19:186). He also states that, because they rely on reports of behavior rather than observations of behavior, surveys can cause bias in the information obtained (19:186-187). He adds, however, that this bias can be reduced by increasing the degree of anonymity felt by the respondent (19:184). Stone, in Research Methods in Organizational Behavior, agrees with Dominowski that an uncoded mail survey produces the maximum anonymity (56:69; 19:185).

Dominowski states that "surveys can be used simply to estimate population characteristics or to study relations between variables" (19:185). This survey did both.

Fowler, in his book Survey Research Methods, favors the personnel survey method. Among this method's many advantages, he lists its effectiveness in gaining the cooperation of respondents and the ability of the interviewer to probe for deeper, more succinct answers to complex questions (22:70). However, the time and expense required to set up and conduct such series of interviews would have exceeded that available.

Fowler lists as some of the advantages of thc telephone interview, the potential for a much shorter data collection period than either the personal or mail survey method, a better likely response rate than for a mail survey, and low costs (especially where an organizational telephone network such as AUTOVON is available). The main disadvantage is seen as the limitation on the range of response alternatives that can be offered over the telephone (22:71).

The mail survey method was chosen rather than telephone or personal interview for three reasons: first, the writer has insufficient time to visit each MAJCOM and base; second, to avoid the risk of being misunderstood by respondents during telephone conversations; and third, to permit the respondents to answer structured, subjective questions freely, honestly, and thoughtfully, with a maximum of anonymity and the flexibility to look up records and consult with others if required (22:71).

Populations

MAJCOMS. Due to the small number of MAJCOMS, all were sent the identical letter. This constituted a census of Command policies for regulating base procedures and Command procedures for monitoring base efforts.

Mail Survey. The author chose to survey Chiefs of Design (DEEE) and Chiefs of Real Property (DEER) at Continental United States (CONUS) Air Force BCE organizations. As many of the survey questions required factual responses it was felt that only one response was required from each of the two sections of each organization. For example, the methods and procedures of architectural design and space management used by BCE staff should be known by these section chiefs. Also, it was felt that these individuals would probably be, as a group, more concerned with improving their organization's effectiveness in facility utilization than their staff, and so their perceptions would be of most value.

A list of the 82 CONUS Base Civil Engineering squadrons was obtained and a separate questionnaire was sent to each of the two office bearers, giving a survey population of 164. For such a small population, a census was chosen. It was assumed that most of the population would be civilian, although confirmation of this was neither sought by, nor considered relevant to, the study. Although the names of respondents were not requested, the questionnaires were coded by hand prior to distribution to allow the author to identify the base and office for each response.

Data Collection

The MAJCOM letter sought open-ended responses only. The mail survey questionnaire was sent to the Personnel Survey Branch, Air Force Manpower and Personnel Center (AFMPC) on 24 April 1987 for approval. The approved questionnaire was given USAF survey control number 87-61, expiring 1 August 1987. The questionnaires were mailed, one to each Chief of Real Property and Chief of Design, on 2 June 1987. From the pre-distribution codings, responses were identified as being either from a Chief of Design or from a Chief of Real Property. Throughout the entire questionnaire both groups, or sub-populations, were asked to respond to the same questions whether they referred to space planning or space management issues.

The survey questionnaire was constructed in eight parts and sought to provide a mixture of quantitative and perceptual data. The first seven parts were directly related to the research objectives, while Part 8 focused on the background of the respondent. Most questions in Parts 1 to 7 provided a statement which called for a judgment or opinion. These questions requested responses on a Likert scale, from 'strongly disagree' to 'strongly agree,' as shown below.

1 = Means you _strongly disagree_ with the statement.
2 = Means you _moderately disagree_ with the statement.
3 = Means you _slightly disagree_ with the statement.
4 = Means you _neither agree nor disagree_ with the statement.
5 = Means you _slightly agree_ with the statement.
6 = Means you _moderately agree_ with the statement.
7 = Means you _strongly agree_ with the statement.

A second type of question asked respondents to make a selection from a list of independent and unordered responses such as procedures, design tools, and data sources. A third type of question provided a list of ordered, quantitative responses. Both of these types of questions required factual answers rather than perceptual.

A definition of each of the four levels of data commonly generated by surveys is provided below:

Nominal - people, organizations, events, are sorted into unordered categories with respect to a particular attribute or variable.

Ordinal - people, organizations, events, are ordered or placed in ordered categories along a single dimension with respect to a particular attribute or variable.

Interval - numbers are attached that provide meaningful information about the distance between ordered stimuli or classes.

Ratio - numbers are assigned that have absolute meaning, such as a count or measurement by an objective, physical scale such as distance, weight, or pressure (22:85).

In Parts 1 to 7, the agree-disagree questions produced interval level data, the second type generated nominal level data, and the third type generated ratio level data (actual square feet of area), although the data from these questions was treated only as ordinal in the analysis.

Sonquist and Dunkelberg, in their book Survey and Opinion Research, state that the assumptions of the Likert model "lead to a linear combination of items (eg. their sum or average) and so to an interval scale, rather than one with merely ordinal properties" (51:263). They also generalize on the adaptability of the Likert model to different research requirements -

> With enough items, Likert scales can apparently be made highly reliable, they are relatively easy to construct, and they can easily be adapted to many different types of measurement situations (51:265).

They outline various methods for constructing surveys having questions with different ranges of possible responses and subsequently normalizing them to a common range.

Fowler recognizes the prevalence of agree-disagree questions in survey research today and notes two main potential limits. First, "The statement, in order to be interpretable, must be located at the end of a continuum" (22:89), meaning that statements which describe a potential judgment or opinion that is non-committal should be avoided as they will provide unreliable responses.

Data Analysis

Letter responses to the MAJCOM letter were received and comments to the various questions posed were tabulated on word processor and compared by hand.

Survey responses were analyzed using the AFIT ASC computer system, comprising a VAX 11/785 running the UNIX operating system. The Statistical Package for the Social Sciences (SPSS) was utilized to perform a variety of statistical analyses and tests. All summary sample statistics and results of analyses and tests made using the following SPSS procedures are presented in Chapter IV with a discussion of their significance.

Research Steps for Each Research Objective

Each objective is restated below, followed by the means of researching it, those sections of the survey questionnaire which provided data for analysis, the statistical methods of analysis used, and the SPSS procedures used. Only brief explanations of statistical principles are given.

Research Objective 1.

Determine what methods are currently being used by facility designers and planners in AFCE, RAAF, and civilian organizations, to design efficient building layouts and to manage a facility's space throughout its design life.

Methods of space planning and management used by RAAF and US civilian organizations were researched and reported in Chapter II. Chapter II researched all available methods, including techniques and programs, whether they are used widely in practice or not.

A sample of the space inventory exercises that have been conducted by A-E firms as part of USAF Base Comprehensive Planning contracts and a summary of the capabilities of WIMS in the area of real property space accounting were also presented in Chapter II. A previous study by Mitnik (40) identified the amount of time spent by AFCE architects in conceptual layout planning and space allocation in relation to their other activities. It also identified the degree of Computer Aided Design (CAD) practiced in these tasks. Some of his data and conclusions are reported.

The letter to MAJCOMs requested more specific data on methods of space planning and management used by BCE personnel, including the extent of use of computers for these purposes. MAJCOM responses to the questions asked are reported and are subjectively compared to the survey questionnaire responses in order to assess whether specific methods are recognized and promoted throughout the USAF.

Part 1 of the survey questionnaire contained 13 questions. Of these, questions 3, 6, 9, 11, 12, and 13 were directed at determining the methods that are actually practiced in AFCE.

Questions 1, 2, 4, and 5 sought perceptions of the adequacy of AFRs and AFMs in providing guidance to BCE personnel but the responses to these questions were not used in the data analysis as they could not be related directly to any of the research objectives. In later sections Questions 33 and 37 were also related to space management methods.

Question 3 referred to the level of intuition used by respondents when designing a new floorplan layout or redesigning the layout of an existing facility. It was assumed that both groups are involved to some extent in layout activities in the course of their duties. In order to determine if intuition is used more in space planning by real property personnel than by designers, an independent samples t-test was carried.

The purpose of this test is to see if the true group or sub-population means are significantly different statistically (52:267). Without a 100 percent response rate true population mean responses to individual questions cannot be obtained. The independent samples t-test compares the means of the two samples and allows the researcher to make a statistical inference as to the equality of the two true group means, according to the level of significance chosen by the researcher. A hypothesis can be made as follows:

$$H_o : \mu_1 = \mu_2$$

and

$$H_a : \mu_1 \neq \mu_2$$

where

H_o = the hypothesis that the true mean of group 1 (ie. μ_1) is equal to the true mean for group 2 (μ_2)
H_a = the alternate hypothesis that the two true group means are not equal

The sample means and variances and the t-statistic are computed. The probability p that the true difference in the means will be higher than the absolute value of the t-statistic or lower than its negative value is computed. If this probability is lower than the level of significance α chosen, then the hypothesis H_o is rejected in favor of H_a.

The level of significance is defined as the least value of p that is accepted as reasonably being caused by chance or sample variability and thus for which H_o is accepted (44:268; 18:102-104). It can be thought of as the probability of making a Type I error, that is, rejecting H_o when it is true. A level of significance of 0.1 was chosen for all statistical tests conducted in the course of this research, and all were tests of means. As the data analyzed dealt mainly with broad methods used by, and perceptions of, the population, it was not considered essential to ensure a lower probability of making a Type I error. If p is greater than α (ie. if $p>\alpha$) this does not mean that H_o is true, but that there is insufficient evidence to reject it. If p is less than α (ie. if $p<\alpha$) then there is sufficient evidence to reject H_o in favor of H_o. This procedure is known as a two-sided t-test.

Alternatively, the hypothesis may be one-sided. That is, the alternate hypothesis can be that the true mean of one group's responses is either lower or higher than the true mean of the other group. An example is:

$$H_o : \mu_1 = \mu_2$$

and $$H_a : \mu_1 < \mu_2$$

In this case, H_o is rejected if p is less than $\alpha/2$ (ie. if $p < \alpha/2$) as we are interested in only one side of the probability distribution.

The SPSS procedure T-TEST was used to conduct independent sample t-tests of the mean responses of the two groups to questions 3, 6, and 9. The hypotheses tested for questions 3 and 6 were:

$$H_o : \mu_1 = \mu_2$$

and

$$H_a : \mu_1 < \mu_2$$

where

μ_1 = the true mean of responses from Design Chiefs
μ_2 = the true mean of responses from Real Property Chiefs

The alternate hypotheses H_a state: 1) for question 3, that Design personnel rely less on intuition than do Real Property personnel when laying out floor plans for either new or existing facilities, and 2) for question 6, that Design personnel perceive Real Property personnel as having less responsibility for the redesign of existing facility layouts than is perceived by real property personnel themselves.

The hypothesis tested for question 9 was:

$$H_o : \mu_1 = \mu_2$$

and

$$H_a : \mu_1 > \mu_2$$

where μ_1 and μ_2 are defined above.

In this case the alternate hypothesis H_a is that Design Chiefs perceive that architectural design expertise is more readily provided to redesign layouts in existing facilities than is perceived by Real Property Chiefs.

The SPSS procedure FREQUENCIES was used to calculate response frequency distributions and sample statistics such as the mean, median, mode, and standard deviation for responses to all questions. Questions 12 and 13 sought to establish what general floorplan design methods are used by AFCE building designers and real property managers. Question 11 sought to establish what general methods are used by organizations to assess whether or not a user is utilizing his space effectively. All three questions produced nominal level data and the their frequency distributions and modes are reported.

The SPSS precedure CROSSTABS was used to analyze question 12 and 13 responses, to establish if there is a significant difference in floorplan layout methods used by the two groups of respondents. As the data was nominal, the Chi-square statistic was used.

The CROSSTABS procedure tabulates the responses into two-way contingency tables. It computes the cell frequencies which would be expected if no relationship is present between two classificatory level variables and compares these with the actual cell frequencies produced in the table. The greater the discrepancies between the expected and actual cell frequencies, the larger will be the Chi-square statistic. Small values for Chi-square are interpreted as indicating no relationship, or statistical independence (52:218-224).

The Chi-square test hypothesizes independence. The probability of obtaining a higher value of the Chi-square statistic than that calculated if the variables are independent, is found. If this probability is smaller than the level of significance α (0.1), then the hypothesis of independence is rejected. In this case the Chi-square statistic is said to be statistically significant at level α and we can conclude that the variables are dependent (52:224). A probability greater than α indicates independence.

CROSSTABS was also run with the coded group number and question 11 responses in order to determine if there is dependence between the two groups and the perception of what general methods are used by their organizations to manage existing facility space.

Research Objective 2.

> Determine the effectiveness of such methods, and make recommendations to assist AFCE in making the most of its building space resources.

The interviews of HQ USAF personnel and the letter to MAJCOMS attempted to determine a quantitative means of measuring the effectiveness of CONUS bases in laying out and managing its facility space. The survey questionnaire later combined quantitative questions with perceptual questions in order to produce this measure.

Although Part 2 of the questionnaire contained seven questions, only questions 18 and 19 were considered during the analysis as objectively indicating the effectiveness of an organization's efforts to maximize the utilization of its facility space. Question 10 from Part 1 and questions 52 and 53 from Part 6 were also considered to objectively indicate effectiveness. Question 14 measured self-rated organizational effectiveness and question 15 measured perceived effectiveness of the Air Force as a whole, and so neither were considered appropriate for inclusion into an objective multi-item measure. A measure of organizational effectiveness in utilizing facility space was created by combining the responses to questions 10, 18, 19, 52, and 53. As these questions were a mixture of agree-disagree and quantitative questions requiring an interval level response, responses to questions 19, 52, and 53 were recoded to permit direct summation with the Likert scale responses of questions 10 and 18.

For question 19, a building space surplus of over 100,000 SF was seen as equivalent to 'strongly disagree' on the Likert scale with respect to effectiveness. A surplus of less than 20,000 SF was taken as equivalent to 'strongly agree'. The intervening responses were recoded in rough proportion. For questions 52 and 53, paragraph 13-3 of AFM 86-2 states that the acceptable space allowance for net office area per building occupant in administrative facilities is 80-90 SF. Thus, a response of 90 SF to either question would be equivalent to 'neither agree nor disagree' on the Likert scale with respect to effectiveness, 75 SF or less would indicate 'strongly agree', and more than 90 SF would indicate 'slightly disagree'. Other responses were recoded proportionally.

Before the measure was used to analyze other data, it was tested for reliability. Reliability, in this case, is synonomous with internal consistency, dependability, stability, predictability, and accuracy (56:44). Stone, in Research Methods in Organizational Behavior, describes reliability as "the degree to which measurement of any attribute contains error" (56:44). The less error contained in the measure, the more reliable it is as a measure of the construct or attribute in question.

The reliability coefficient chosen to indicate the internal consistency of the measure of effectiveness and all other measures in this research was Cronbach's alpha. This coefficient is an indicator of how well each pair of variables in a measure correlate with each other. Steel (55) uses the heuristic (rule of thumb) guide in Table II to assess the reliability of a measure:

Table II

Heuristic for Determining the
Reliability of a Measure (55)

Cronbach's alpha	Assessment
0.70 - 0.79	Fair Reliability
0.80 - 0.89	Good Reliability
0.90 - 1.00	Excellent Reliability

The SPSS procedure RELIABILITY was used to calculate Cronbach's alpha. It also produced a table of alpha values for the measure if each variable was separately deleted from the measure. These values indicated which variable(s) detracted from thw measure's reliability and should therefor be removed from the measure. In this manner, the measure of effectiveness and other measures were tested and modified to obtain the maximum reliability for each before using the measure in further statistical tests.

Stone states that the reliability of a measure places an upper limit on its correlation with any other measure. The observed correlation between two measures having less than perfect reliability (that is, 1.00), will equal the product of their 'true' correlation and the square root of the product of their respective reliabilities (56:50). This means that the observed correlation between two measures will be considerably lower than their true correlation if one or both measures have a low reliability. The Chapter V analysis accounts for this when evaluating the strengths of relationships between measures and variables based on Pearson r correlation coefficients.

Summary statistics of the measure of effectiveness were computed using the FREQUENCIES procedure. The relative effectiveness of the various design and space management methods used by AFCE organizations were determined using the SPSS procedure ANOVA. The population was broken down into groups according to their responses to questions 11 and 12, and the true mean effectiveness of each group's organizations were compared using the following hypothesis:

$$H_o : \mu_1 = \mu_2 = \dots = \mu_n$$

and H_a : At least two of these means are unequal

where n is the number of methods offered as responses to questions 11 or 12. A high F statistic with a low associated probability ($p<0.1$), indicates that the hypothesis can be rejected and that at least two of the means are significantly different.

Finally, the perceived effectiveness of AFCE organizations in planning and managing the utilization of their base facilities was hypothesized to be different for each of the two groups. The T-TEST procedure was again used to determine if there is a difference in effectiveness between the two groups' responses. The hypothesis was:

$$H_o : \mu_1 = \mu_2$$

and

$$H_a : \mu_1 \neq \mu_2$$

where

μ_1 = the true mean effectiveness as perceived by Design Chiefs

μ_2 = the true mean effectiveness as perceived by Real Property Chiefs

This t-test was performed on three measures: 1) the multiple item measure of space utilization effectiveness, 2) the question 14 measure of self-rated effectiveness, and 3) the question 15 measure of perceived Air Force wide effectiveness.

Research Objective 3.

> Gather perceptions of AFCE facilities design and real property planning personnel on the comprehensiveness, accuracy, and accessibility of the data that is collected to manage the utilization of building space, and determine if there is a relationship between these factors and the effectiveness of their efforts.

The survey questionnaire, primarily at Part 3, asked BCE personnel if they thought that the data collected to assess building utilization was comprehensive, accurate with reregard to the true effective utilization of a building's space, and if it was readily accessible.

Measures for three constructs - comprehensiveness, accuracy, and accessibility of the data - were constructed by summing responses to questions into multi-item scales, as follows:

a. Comprehensiveness - questions 21, 25, 28, and 29.

b. Accuracy - questions 8, 16, 22, 26, and 29

c. Accessibility - questions 17, 24, and 27

Responses to questions 8, 26, and 29 were recoded to reverse the negativity of these questions. The SPSS procedure RELIABILITY was used to determine the reliability of each measure and to improve it by deleting any variables which did not correlate well with others in the measure.

Summary statistics for these measures were produced using the FREQUENCIES procedure and the means are reported. The T-TEST procedure was used to compare the perceptions of Design Chiefs with those of Real Property Chiefs on all three constructs. The hypothesis, for each construct, was:

$$H_o : \mu_1 = \mu_2$$

and

$$H_a : \mu_1 \neq \mu_2$$

where

μ_1 = the true mean as perceived by Chiefs of Design
μ_2 = the true mean as perceived by Chiefs of Real Property

These multi-item measures were correlated with the measure of effectiveness developed for research objective 2 in order to determine if these three constructs were related to the effectiveness of organizations in utilizing their facility space. The SPSS procedure PEARSON CORR was used for this purpose. _SPSS - Statistical Package for the Social Sciences_ states that the Pearson correlation coefficient r is used to measure the strength of relationship between two interval level variables. Also, when r is squared, it indicates the proportion of variance in one variable explained by the other (44:280).

As referenced earlier in this chapter, Likert-scale questions do produce interval-level data (51:263). The multi-item scales were composed of Likert-scale questions and the resultant summed data is thus also interval-level. The Pearson r coefficients are reported, together with a subjective analysis of the strength of the relationships according to the heuristic scale presented in Table III (12):

Table III

Heuristic for Determining the Strength of Relationship Between Two Variables Based on Pearson r (12)

Absolute value of 'r'	Strength of Relationship
1.0	Perfect
0.8 - 0.99	Very strong
0.6 - 0.79	Strong
0.4 - 0.59	Moderate
0.2 - 0.39	Weak
0.01 - 0.19	No relationship

Question 31 sought to establish the degree of computerization in the maintenance of AFCE real property databases. In order to assess if this had any relationship to the organizations' effectiveness in utilizing its facility space, the ANOVA procedure was used to detect any statistical difference in the mean effectiveness of the four groups as categorized by question 31. Here, the hypothesis was:

$$H_o : \mu_1 = \mu_2 = \mu_3 = \mu_4$$

and H_a : At least two of these means are unequal

where

μ_1 = the true mean space utilization effectiveness of organizations using WIMS for real property database management

μ_2 = the true mean effectiveness of organizations using DBMS software on personal computers for real property database management

μ_3 = the true mean effectiveness of organizations using manual records for real property database management

μ_4 = the true mean effectiveness of organizations using BEAMS for real property database management

Question 31 did not initially incorporate a fourth possible response for BEAMS. A significant number of respondents pencilled in BEAMS, so this was added during the analysis of data.

Similar applications of the ANOVA procedure were made to determine if there appears to be a relationship between the type of real property data management system used and the comprehensiveness, accuracy, and accessibility of the data produced by that system. The data produced by the three multi-item measures of comprehensiveness, accuracy, and accessibility was divided into four groups, as classified by question 31. The means of comprehensiveness, accuracy, and accessibility for each of these groups were compared to detect any significant differences. The hypotheses for the three tests are as follows:

$$H_o : \mu_1 = \mu_2 = \mu_3 = \mu_4$$

and H_a : At least two of these means are unequal

where

μ_1 = the true mean comprehensiveness, accuracy, or acessibility of real property data for organizations using WIMS for real property database management

μ_2 = the true mean comprehensiveness, accuracy, or acessibility of organizations using DBMS software on personal computers for real property database management

μ_3 = the true mean comprehensiveness, accuracy, or acessibility of organizations using manual records for real property database management

μ_4 = the true mean comprehensiveness, accuracy, or acessibility of organizations using BEAMS for real property database management

All Pearson r coefficients produced and the results of the ANOVA and T-TEST procedures are reported.

Research Objective 4

Determine who actually controls the utilization of building space on USAF installations. What roles do the Base Civil Engineer (BCE) and the Facilities Board (FB) have in this task? Do unit commanders manage the use of space within their own allocated buildings, or is this function also performed centrally to coordinate all base requirements?

Part 4 of the questionnaire addressed each of these questions directly. Although regulations state that the FB controls the use of all facilities, the BCE must receive and coordinate requests for space, suggest and evaluate alternative means of satisfying these requests, make recommendations to the FB, budget for new construction and modifications, program the work, and implement the decisions of the board.

Since BCE personnel are involved with all stages of this process, it is possible that a BCE who perceives this task as his responsibility and whose FB trust his recommendations, will have a greater control over space allocation and be more successful in finding accommodation for new requirements as they arise.

With the exception of questions 37 and 40, all Part 4 questions (34 to 42) were combined to form a multi-item measure of the perceived degree of BCE control over space allocation within USAF facilities. Questions 35, 36, 39, and 42 were recoded to ensure that low values on the Likert scale corresponded to a respondent's perception that the BCE had little control over space allocation, and that high values corresponded to the perception that the BCE had good control.

The SPSS procedure RELIABILITY was used to improve the reliability of this measure by deleting any variables not correlating well with others in the measure. The summary statistics for the final combined measure are reported.

The T-TEST procedure was used to determine whether this perception varied between design and real property chiefs. The hypothesis was:

$$H_o : \mu_1 = \mu_2$$

and

$$H_a : \mu_1 \neq \mu_2$$

where

μ_1 = the true mean of summed responses from Design Chiefs

μ_2 = the true mean of summed responses from the Chiefs of Real Property

The PEARSON CORR procedure was used to determine if a relationship existed between the perceived level of BCE control and the organizations' effectiveness at utilizing its facility space. A Pearson r coefficient was obtained for this relationship by correlating these two multi-item measures. All T-TEST results and the Pearson r coefficient are reported.

Research Objective 5.

Determine what constraints there are to the effective management of building space.

Part 5 of the questionnaire was directed at identifying these constraints. From personal experience a list of possible constraints was composed and framed as statements for respondents to consider. These were:

a. the age and condition of facilities - question 43;

b. the difficulty in physically separating surplus space from a user's approved space allocation - question 44;

c. the relative availability of Operation and Maintenance (O&M) funds and Military Construction Program (MCP) funds - question 45;

d. the difficulty in assessing the effectiveness of a facility's utilization - question 46;

e. the lack of funds for modifications required to make surplus space functional - question 47;

f. building habitability - question 48;

g. disruption of user operations during rearrangement and alteration - question 50; and

h. user objections to sharing facilities with other users - question 51.

During data analysis it was decided that question 43 was badly worded and responses did not indicate whether a respondent perceived age and condition to be a constraint, so this question was not used. A response on the upper side of the Likert scale (that is, in the 'agree' range), for questions 44, 45, 46, 47, and 51, was taken as meaning that the constraint is considered real to the extent indicated. For questions 48 and 50 a low response was taken as indicating that the constraint is considered real.

Research Objective 6.

Construct a list of planning factors involved in the redistribution of building space.

Part 6 of the questionnaire listed possible planning factors, or criteria, for consideration by BCE personnel when either designing floor layouts or redistributing existing space between users. As in research objective 5, they were framed as statements for respondents to consider. These criteria were:

a. allowable 'net office area' per building occupant for new office accommodation design purposes - question 52;

b. allowable 'net office area' per building occupant used for redistributing space for offices in existing accommodation - question 53;

c. the need for proximity between related activities - question 54;

d. the cost of satisfying user requirements for space - question 55;

e. minimization of low use and circulation areas - question 56;

f. subsequent flexibility of the layout (cost and ease of making later modifications) - question 57;

g. use of open plan design as a means of enhancing flexibility and reducing subsequent costs - questions 58 and 59;

h. the importance of facilitating circulation (flow of personnel) through a facility - question 60; and

i. the speed of fulfilling the space requirement - question 61.

Sample statistics for the responses to each of these questions are reported.

The first two of these factors have a large impact on space utilization. MAJCOMs agreed in their responses to the author's letter that a per person net office area allowance of less than 75 SF of net office area causes overcrowding. AFM 86-2 suggests that 80-90 SF be used as a planning figure.

An allowance of over 90 SF could indicate underutilization of space.

Due to the constraints imposed by using existing buildings to house functions for which they were not designed, it was expected that the space allowance used for renovating and re-using existing facilities (question 53) would exceed that for use in planning new facilities (question 52). This was tested using the T-TEST procedure. A paired samples t-test was made because the mean responses of the overall population to two different questions were being compared rather than the different groups' responses to the same question, as was the case with all previous independent-sample t-tests. The hypothesis was:

$$H_o : \mu_1 = \mu_2$$

and $$H_a : \mu_1 < \mu_2$$

where

μ_1 = the true population mean response to question 52
μ_2 = the true population mean response to question 53

The probability associated with the resulting t-statistic was interpreted in the same way as for the independent samples t-test. Questions 52 and 53 produced at least interval level data.

As with the constraints in research objective 5, a response in the `agree' range to the other Part 6 questions (54 to 61) signify that respondents feel that these possible factors <u>are</u> important.

Research Objective 7.

> Determine what effort is actually made to consider the possible reallocation and/or rehabilitation of existing building space as an alternative to new construction.

As stated in Chapter I, if all possible means of accommodating a requirement from within existing facilities are considered, then unnecessary new construction may be avoided.

Part 7 of the questionnaire requested respondents to outline the steps that are taken by their organization to satisfy new requirements for space. Statements were provided concerning the respective roles of Real Property and Design Sections in the requirement review process, and in the formulation and evaluation of alternative means of accommodating these requirements.

Questions 62 to 68 were of the Likert scale agree-disagree type. High responses were interpreted as meaning that these possible steps are actually taken to evaluate space requirements and to select the best course of action. The magnitude of the response was interpreted as indicating the degree to which these steps are institutionalized as standard practices. Responses to question 64 were not used in the analysis as the statement did not present a position close to the end of a continuum as recommended by Fowler (22:89).

Question 69 is a classificatory question which provided a selection of four possible responses. It sought to determine the population's perceptions of the most important criterion used by USAF base management in determining whether to redistribute existing space (and possibly renovate it) or to construct new facility space, when faced with a requirement. The CROSSTABS procedure was used to establish if the perceptions of Real Property Chiefs and Design Chiefs as to the most important criterion are similar. The Chi-square statistic and the associated probability of exceeding it were used determine whether or not the perceptions of these two groups are dependent.

Sample statistics for all Part 7 questions and the Chi-square statistic are reported.

IV. Results

Chapter Overview

This chapter presents the data collected from the two survey instruments and the results of the statistical tests described in Chapter III. First, frequency distributions for responses to all demographic, classificatory and multi-level quantitative questions are presented. Next, for all questions requiring a response on the seven level agree-disagree Likert scale, the sample means and standard deviations are given. The results of the statistical tests outlined in Chapter III for each of the seven research objectives are then reported. A selection of written comments by survey respondents is then presented, followed by written responses to questions in the letter to MAJCOM/DEs.

Presentation of Findings of Survey Questionnaire

Survey Response. A letter hastening responses was sent on 12 June 1987. From 164 questionnaires distributed, 89 responses were received by the cut-off date of 16 July 1987, giving a response rate of approximately 54 percent of the population. From the two sub-populations of 82 Chiefs of Real Property and 82 Chiefs of Design, 52 and 37 responses respectively were received. This constituted response rates of 63 and 45 percent. Seeing that a census was taken of the population rather than a sample, this overall response rate is sufficient to infer population characteristics.

As the number of responses from each sub-population were both greater than 30, the Central Limit Theorem permitted analysis of the survey data using statistical tests which assume that the data is normally distributed.

Responses to each of the survey questions by the respondents are in the computer generated list in Appendix H. Missing data was excluded from analysis by setting the number of responses to each individual question as the sample size for that question.

Demographic Data. Questions 70, 71, 72, and the pre-distribution codings established the duties and academic background of respondents. Frequency distributions are presented in Tables IV, V, VI and VII. From Table IV, the distribution of the 22 'other' responses to Question 70 is given in Table VIII.

Classificatory Questions. Questions 11, 12, 13, 31, 32, 33, and 69 required a selection from a range of independent responses. The question is repeated followed by the frequency distributions, in Tables IX to XIV.

Table IV

Undergraduate Degree of Survey Respondents

Degree	Number	Percent
Architecture	8	9.0
Town/City/Urban Planning	0	0
Civil Engineering *	23	25.8
Mechanical Engineering	4	4.5
Other Engineering	10	11.2
Building Sciences	2	2.2
Other	22	24.7
None	18	20.2
- No response -	2	2.2
Total	89	

* Mode

Table V

Current Primary Duty of Survey Respondents

Duty	Number	Percent
Architectural Design	6	6.7
Real Property Management *	46	51.7
Engineering Management	29	32.6
Other	6	6.7
- No response -	2	2.2
Total	89	

* Mode

Table VI

Years Experience in Current Primary Duty

Years	Number	Percent
1 yr or less	4	4.5
Between 1 and 2 yrs	2	2.2
Between 2 and 3 yrs	3	3.4
Between 3 and 4 yrs	3	3.4
4 yrs or more *	75	84.3
- No response -	2	2.2
Total	89	

* Mode

Table VII

Distribution of Respondents by Discipline

Chief of:	Number	Percent
Design	37	41.6
Real Property *	52	58.4
Total	89	

* Mode

Table VIII

Distribution of 'Other' Responses from Table IV

Degree	Number	Percent (of total)
Real Property/Real Estate	8	9.0
Business Admin./Real Estate *	9	10.1
English major	1	1.1
Psychology major	1	1.1
Education/Business Admin.	1	1.1
Accounting	1	1.1
Foreign Languages	1	1.1
Total	22	

* Mode

Table IX

Distribution of Methods Used to Assess Underutilization of Facility Space (Survey Question 11)

Response	Number	Percent
Known occupancy/allowances of AFM 86-2 *	29	32.6
Known occupancy/equipment space req'ts	11	12.4
Visiting buildings/subjective assessment	19	21.3
Personal knowledge of base facilities and the relative efficiency of their usage	10	11.2
Other	17	19.1
- No response -	3	3.4
Total	89	

* Mode

Table X

Distribution of Design Tools Used for Floorplan Layout (Survey Question 12)

Response	Number	Percent
Some type of computer software	0	
Bubble diagrams	18	22.8
Functional Relationship chart	15	16.9
AFM 88-2 standard designs	10	11.2
Linear programming	0	
Intuition and experience *	30	33.7
Other	6	6.7
- No response -	10	11.2
Total	89	

* Mode

Table XI

Distribution of Computer Usage
for Floorplan Layout
(Survey Question 13)

Response	Number	Percent
CADkey on a PC	0	0
AutoCAD on a PC	3	3.4
VersaCAD or EasyCAD on a PC	0	0
WANG AutoCAD on WIMS	1	1.1
Some other CAD software on PC	1	1.1
A computer programming language	0	0
Linear programming software	0	0
No computer *	72	93.5
- No response -	12	13.5
Total	89	

* Mode

Table XII

Distribution of Automation of Real Property
and Building Databases
(Survey Questions 31 and 32)

Question 31. Is the Real Property database in your office computerized?

Question 32. Is the building information database in your office computerized?

Response	Number		Percent	
	Q31	Q32	Q31	Q32
Yes - WIMS *	40	33	44.9	37.1
Yes - Database Management software on PC	23	14	25.8	15.7
No - Manual records	14	30	15.7	33.7
Yes - BEAMS	8	7	9.0	7.9
- No response -	4	5	4.5	5.6
Totals	89	89		

* Mode for both questions

Table XIII

Distribution of Methods Used to Update Space Utilization Records (Survey Question 33)

Response	Number	Per cent
Regular building visits by BCE personnel *	35	39.3
Regular BCE surveys of building managers	11	12.4
There is no 'system' for collecting data	28	31.5
Other	7	7.9
- No response -	8	9.0
Total	89	

* Mode

Table XIV

Distribution of Most Used Criterion for Deciding How to Best Satisfy Space Requirements (Survey Question 69)

<u>Question 69</u>. Which of the following possible responses best describes the criterion most used to make decisions on whether to renovate, lease, or construct a new facility?

Response	Number	Percent
A cost analysis of all possible alternatives	16	18.0
Relative availability of MCP and O&M funds	17	19.1
Base politics	18	20.2
The best interests of mission fulfillment *	29	32.6
- No Response-	9	10.1
Total	89	

* Mode

Quantitative Questions. Frequency distributions, modes, and means for responses to questions 19, 20, 52, and 53 are presented in Tables XV and XVI.

Table XV

Distribution of Building Space Deficiencies and Surpluses (Survey Questions 19 and 20)

Question 19. My base has a list of building space surpluses totalling approximately:

Question 20. My base has a list of approved but currently unsatisfied requirements for building space totalling approximately:

Responses	Number		Percent	
	Q19	Q20	Q19	Q20
Less than 20,000 SF *	62	19	69.7	21.3
Between 20,000 and 40,000 SF	4	8	4.5	9.0
Between 40,000 and 60,000 SF	1	6	1.1	6.7
Between 60,000 and 80,000 SF	0	8	0	9.0
Between 80,000 and 100,000 SF	2	10	2.2	11.2
Over 100,000 SF **	4	22	4.5	24.7
- No response	16	16	18.0	18.0
Totals	89	89		

Modes	Means	Standard Deviations
Q19 - *	Q19 - 1.466	Q19 - 1.313
Q20 - **	Q20 - 3.658	Q20 - 2.036

Table XVI

Distribution of Net Office Area Planning Criteria
(Survey Questions 52 and 53)

<u>Question 52</u>. What "net office area per building occupant" (as defined at AFM 86-2, para 13-3) is used at your base for planning space requirements for <u>new</u> administrative facilities?

<u>Question 53</u>. What "net office area per building occupant" is used at your base for managing and redistributing space in <u>existing</u> administrative facilities?

Responses	Number		Percent	
	Q52	Q53	Q52	Q53
Less than 75 SF	4	5	4.5	5.6
75 SF	2	3	2.2	3.4
80 SF	5	7	5.6	7.9
85 SF	9	9	10.1	10.1
90 SF	38	27	42.7	30.3
More than 90 SF	17	24	19.1	27.0
No Response	14	14	15.7	15.7
Totals	89	89		

<u>Modes</u>	<u>Means</u>	<u>Standard Deviations</u>
Q52 - 90 SF	Q52 - 4.680	Q52 - 1.275
Q53 - 90 SF	Q53 - 4.627	Q53 - 1.459

<u>Agree-Disagree Questions</u>. These questions are repeated, with the mean response and standard deviation. Responses were on the following scale.

1 = Strongly disagree
2 = Moderately disagree
3 = Slightly disagree
4 = Neither agree nor disagree
5 = Slightly agree
6 = Moderately agree
7 = Strongly agree

1. Design regulations provide adequate guidelines for ensuring that architects/planners minimize space wastage in floor layout.

Mean = 4.012 Std dev = 1.787

2. Functional relationships are the most important criteria in building layout design.

Mean = 5.631 Std dev = 1.360

3. I rely on my intuition to come up with an initial conceptual floorplan layout when designing a new building or reallocating space in an existing building.

Mean = 3.576 Std dev = 1.898

4. The use of standard designs (AFM 88-2) does not permit designers to tailor a facility to the needs of individual users.

Mean = 3.915 Std dev = 2.007

5. Real Property regulations adequately cover how to monitor building usage.

Mean = 3.709 Std dev = 2.097

6. Real Property personnel in my organization are responsible for determining required changes to the physical layout of functions within existing buildings.

Mean = 2.460 Std dev = 1.999

7. Space utilization studies of existing facilities are carried out regularly, even if there are no requirements to satisfy.

Mean = 3.186 Std dev = 2.183

8. Our Real Property records do not indicate how efficiently a user is using the space that he has been allocated.

Mean = 5.977 Std dev = 1.594

9. Architect or engineer assistance is provided only on request by Real Property personnel, which is usually if building modifications are required, or if the functional layout problem is particularly complex.

Mean = 4.756 Std dev = 2.158

10. If space is <u>known</u> to be underutilized or used for some unapproved or wasteful purpose, action is usually taken to reallocate it.

Mean = 4.483 Std dev = 2.214

14. My organization manages the use of installation building space as well as possible, considering the constraints imposed.

Mean = 5.352 Std dev = 1.736

15. The USAF manages the utilization of its building space well.

Mean = 3.898 Std dev = 1.598

16. Our real property records usually track building usage well.

Mean = 4.580 Std dev = 1.916

17. Space surplus to a user's requirements can be readily identified.

Mean = 4.000 Std dev = 2.011

18. In most cases, surplus space can be modified to satisfy some outstanding requirement.

Mean = 4.977 Std dev = 1.851

21. New requirements data is usually detailed enough to allow Real Property personnel to look for a suitable accommodation.

Mean = 3.593 Std dev = 1.843

22. Summary data on all outstanding requirements is available from a single source, without having to look through individual hardcopy project files.

Mean = 3.226 Std dev = 1.947

23. The data we keep on utilization of existing building space is accurate enough to tentatively match a requirement to it.

Mean = 4.471 Std dev = 1.743

24. Available building space is readily identifiable from real property records.

Mean = 4.235 Std dev = 2.158

25. Our records list functions located within all buildings.

Mean = 5.247 Std dev = 1.920

26. Surplus space is usually identified by building users.

Mean = 2.337 Std dev = 1.913

27. Up to date building usage data is usually available when needed by planners and designers.

Mean = 4.477 Std dev = 2.033

28. It is important to have current data on the number of personnel working in a facility, and the layout of equipment.

Mean = 5.859 Std dev = 1.521

29. Real Property records do not contain enough information to conduct a detailed analysis of efficient space usage within facilities.

Mean = 5.198 Std dev = 1.807

30. Space that is known to be misused or wasted is recorded as such, either in real property reports or on file, for possible future re-allocation should the need arise.

Mean = 3.616 Std dev = 2.104

34. It is primarily the BCE's responsibility to ensure that building space is utilized effectively.

Mean = 4.279 Std dev = 2.389

35. It is the Facilities Board's (FB) responsibility to ensure that building space is utilized effectively.

Mean = 5.407 Std dev = 2.060

36. Major tenants on this installation are reasonably free to decide how they use space within their allocated buildings.

Mean = 5.535 Std dev = 1.992

37. BCE personnel systematically visit every base facility to reassess utilization.

Mean = 4.453 Std dev = 2.045

38. The BCE actually decides how space will be allocated.

Mean = 3.070 Std dev = 2.238

39. The FB makes the decisions on the allocation of space.

Mean = 5.384 Std dev = 2.030

40. The BCE implements the FB's decisions.

Mean = 6.221 Std dev = 1.384

41. The BCE influences the FB's decisions - they usually accept his recommendations.

Mean = 5.256 Std dev = 1.653

42. We have a Space Allocations Panel (or similar) composed of tenant representatives, which acts as a forum for analyzing space shortage problems, identifying possible solutions, and recommending action.

Mean = 3.859 Std dev = 2.587

43. Structurally unsound or maintenance-intensive buildings are often renovated and used beyond their intended design life.

Mean = 5.105 Std dev = 2.064

44. It is often impractical to physically separate a user's 'surplus' space from his 'approved' space such that it can accommodate another requirement.

Mean = 5.605 Std dev = 1.625

45. It is easier to fund the renovation or modification of an existing old building to satisfy a new requirement, albeit unsound or maintenance-intensive, than to obtain MCP funds to construct a new facility.

Mean = 6.235 Std dev = 1.394

46. It is often difficult to assess if space within a building is utilized well.

Mean = 4.919 Std dev = 1.960

47. Insufficient funds are available to modify <u>all</u> surplus space to make suitable for other requirements.

Mean = 5.788 Std dev = 1.619

48. The effective utilization of building space is more important than building habitability, should the two conflict.

Mean = 3.847 Std dev = 2.073

49. Building modifications associated with space re-allocation often cause disruptions to user operations.

Mean = 5.337 Std dev = 1.546

50. The negative operational effects of disruptions caused by space re-allocations are outweighed by the benefits of utilizing space more effectively.

Mean = 4.988 Std dev = 1.842

51. Allocating one facility to more than one organization often causes problems for all users.

Mean = 4.200 Std dev = 1.876

54. Activities within a building should be located according to their need for proximity.

Mean = 5.651 Std dev = 1.578

55. Building modifications associated with space re-allocation are more economical than new construction.

Mean = 4.558 Std dev = 1.656

56. Net usable space should be maximized. Circulation and low use areas should be minimized.

Mean = 5.884 Std dev = 1.323

57. Building design should include features that minimize the potential cost of future extensions or modification.

Mean = 6.151 Std dev = 1.260

58. Open plan designs maximize the ease involved in the possible future rearrangement due to changing functions and relationships.

Mean = 6.047 Std dev = 1.308

59. Open plan design should be used for office and work areas wherever possible.

Mean = 5.424 Std dev = 1.930

60. Building layout should maximize the orderly flow of personnel through the building and minimize unnecessary traffic through main working areas.

Mean = 6.558 Std dev = 1.058

61. The availability of suitable space for renovation will usually enable a requirement to be satisfied quicker than by new construction.

Mean = 5.919 Std dev = 1.573

62. When a new requirement for space is received it is staffed first by Real Property personnel.

Mean = 4.541 Std dev = 2.398

63. The requirement is checked against AFM 86-2 to ensure that the request is in accordance with space entitlements.

Mean = 5.906 Std dev = 1.586

64. Space already allocated to a low priority use is sometimes re-allocated to a new requirement with a higher operational priority.

Mean = 5.071 Std dev = 1.713

65. A cost analysis is usually done to assess whether to renovate existing space, extend an existing facility, construct a new facility, or lease space - whichever are feasible.

Mean = 4.447 Std dev = 2.050

66. Real Property personnel always attempt to find suitable space available within existing facilities before recommending new construction.

Mean = 5.812 Std dev = 1.763

67. Prior to deciding if an identified surplus space is suitable for a particular requirement, a site visit is usually made.

Mean = 6.314 Std dev = 1.313

68. The prospective user of a re-allocated space takes an active role in assessing its suitability for his requirement.

Mean = 6.412 Std dev = 0.890

Statistical Tests. The results of all statistical tests conducted using the survey questionnaire data are reported in order of the research objective which they support.

Research Objective 1.

Determine what methods are currently being used by facility designers and planners in AFCE, RAAF, and civilian organizations, to design efficient building layouts and to manage a facility's space throughout its design life.

Comparison of the mean reliance of Design and Real Property Chiefs on intuition when planning floor layouts for new or existing buildings (Question 3) is shown below.

Group	Number	Mean
Design	37	3.568
Real Property	48	3.583
	----	-------
Combined	85	3.576
t= -0.04	Probability, p= 0.970	

As p>0.05 (that is, $\alpha/2$), the hypothesis that intuition is equally relied on by both groups is not rejected at the 0.1 level.

Comparison of the mean perceptions of Design and Real Property Chiefs regarding the level of responsibility held by Real Property Sections for the redesign of existing facility layouts (Question 6) is shown below.

Group	Number	Mean
Design	37	1.730
Real Property	50	3.000
	----	-------
Combined	87	2.460
t= -3.35	Probability, p= 0.001	

As p<0.05, the hypothesis that the groups agree on the level of responsibility held by Real Property Sections is rejected at the 0.1 level.

The comparison of the mean perceptions of Design and Real Property Chiefs regarding the level of assistance given by architects within the Design section to Real Property personnel in the redesign of existing floor layouts (Question 9) resulted as shown below.

Group	Number	Mean
Design	36	4.750
Real Property	50	4.760
	----	-------
Combined	86	4.756

t= -0.02 Probability, p= 0.983

As p>0.05, the hypothesis that the groups agree on the level of assistance given by Design staff is not rejected at the 0.1 level.

Crosstabulation of the two sub-populations with design tools that could possibly be used in floor plan layout (Question 12) yielded the following contingency table:

	Bubble Diagram	Relation-ship chart	AFM 88-2	Exper-ience	Other	ROW TOTALS
Design	11	6	5	11	3	36 (45.6%)
Real Prop	7	9	5	19	3	43 (54.4%)
COL TOTALS	18 (22.8%)	15 (19.0%)	10 (12.7%)	30 (38.0%)	6 (7.6%)	79 (100%)

The Chi-square statistic, obtained by the comparison of expected cell values with actual cell values, and the associated probability of exceeding it if the variables are independent, were:

Chi-square = 3.02573 Probability = 0.5535

As p>0.1, the hypothesis that the sub-population and the design tool preference are independent variables is not rejected at the 0.1 level.

Crosstabulation of the two sub-populations with methods which could be used assess the effectiveness of a facility's space utilization (Question 11) produced the following contingency table:

	AFM 86-2	Occupancy & Equip	Visits	Personal Knowledge	Other	ROW TOT
Design	9	9	5	5	9	37 (43.0%)
Real Prop	20	2	14	5	8	49 (57.0%)
COL TOT	29 (33.7%)	11 (12.8%)	19 (22.1%)	10 (11.6%)	17 (19.8%)	86 (100%)

The Chi-square statistic and associated probability were:

Chi-square = 11.49840 Probability = 0.0215

As p<0.1 the hypothesis, that the sub-population and the assessment method perceived as being used are independent variables, is rejected at the 0.1 level.

Research Objective 2.

> Determine the effectiveness of such methods [of space planning and space management], and make recommendations to assist AFCE in making the most of its building space resources.

Input from HQ USAF/LEE experts and MAJCOM/DEs was solicited to construct a measure for assessing a base's effectiveness in utilizing its building space. Mr Dick Jonkers (HQ USAF/LEER) agreed that a comparison of surplus building space with outstanding requirements for building space may be a good indicator of a base's ability to manage its space and to effect timely relocations and renovations. Hard data on space surpluses and deficiencies from BCE records was sought to measure this.

The responses to question 19 indicate a mean building space surplus of less than 20,000 square feet. The accuracy of responses to this question depends upon the accuracy of the data kept in the BCE records. If underutilized space is considered as partially surplus to the user's requirements then the accuracy of real property data on surplus space depends on the capability of Real Property personnel assess utilization. The responses to question 20 indicate a mean but variable building space deficiency of between 40,000 and 60,000 square feet (SF) per base.

The difficulty in assessing if space is utilized well was measured by question 46. The response indicates that there is general agreement that assessing utilization is difficult. This casts some doubt on the accuracy of question

19 responses on buiding space surpluses. However, as no more accurate data on surplus space was available, question 19 was included initially in the measure of effectiveness.

The proposed measure of effectiveness using questions 10, 18, 19, 52, and 53, was found to be unreliable. It returned a Cronbach's alpha of only 0.30, which is too low by Steel's heuristic (Table II) to rate any degree of reliability at all. Withdrawing from the measure question 19, which dealt with the quantity of building surpluses, improved the reliability marginally to 0.42.

After responses to questions 52 and 53 were recoded, they were summed directly with the Likert scale responses to questions 10 and 18 as discussed in Chapter III. This produced a multiple item Likert scale measure of space utilization effectiveness with the following main divisions.

4 = Strongly disagree
8 = Moderately disagree
12 = Slightly disagree
16 = Neither agree nor disagree
20 = Slightly agree
24 = Moderately agree
28 = Strongly agree

The mean and standard deviation for the combined responses to this multiple item measure were:

Mean = 16.716 Std dev = 5.015

To determine if there is a true difference between Design and Real Property Chiefs' perceptions of the effectiveness of their base's efforts to utilize building space well, their mean responses to the objective multiple item measure were compared followed by their responses to the self-rated measure at question 14. The results are shown below.

1. Multiple item measure of effectiveness.

Group	Number	Mean
Design	37	14.081
Real Property	51	18.628
	----	--------
Combined	88	16.716

t= -4.47 Probability, p= 0.000

2. Self-rated effectiveness.

Group	Number	Mean
Design	37	4.892
Real Property	51	5.686
	----	-------
Combined	88	5.352

t= -2.16 Probability, p= 0.033

In each case p<0.1 and thus the hypotheses that both groups equally perceive their organizations' effectiveness, is rejected.

The perceptions of Design and Real Property Chiefs on Air Force wide effectiveness at utilizing space (Question 15) were compared. The result is shown below.

Group	Number	Mean
Design	37	3.622
Real Property	51	4.098
	----	-------
Combined	88	3.898

t= -1.39 Probability, p= 0.169

As $p>0.1$ the hypothesis, that the perceptions of the two sub-populations on the effectiveness building space utilization Air Force wide are the same, is not rejected.

The population was then divided into five groups according to their preferred method of assessing whether a facility is underutilized (Question 11). The effectiveness of these space assessment methods was tested using the measure of effectiveness constructed previously. The F statistic and associated probability resulting from this comparison of five means is shown below.

$F = 1.515$ Probability = 0.206

As $p>0.1$, the hypothesis that the methods are equally effective is not rejected.

A similar test was constructed to assess if there is any difference in the effectiveness of a base's space utilization as a result of the space planning design tool used (Question 12). The result is shown below.

$F = 2.881$ Probability = 0.031

As $p<0.1$, the hypothesis that the methods are equally effective is rejected.

Research Objective 3.

> Gather perceptions of AFCE facilities design and real property planning personnel on the comprehensiveness, accuracy, and accessibility of the data that is collected to manage the utilization of building space, and determine if there is a relationship between these factors and the effectiveness of their efforts.

Measures of real property database comprehensiveness, accuracy, and accessibility were constructed in the same way as the measure of effectiveness in research objective 2.

Comprehensiveness. Questions 21, 22, 25, 28, and 29 were used initially. This measure was found to be unreliable, by Steel's heuristic (Table II), returning a Cronbach's alpha coefficient of 0.54. Withdrawing from the measure question 28, which dealt with the need for the BCE to know personnel numbers and equipment quantities and layouts for all facilities, improved the measure's reliability marginally to 0.62.

The main Likert scale divisions for this measure, and the means and standard deviations of the combined responses are:

4 = Strongly disagree	20 = Slightly agree
8 = Moderately disagree	24 = Moderately agree
12 = Slightly disagree	28 = Strongly agree
16 = Neither agree nor disagree	

Mean = 14.733 Std dev = 5.230

Accuracy. Questions 8, 16, 23, 26, and 30 were used initially. This measure was also found to be unreliable, returning a Cronbach's alpha of 0.34. Withdrawing from the measure question 26, which asked whether buiding users identified surplus space, improved the reliability considerably to 0.59.

The main Likert scale divisions for this measure, and the means and standard deviations of the combined responses are:

4 = Strongly disagree
8 = Moderately disagree
12 = Slightly disagree
16 = Neither agree nor disagree
20 = Slightly agree
24 = Moderately agree
28 = Strongly agree

Mean = 14.109 Std dev = 4.996

<u>Accessibility</u>. Questions 17, 24, and 27 were used for this measure. It was found to be 'fairly reliable', returning a Cronbach's alpha of 0.77. No improvement could be made.

The main Likert scale divisions for this measure, and the means and standard deviations of the combined responses are:

3 = Strongly disagree
6 = Moderately disagree
9 = Slightly disagree
12 = Neither agree nor disagree
15 = Slightly agree
18 = Moderately agree
21 = Strongly agree

Mean = 12.466 Std dev = 5.188

The means of the responses by Design and Real Property personnel to each of these constructs were compared to determine if any significant differences in their perceptions existed. The results are shown below.

1. Comprehensiveness

Group	Number	Mean
Design	35	13.200
Real Property	51	15.784
	----	--------
Combined	86	14.733

t= -2.31 Probability, p= 0.023

2. Accuracy

Group	Number	Mean
Design	37	12.351
Real Property	51	15.902
	----	--------
Combined	88	19.943

t= -3.50 Probability, p= 0.001

3. Accessibility

Group	Number	Mean
Design	37	10.432
Real Property	51	13.941
	----	--------
Combined	88	12.466

t= -3.31 Probability, p= 0.001

In all cases $p<0.05$ signifying that all three hypotheses are rejected at the 0.1 level.

Pearson correlation coefficients (r) were generated to determine the strengths of relationships between a base's effectiveness at utilizing its building space and the perceived comprehensiveness, accuracy, and accessibility of the base's real property data. These coefficients were as follows:

	Observed Correlation
Effectiveness with comprehensiveness	0.36
Effectiveness with accuracy	0.46
Effectiveness with accessibility	0.42

The Chapter V data analysis examines these correlations with respect to the reliabilities of each measure.

A series of four tests were then performed. The population was divided into four groups according to the type of real property database automation used at their bases: 1) WIMS; 2) BEAMS; 3) Database Management Software (DBMS) using a personal computer; or 4) Manual records (Question 31). The tests compared group means to assess whether the type of real property database automation makes a significant difference in :

1. the effectiveness of a base's space utilization efforts;
2. the perceived comprehensiveness of real property data;
3. the perceived accuracy of real property data; or
4. the perceived accessibility of real property data.

In each case it was hypothesized that the mean responses of Design and Real Property Chiefs were equal. The results are given below.

Test	F statistic	Probability
Type of automation vs. Space Utilization Effectiveness	1.714	0.171
Type of automation vs. Comprehensiveness	0.007	0.999
Type of automation vs. Accuracy	0.192	0.902
Type of automation vs. Accessibility	0.103	0.958

As $p>0.1$ in all cases, there is insufficient evidence to reject any of the four hypotheses.

Research Objective 4.

> Determine who actually controls the utilization of building space on USAF installations. What roles do the Base Civil Engineer (BCE) and the Facilities Board (FB) have in this task? Do unit commanders manage the use of space within their own allocated buildings, or is this function also performed centrally to coordinate all base requirements?

The multiple item measure of the perceived degree of BCE control over facility space allocation was initially a direct summation of responses to survey questions 34, 35, 36, 38, 39, 41 and 42 after responses to questions 35, 36, 39, and 42 were recoded. It was found to be unreliable, returning a Cronbach's alpha of 0.32 although when applied only to Design Chiefs responses it returned a alpha of 0.65. It proved totally unreliable for the Real Property Chiefs responses, returning a negative alpha. Withdrawing questions

41 and 42 from the measure improved the overall reliability of this measure to 0.45.

The main Likert scale divisions and the mean and standard deviation of the measure are shown below.

5 = Strongly disagree
10 = Moderately disagree
15 = Slightly disagree
20 = Neither agree nor disagree
25 = Slightly agree
30 = Moderately agree
35 = Strongly agree

Mean = 15.302 Std dev = 6.097

The mean of this measure for the Design Chiefs' responses was compared to the mean for the Real Property Chiefs' responses. The result is shown below.

Group	Number	Mean
Design	35	14.629
Real Property	51	15.765
Combined	86	15.302

t= -0.85 Probability, p= 0.399

As p>0.1 there is no evidence to support the rejection of the hypothesis that the means are equal, at the 0.1 level.

The Pearson correlation coefficient generated by correlating the level of BCE control over space allocation with a base's effectiveness in utilizing its building space was -0.0002. The Chapter V data analysis examines this correlation with respect to the reliabilities of the two measures.

The responses to question 36, whether major facility users are reasonably free to decide how they will use their allocated space, had a mean of 5.535 on the seven point Likert scale.

Research Objective 5.

Determine what constraints there are to the effective management of building space.

Questions 44 to 51 required an agree-disagree response to assess whether respondents felt the statements expressed a valid constraint to the effective management of building space. The means and standard deviations of responses to these questions are restated below.

Question	Mean	Std dev
44	5.605	1.625
45	6.235	1.394
46	4.919	1.960
47	5.788	1.619
48	3.847	2.073
50	4.988	1.942
51	4.200	1.876

Research Objective 6.

Construct a list of planning factors involved in the redistribution of building space.

Questions 54 to 61 required an agree-disagree response to assess whether respondents felt the statements identified planning factors which are or should be used when redistributing building space between users. The means and standard deviations of these responses are restated below.

	Question	Mean	Std dev
54.	Need for proximity	5.651	1.578
55.	Modifications are more economical than new construction	4.558	1.656
56.	Maximize net usable space	5.884	1.323
57.	Minimize future extension/ modification costs	6.151	1.260
58.	Open plan design enhances flexibility	6.047	1.308
59.	Use open plan design wherever possible	5.424	1.930
60.	Maximize the orderly flow of personnel	6.558	1.058
61.	Satisfy requirement as quickly as possible	5.919	1.573

A paired samples comparison of the mean responses to questions 58 and 59 was made. It was hypothesized that the means are equal, the alternate hypothesis being that they are unequal. The result is shown below.

	Question	Number of Responses to both questions	Mean
58.	Open plan designs maximize the ease of performing future rearrangements.	85	6.047
59.	Open plan designs should be used for office and work areas wherever possible.		5.423

$t = 4.07$ Probability, $p = 0.000$

As $p < 0.1$ the hypothesis is rejected at the 0.1 level.

Quantitative planning factors were sought by questions 52 and 53. The means and standard deviations of the responses to these questions are restated below.

	Question	Mean	Std dev
52.	"Net office" area/personnel ratio for design of new office accommodation.	4.680	1.225
53.	"Net office" area/personnel ratio for redesigning existing facilities as offices.	4.627	1.459

where the scale used was:

1.	Less than 75 SF	4.	85 SF
2.	75 SF	5.	90 SF
3.	80 SF	6.	More than 90 SF

Comparison of these two means using a paired samples t-test resulted as follows:

Factor	Number of Responses to both questions	Mean
'Net office' area/person ratio used for new design	73	4.726
'Net office' area/person ratio used for redesign		4.616

t = 1.00 Probability, p = 0.321

As p>0.05, there is insufficient evidence to reject, at the 0.1 level, the hypthesis that the two ratios are equal.

Research Objective 7.

Determine what effort is actually made to consider the possible reallocation and/or rehabilitation of existing building space as an alternative to new construction.

Questions 62, 63, 65, 66, 67, and 68 requested an agree-disagree response on steps that may be taken by BCE organizations to satisfy a new requirement for building space. The means and standard deviations of the responses are restated below:

Question	Mean	Std dev
62. Initial staffing by Real Property	4.541	2.299
63. Check requirement against AFM 86-2	5.906	1.586
65. Cost analysis of alternatives	4.447	2.050
66. Satisfaction from within existing facilities if possible	5.812	1.760
67. Site visit to assess suitability of proposed space	6.314	1.313
68. Participation of user in space suitability	6.412	0.899

Four possible criteria which might be used to make decisions on whether to lease, renovate, or construct a facility in order to satisfy a space requirement were crosstabulated with the sub-populations. The following contingency table was produced.

Decision-making Criteria

	Cost Analysis	Funds Source	Base Politics	Mission Fulfillment	ROW TOTALS
Design	5	11	9	7	32 (40%)
Real Prop	11	6	9	22	48 (60%)
COL TOTALS	16 (20.0%)	17 (21.3%)	18 (22.5%)	29 (36.3%)	80 (100%)

The Chi-square statistic and associated probability were:

Chi-square = 8.8756   Probability, $p = 0.0643$

As $p<0.1$, the hypothesis that the perception of the most important decision-making criterion is independent of the sub-population is not rejected at the 0.1 level.

Comments by Survey Questionnaire Respondents. Comments were sought periodically throughout the questionnaire. A selection of those received are in Appendix I.

MAJCOM Responses to Survey Letter

From 12 MAJCOMs surveyed, one (HQ AFCC) sent a nil response due to a lack of knowledge by the author that that Command did not exercise direct control over any USAF bases. Written responses were received from HQ TAC/DE, HQ USAFE/DE, HQ SAC/DE, HQ ATC/DE, and HQ AFSC/DE, and an invitation was extended by HQ AFLC/DE for the author to conduct a series of informal interviews in lieu of a written response.

Responses by MAJCOM/DEs to each of the questions in the Appendix F letter are listed in Appendix J. Not all questions were answered by each MAJCOM. Due to their length, some of the responses have been paraphrased.

V. Analysis and Discussion

Chapter Overview

This chapter contains an analysis of the data collected by the survey questionnaire and the survey letter to MAJCOM/DEs. Each research objective is analyzed separately, and analysis is based largely on the results of the SPSS procedures described in Chapter III. MAJCOM responses are discussed in relation to each objective where applicable, in order to establish agreement or disagreement between MAJCOMs and between MAJCOMs and bases regarding actual Air Force Civil Engineering (AFCE) practices in space planning and space management.

Research Objective 1

> Determine what methods are currently being used by facility designers and planners in AFCE, RAAF, and civilian organizations, to design efficient building layouts and to manage a facility's space throughout its design life.

Chapter II reviewed space planning and space management techniques developed and used by academicians, A-E firms, and other organizations. The more complex design techniques are computer oriented, due to the repetitive and rigorous mathematical requirements of satisfying many functional relationships and other criteria when positioning and dimensioning floor spaces.

The responses to the letter sent to MAJCOMs (Appendix J) indicate that BCE personnel do not have a great deal of expertise in planning layouts systematically, and that A-E firms are usually contracted for this purpose if required. Most MAJCOMs indicated that some of their bases had acquired, or were in the process of acquiring, CAD systems. However, none indicated that the systems, whether Intergraph or a PC based system such as CadKey or AutoCAD, were being used for space planning purposes.

MAJCOMs lack specific knowledge on the application of these systems by BCEs for architectural design. HQ TAC alone advised that none of its bases use CAD for floorplan layout. Also, no MAJCOM indicated any plan, intent, or need to introduce CAD as a WIMS application package, although they accept and promote the purchase and use of stand alone CAD systems and CAD software for WANG computer hardware.

The survey questionnaire responses in Chapter IV indicate that although 50 percent of the respondents have laid out floor plans for buildings using bubble diagrams, relationship charts, or definitive designs, less than 6 percent (all architectural design personnel) have used CAD for this purpose (Tables X and XI). This result supports the MAJCOM feeling that CAD is not used by AFCE personnel for space planning.

As for space management, HQ ATC and HQ AFSC recognize that A-E firms have expertise in conducting large scale space surveys, but HQ ATC indicated that base personnel can adequately conduct such surveys, assess space requirements, and reallocate space according to base priorities. Most MAJCOMs indicated that although Real Property personnel in BCE organizations have the expertise to do such surveys, manpower availability restricts their efforts to the support of specific projects, primarily weapons systems bed-downs. HQ USAFE alone indicated that it had a program for monitoring facility utilization on its bases on a regular basis.

Responses to questions 10, 14, and 16 of the survey questionnaire (see Chapter IV) indicate that respondents believe BCE organizations generally manage facility space usage well despite the numerous comments (listed in Appendix I) that Real Property sections are undermanned and lack the resources to undertake regular utilization surveys.

The reliance of Design and Real Property Chiefs on intuition and experience when planning floor layouts was compared. The results indicated that Design Chiefs do not rely significantly less on intuition than do Real Property Chiefs.

The perceptions of Design and Real Property Chiefs regarding the level of responsibility held by Real Property Sections for the redesign of existing facility layouts were compared. The result indicated that Design Chiefs perceive the Real Property Section as having a significantly lower responsibility for redesigning floor layouts for existing facilities than is perceived by Real Property Chiefs. The low combined mean response signifies that Real Property Sections generally have a low degree of responsibility for this activity.

The perceptions of Design and Real Property Chiefs regarding the level of assistance given by architects within the Design Section to Real Property personnel when redesigning existing facility floor layouts were compared. The result indicates that Design Chiefs and Real Property Chiefs have similar perceptions of the level of assistance given. The mean response is greater than 4.0, signifying that respondents agree that Design Section assistance is given. This result, combined with the result of the previous test, indicates Design Sections generally hold more responsibility for redesigning floor layouts for existing facilities, in support of renovation and relocation projects, than do Real Property Sections.

33.7 percent of the population use primarily intuition and experience to design floorplans; that is, no 'method' at all (Table X). Design tools used by the population in floorplan layout are, in order of preference: Bubble Diagrams, Relationship Charts, and Definitive Designs. These design tools were cross tabulated with the two sub-populations. The results indicate that there is no relationship between the sub-population and the design tool preference, or that they are statistically independent.

The use of computers by AFCE personnel in floorplan layout is almost non-existent. Table XI shows only three respondents (all Design Chiefs) have used computers for this. None have used linear programming techniques, and only five have ever used a CAD software package. As 75 percent of the contingency table cells had frequencies less than five, the Chi-square statistic and associated probability cannot be used to indicate the presence of a relationship between sub-population and the use of computers for space planning. The result of this test is not valid and is not reported.

Methods used by BCEs to assess whether space is utilized effectively in facilities are shown in Table IX. The two most common methods are: 1) a straight comparison of known building occupancy with the space allowances of AFM 86-2, and 2) subjective assessments made by BCE personnel by visiting a building.

The two sub-populations were crosstabulated with possible methods perceived by personnel as being used to assess the effectiveness of a facility's space utilization. The results indicate a relationship between the sub-population and the perceived method used, or that they are statistically dependent at the 0.1 level. This result not only shows which methods Real Property personnel actually use, but also that Design Chiefs may not all be fully aware of how utilization is assessed at their bases.

Research Objective 2

> Determine the effectiveness of such methods [of space planning and space management], and make recommendations to assist AFCE in making the most of its building space resources.

The data indicates a mean building space surplus per base of less than 20,000 square feet. The accuracy of responses to this question depends upon the accuracy of the data kept in the BCE records. If underutilized space is considered as partially surplus to the user's requirements then the accuracy of real property data on surplus space depends on the capability of Real Property personnel to assess utilization.

It was generally agreed that assessing utilization of a facility's space is difficult. This casts some doubt on the accuracy of building space surpluses reported.

The measure used to assess a base's effectiveness at utilizing its building space was not reliable, even after one variable was withdrawn. This indicates either a bad choice of survey questions aimed at measuring effectiveness or that this construct is difficult to measure. The measure was used despite its unreliability.

There is a significant difference between the two sub-populations' perceptions of the effectiveness of their base's space utilization measured by both the multiple item measure and the self-rated measures. These results indicate that Real Property Chiefs perceive their bases' space utilization effectiveness to be higher than is perceived by Design Chiefs.

No difference was indicated in the perceptions of the two sub-populations on the effectiveness of facility space utilization Air Force wide. While both sub-populations perceive that their bases manage building space better than do other USAF bases, either Design Chiefs tend to underrate or Real Property Chiefs tend to overrate their own bases' effectiveness.

The comparison of respondents' preferred methods for assessing a facility's space utilization does not indicate any difference in the effectiveness of the methods. This suggests that the choice of method does not affect a base's space utilization effectiveness.

The comparison of respondents' preferred space planning design tool indicates at least two of the group means are statistically different. This suggests that the choice of design tool for laying out floorplans does have some impact on the effectiveness of a base's efforts to utilize its building space well. The tool resulting in the highest effectiveness cannot be determined from this result.

Research Objective 3

> Gather perceptions of AFCE facilities design and real property planning personnel on the comprehensiveness, accuracy, and accessibility of the data that is collected to manage the utilization of building space, and determine if there is a relationship between these factors and the effectiveness of their efforts.

The measures of real property data comprehensiveness and accuracy proved to be unreliable, by Steel's heuristic (Table II). The measure of accessibility proved 'fairly' reliable.

Using these measures, the comparison of Design and Real Property Chiefs' perceptions of real property data indicates that Design Chiefs perceive it to be significantly less comprehensive, accurate, and accessible than do Real Property Chiefs.

The observed Pearson correlation coefficients (r) that were generated between the measures of effectiveness and comprehensiveness, accuracy, and accessibility must be analyzed in conjunction with the reliabilities of these measures. Using the method of correction for unreliability of measures outlined by Stone (56:50), the 'true' correlation coefficients are as follows:

	Observed Corr	True Corr
Effectiveness with comprehensiveness	0.36	0.69
Effectiveness with accuracy	0.46	0.92
Effectiveness with accessibility	0.42	0.74

According to Davis' rule of thumb guide in Table III, the relationships between effectiveness and comprehensiveness, and effectiveness and accessibility, can be classified as 'strong'. The relationship between effectiveness and accuracy can be classified as 'very strong'. This indicates that one way to increase the effectiveness of building space utilization is to improve the comprehensiveness, accuracy, and accessibility of the BCE's real property data.

The comparison of the types of real property database automation used by the organization (that is, WIMS, BEAMS, DBMS software on Personal Computer, and Manual Records) indicates no significant differences in the space utilization effectiveness or the perceived comprehensiveness, accuracy, and accessibility of the real property database as a result of the use of any method.

Research Objective 4

> Determine who actually controls the utilization of building space on USAF installations. What roles do the Base Civil Engineer (BCE) and the Facilities Board (FB) have in this task? Do unit commanders manage the use of space within their own allocated buildings, or is this function also performed centrally to coordinate all base requirements?

The measure constructed for determining the extent of BCE control over space allocation within base facilities proved to be unreliable, using Steel's heuristic (Table II). While proving 'fairly' reliable for Design Chiefs' responses, it proved totally unreliable for Real Property Chiefs' responses. Nevertheless, it was used in subsequent statistical tests.

The comparison of Design and Real Property Chiefs' responses for this measure indicates that there is no significant difference in the perceptions of Design and Real

Property Chiefs regarding the level of BCE control over facility space allocation on USAF bases.

The Pearson correlation coefficient between the measure of BCE control over space allocation and the measure of base's effectiveness in utilizing its building space was examined with respect to the unreliability of both measures. Correcting the correlation to allow for the unreliability of the two measures, using the technique outlined by Stone (56:50), returned a 'true' correlation of -0.0005. This result indicates no relationship using Davis' heuristic (Table II).

The high mean response to question 31 indicates that major facility users are reasonably free to decide how they will use their allocated space. This suggests that Facility Boards delegate the responsibility of ensuring effective utilization of facility space to unit commanders.

Research Objective 5

> Determine what constraints there are to the effective management of building space.

The low mean response to question 48 indicates that building habitability is not considered a constraint. For the other questions, responses indicate that they are considered to be real. The responses to the other survey questions which sought to identify constraints indicate the following, in descending order of agreement, to be constraints to the effective management of building space:

1. the relative availability of Operations and Maintenance (O&M) funds;

2. the lack of funds for modifications required to better utilize surplus space;

3. the difficulty in physically separating surplus space from a user's approved space allocation;

4. the disruption of user operations during rearrangement and renovation; and

5. the difficulty in assessing the effectiveness of a facility's utilization.

From the written comments received both from questionnaire respondents and MAJCOMs, it was apparent that there was strong support for including the lack of manning in Real Property Sections as a constraint to effective management of facility space.

<u>Research Objective 6</u>

> Construct a list of planning factors involved in the redistribution of building space.

The responses to survey questions which sought to establish planning factors which are or should be used when redistributing building space between users, identified the following factors in descending order of importance:

1. the orderly flow of personnel through a facility;

2. minimization of potential costs of future extensions or modifications;

3. the use of open plan designs;

4. construction methods that increase flexibility and minimize future modification costs;

5. minimization of low use and circulation areas, and the maximization of net usable space; and

6. the location of activities within a building according to their need for proximity;

The result of the paired samples comparison of the two survey questions which dealt with open plan design as a planning tool for space redistribution (Questions 58 and 59) was interesting. It indicates a statistically significant difference between: 1) the level of recognition by the population that open plan design enhances flexibility, and 2) the willingness of the population to use the concept wherever possible.

Responses to the two quantitative planning factor questions indicate that the 'net office' area per person ratios used when designing new office accommodation and when redesigning existing facilities as offices are both within the limits of 80-90 SF set by AFM 86-2, Chapter 13. The factor used for redesigning existing spaces as office accommodation is slightly lower but has a greater variability than that used for designing new office accommodation. This indicates that AFM 86-2 may not be seen as being as mandatorily applicable to redesign. This may be caused by the additional constraints placed on designing renovations by the characteristics of existing spaces.

The result of the paired samples comparison the two 'net office' area per person ratios indicates no statistically significant difference between that used when designing new office accommodation and that used when redesigning existing facilities as offices.

The MAJCOM responses to the survey letter indicate the AFM 86-2 guidelines are supported by MAJCOMs. However, they also indicate that where open planning and systems furniture are used in office accommodation, the area/personnel ratios should be decreased below the guidelines in accordance with Engineering Technical Letter 86-12, Pre-wired Work Stations and Systems Furniture. This may have caused both ratios to be lower than 90 SF, the upper limit set by AFM 86-2.

Research Objective 7

> Determine what effort is actually made to consider the possible reallocation and/or rehabilitation of existing building space as an alternative to new construction.

Responses to the survey questions which sought to identify steps that are taken by BCE organizations to satisfy a new requirement for building space indicate that the most common steps are, in descending order:

1. Inclusion of the prospective user of a space in the assessment of its suitability for his requirement;

2. Visiting a building before assessing its suitability to fulfil a requirement;

3. Checking of the requirement against AFM 86-2 allowances to determine its validity; and

4. Attempting to satisfy the requirement from within existing facilities before recommending new construction.

From this result it appears that customer service ranks high in the BCE's priorities when satisfying requirements for building space. It appears that cost analyses of alternative means of satisfying the requirement (that is; leasing, renovation, new construction, compression of other functions are conducted. However, this step is not regarded as being as important as any of the other steps suggested by the author.

The crosstabulation of decision-making criteria with sub-population indicates that the criterion considered to be most important when deciding how to best satisfy a space requirement is statistically dependent on the sub-population. The criterion seen as most important is 'Mission Fulfillment', which indicates mission requirements have a greater influence over these decisions than cost or base politics.

This supports the MAJCOM responses in Appendix J. However, the modal response for Design Chiefs was the relative availability of MCP and O&M funds. This may indicate Design Chiefs are more concerned with the practicalities of ensuring a project can be funded than are Real Property Chiefs.

VI. Summary, Conclusions and Recommendations

Chapter Overview

This chapter summarizes the main points of this study and draws conclusions, from the literature review and data analysis, about the space planning and space management practices of the RAAF and USAF. It contains recommendations for changes to the space planning policies and practices of both the RAAF and USAF to improve facility utilization and minimize new construction. Conclusions and recommendations on RAAF practices are based on lessons learned from the analysis of USAF methods and on the author's subjective comparison with RAAF methods. Recommendations for further research on both RAAF and USAF practices are also suggested.

Conclusions

RAAF. No specific data was collected on actual space management practices at different RAAF bases, but a review of regulations and guidelines for facility design and for Real Property Accounting was made in Chapter II. Conclusions are based on this review, the review of non-military literature, and the author's personal knowledge of practices.

Prior to the design of a RAAF facility, Air Force Office (AFO) project officers from the Director-General Facilities - Air Force (DGF-AF) construct Bubble Diagrams and/or Relationship Charts as part of the Functional Design Brief

(FDB) process. These provide design guidance to Department of Housing and Construction (DHC) architects when laying out facility floor plans. Design of government buildings is a DHC responsibility and no further input at this stage by a client Department is considered appropriate. However, the formulation of these diagrams and charts is an important part of the client's brief to DHC as they describe the intended operation of the facility by the user.

There is no instruction on the use of Bubble Diagrams and Relationship Charts. Most Facilities Officers are civil engineers and the only architectural expertise they have is acquired on the job. As a result, the best use of these powerful design tools is often not made. Space needs are not always assessed accurately from user input, especially where equipment purchases are involved from another funding source and equipment details such as dimensions, weight, and utility requirements are not known. Functional relationships and lines of written and oral communication between unit personnel are not always established accurately at this stage.

DHC architects do not appear to use any particular design method such as Systematic Layout Planning (SLP), computer space planning programs, or CAD. Design reviews between DHC, DGF-AF Project Officers, AFC specialist Officers, and prospective base facility users often lead to substantial reconfiguring of preliminary floor layouts.

Although DGF-AF cannot control DHC architectural practices, a thorough assessment of space requirements, determination of relationships, and knowledge of the SLP process by DGF-AF project officers would ensure that DHC architects have an accurate perception of the RAAF's intended operations within a facility. It would also give DGF-AF greater control over a building's design by permitting less architectural licence.

Master Planning of RAAF Bases is also a DHC responsibility, although DGF-AF provides guidance on the long-term facilities requirements and developmental criteria. Future requirements are usually descriptive only, with little quantitative forecasting of personnel numbers and facility space needs. Space surveys are not a requirement of Master Planning exercises although recommendations are made on the Master Plan drawings as to which existing facilities should remain and which should be demolished within the specified developmental time frame.

A RAAF Base's annual Facility Usage Schedule is the only document produced which progressively reports facility utilization. No breakdown of space is reported, there is no indication of how effectively the space is being used, and no assessment of space which is surplus to valid user requirements. There is thus no database of existing or underutilized space which can be called upon to formulate and evaluate alternatives when attempting to satisfy new requirements. An investigation of possible existing available space is required whenever a new requirement is proposed. The outcomes of such investigations rely heavily on Facilities Officers' personal knowledge of, and familiarity with, facility utilization at that particular base.

Most bases have no Facilities Board to control utilization and allocate space. Base management initiates requests for the 'change in use' of a facility, but DGF-AF must approve them. Base Facilities Officers must obtain the support of their Commanding Officers (and sometimes of Command staff and DGF-AF himself) to have space reallocated from one unit to another if mis-use or underutilization is suspected. The RAAF has no usable space management guidelines or procedures.

USAF. The USAF is responsible for the architectural design of its facilities and for the Comprehensive Planning of its bases' long term facilities development. Although much of this work is done by consultants, Air Force Civil Engineering (AFCE) can exercise full control over design and planning as consultants are contracted directly by the Air Force. Base Civil Engineer (BCE) organizations have personnel trained in architectural design and in real property management.

The following conclusions on AFCE facility layout design and space management practices are drawn from the analysis of data collected from MAJCOM DEE and BCE Design and Real

Property Chiefs by the two survey instruments. The input of these Section Chiefs is considered to accurately represent base practices as these personnel are directly responsible for the actions of their staffs in the design of Air Force facilities and in managing Air Force facility space. These conclusions are:

1. Even though Bubble Diagrams, Relationship Charts, and AFM 88-2 definitive drawings are considered design tools, they are widely used by both Design and Real Property personnel (53 percent) when laying out floorplans for new facilities and when renovating or reallocating space within existing facilities. Real Property personnel do participate in designing new floor layouts for existing facilities and perceive themselves as having a significantly greater responsibility for this activity than do Design personnel.

2. About 40 percent of the population rely on [illegible] and experience to create floorplans. However, no [illegible] was found to suggest that Real Property personnel [illegible] this task any more intuitively than do Design [illegible]

3. Although widespread in A-E firms [illegible] institutions, computers are not widely [illegible] planning purposes. Possible reas[illegible] 1) a lack of knowledge of availab[illegible] space planning programs, and [illegible] 2) the belief that [illegible] warranted for the f[illegible]

AD-A188 273 AN ANALYSIS OF METHODS FOR MAXIMIZING THE UTILIZATION OF SPACE IN USAF FACILITIES(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST J P QUINN 3/4

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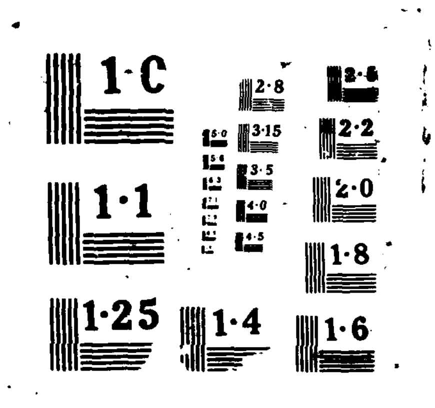
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designers; and 3) a lack of interest of personnel to develop an expertise in this specialized area.

4. There is no evidence that the choice of floorplan layout design tool used at a base is an indicator of how well building space is used. However, there is evidence that the choice of utilization data gathering and assessment method affects how well space is utilized. This research did not establish which methods lead to the most effective utilization of facility space.

5. Design and Real Property personnel's perceptions of methods used to track and assess how effectively space is used, are significantly different. Real Property personnel actually perform this activity and should therefore present the more accurate picture of methods used. It appears then that some Design Chiefs may not take an active interest in the long term effective use of a facility's space.

6. Design and Real Property personnel agree that the effectiveness of a user's utilization of a facility is difficult to assess. There is considerable support within both groups and from MAJCOM/DEs that Real Property Sections generally lack the necessary manpower to accomplish the amount of data gathering required to assess utilization accurately. While space utilization records are kept, they are not perceived as being particularly comprehensive, accurate, or accessible. Design Chiefs perceive them to be significantly less comprehensive, accurate, and accessible

than do Real Property Chiefs. This indicates that the data gathered and reported by Real Property personnel on existing facilities is seen as inadequate for use by Design personnel.

7. Space utilization surveys are usually carried out when the need exists, usually to support a proposal for new construction, or to identify existing available space that may satisfy a requirement. Base-wide surveys are usually carried out by A-E firms to support Base Comprehensive Planning studies or by a Site Activation Task Force (SATAF), or similar Air Force team, to identify base facilities that could be surrendered by users to accommodate weapons system bed-downs.

8. The AFR 87-2 requirement that MAJCOM/DEs should continually evaluate the effectiveness of space utilization at their bases and compress spaces assigned to activities (16: para 2) is not being carried out. Most MAJCOMs feel that this a base responsibility and it is delegated to the BCE and Facilities Board.

9. Real Property personnel perceive that their bases use their available facility space more effectively than do Design chiefs. Either Design Chiefs are less informed on this subject than Real Property Chiefs or the latter exaggerate their base's effectiveness because they are responsible for tracking and assessing utilization. Both the objective and the self-rated measures indicate this

difference. Both groups, however, believe that their bases use their space more effectively than most other USAF bases.

10. The perceived comprehensiveness, accuracy, and accessibility of a BCE's Real Property database all correlate strongly with the effectiveness of a base's space utilization. This result is not surprising as the Facility Board relies on input from the BCE to make decisions on how space should best be used and the BCE's recommendations are influenced by his utilization database. The survey data did indicate that the BCE does not have much control over space allocation but it also indicated that the Facilities Board generally accept the BCE's recommendations. There was no significant difference between Design and Real Property Chiefs' perceptions of how much control the BCE possesses.

11. The level of computerization of Real Property records was shown to have no significant impact on the effectiveness of a base's space utilization. Also, bases keeping manual facility utilization records do not perceive that their data is any less comprehensive, accurate, or accessible than do bases using WIMS, BEAMS, or Database Management software on a personal computer.

12. As a combined group, Design and Real Property Chiefs indicated that there are constraints to the effective management of Air Force facility space. Those indicated are: 1) Real Property manpower shortages; 2) the lack of funds required to modify existing spaces that are considered to be

poorly utilized; 3) the difficulty in physically separating space that is assessed as surplus to a user's valid requirements, so that it can be reallocated to another user; and 4) The disruptions caused to users by space reallocations and consequent building modifications.

13. Open office design, or Open Planning, is promoted by Air Force design guidelines as a means of enhancing flexibility, reducing long-term modification costs, and reducing overall administrative facility space requirements. While Open Planning is recognized by the survey population as greatly enhancing flexibility, their desire to use this concept in design or redesign is significantly less enthusiastic.

14. Factors that are considered to be important factors when planning the layout of new facilities and the redistribution of existing space are: 1) the orderly flow of personnel through a facility; 2) the use of Open Planning concepts if applicable; 3) the use of construction methods that increase flexibility and minimize the cost of future modifications; 4) the speed advantage of renovation over new construction, thereby satisfying a user's requirement faster; 5) functional relationships between activities; and 6) the cost advantage of renovation over new construction. This should not be taken as an exhaustive list, but no further suggestions were offered by survey respondents.

15. Area/personnel ratios used as quantitative planning factors in new facility design and existing facility renovation are not significantly different. Both fall within Air Force design guidelines.

16. When faced with a requirement for building space the following steps that are most commonly taken to satisfy it are: 1) including the prospective user in the assessment of the suitability of an available space for his requirement; 2) making a physical inspection of an available space before making an assessment of its suitability; 3) checking the requirement with AFM 86-2 to establish its validity; and 4) attempting to satisfy the requirement from within existing building space before recommending new construction. These were all suggested planning steps, agreed to by respondents. No other steps were suggested.

17. Fulfillment of the mission is seen as the single most important criterion in deciding how best to satisfy a space requirement. It is seen as generally more important than the availability of funds, comparative costs of different alternative solutions, and political interests such as the equitable distribution of funds between units. However, more Design Chiefs see the availability of funds as being the factor which most controls how a requirement will be satisfied.

Recommendations for Action

RAAF. Bubble Diagrams and Relationship Charts must be generated by Facilities Officers in compiling Functional Design Briefs (FDBs). The RAAF should issue guidance on how they should be produced and how they are used by designers to guide facility layouts. The RAAF should standardize its approach to determining the space needs of new requirements. A more definitive list of space entitlements for different facility types and more standardized functional relationships within facility types would assist DGF-AF in controlling the layout design of common RAAF buildings.

At the same time the RAAF should approach DHC to agree on either standard Australia-wide facility designs for some facility types or standard interior design approaches that best suit RAAF requirements. At the moment, FDBs for similar facilities on different bases often bear no similarity in the internal layout of activities and in the areas allocated to these activities.

A program of evaluation, recording, and progressive reporting of the effectiveness of facility utilization is required for all RAAF facilities. A database of accurate and comprehensive user space entitlements and current space allocations is required as a decision aid for Facilities Officers to recommend redistribution according to base mission requirements. It is also required as a tool for generating and evaluating alternative means of accommodating new or changing requirements.

Such a database would provide DGF-AF with a stronger basis for making decisions on how best to utilize the RAAF's available facilities. It would enable his staff to objectively evaluate user opposition to surrendering facilities that are required for higher priority requirements or for disposal.

USAF. Recommendations for AFCE are directed at MAJCOM/DEs and BCE organizations. Suggestions are made such that the effectiveness of facility space utilization throughout the Air Force can be accurately evaluated and improved. They are as follows:

1. The BCE should ensure that requirements are revalidated immediately prior to design, and that design accurately reflect the space needs of the user and functional relationships between the user's activities. Architectural designers should use their professional expertise by laying out floorplans systematically, whether by the SLP method or by some iterative or automated means. The theory of some of these available methods was presented in Chapter II and Appendix E. The use of systematic means will minimize the wastage of space in new facilities, shorten lines of communication between activities requiring high interaction, and minimize unnecessarily high flows of personnel and material through facilities.

2. The use of Open Office Planning is a concept offering many advantages to the Air Force, not only by reducing administrative facility life cycle costs and compressing space needs, but by providing facilities which are more adaptable to changing mission requirements. The concept is promoted by HQ USAF through Air Force Regulations and supported by MAJCOM/DEs. BCE personnel involved with the internal layout of new or renovated buildings should be encouraged to research the concept themselves and apply it wherever possible, in the interest of long term facility flexibility.

3. This study showed that many Real Property Section personnel are involved in suggesting new layouts for facilities in order to better utilize space. If they have not done so already, BCEs should give some thought to either divesting some of the layout design responsibility for renovation projects from the Design Section to Real Property, or promoting cooperation between them. Although they may not have had the training that architects have in this area, this study shows that they are no less familiar with some of the design tools than are design personnel.

Real Property personnel have a great deal of familiarity with existing facilities, have more direct access to, and familiarity with, the space utilization data that is collected, and may be fully capable of producing good functional layout alternatives for facility renovations and modification projects. They could also conduct studies aimed at redistributing space throughout one or more facilities, including the preparation of conceptual layout sketches. Once the layout has been finalized, and evaluated by structural and mechanical design personnel, the architect could prepare detailed design drawings.

4. Even though BCEs currently produce reports aimed at progressively updating space utilization data, the effectiveness of a facility's utilization is neither assessed nor reported. Although a user may be entitled to a facility of a certain size, his actual activities may not require all of this space. It may also be possible to better arrange the layout of these activities so that his requirements can be reduced. Without such an assessment no usable surplus space will ever be reflected in these reports. HQ USAFE's program (discussed in Chapter II) is the only one attempting to meet this challenge head on.

5. In order to best gauge the real effectiveness of a user's facility space utilization, Real Property Sections need to be manned appropriately. One person, no matter how experienced, cannot perform the task without assistance or support. A team of personnel is required to assess each facility on a cyclical basis. Surplus or underutilized space should be accurately recorded. BCE reports to the Facilities Board would be more accurate and there would be less pressure on the BCE and Facilities Board allocating space for new

requirements. Facility funds would stretch further and some requirements would be satisfied sooner than if new construction was programmed.

6. MAJCOM/DEs should be proactive in stressing the need for building space to be utilized effectively. They should establish utilization assessment guidelines and space survey programs for bases under their command, as is required by AFR 87-2, para 2. Standard measures of effectiveness for Command-wide use should be developed to permit progressive assessment of an installation's space utilization by Inspector General (IG) teams and MAJCOM/DEs. If MAJCOMs believe there are certain criteria which measure effectiveness, then these should be passed to BCEs for guidance. MAJCOM/DEs should also give BCEs their interpretation of the AFR 87-2 requirement for a 'management analysis' when it is revealed that a facility is not being put to maximum use.

Recommendations for Further Research

Two areas of research are recommended. First, there was considerable difficulty in determining the measure of effectiveness for facility space utilization required for this study. This issue requires more substantial input from HQ USAF/LEE, MAJCOM/DEs, and the Air Force Engineering and Services Center (HQ AFESC) than was initially believed by the author. None of the sources that were approached to compile this measure could give any firm input. Research aimed specifically at developing a reliable measure that can be used by MAJCOMs and BCEs as a standard, would be a valuable contribution to AFCE facilities management.

Second, the need for an automated space planning capability within AFCE could be researched. The United States Army Corps of Engineers have used the CAEDS system extensively for its MCP program (Appendix E), and many space planning programs and Computer Aided Architectural Design (CAAD) software packages for minicomputer and personal computer applications are available.

As much of the Air Force's design work for MCP projects is contracted to A-E firms, the financial and training commitment required to introduce such a capability may not be warranted for the level of new facility and renovation layout work performed in-house. However, as interest in Computer Aided Design (not only architectural) is growing within AFCE, architects and engineers may support the introduction of automated space planning techniques on a limited scale.

APPENDIX A

DIRECTOR-GENERAL OF FACILITIES (RAAF) - ORGANIZATION AND RESPONSIBILITIES

Extract from the RAAF Facilities Manual
DI(AF) AAP 3300.001
Chapter 1 of Section 1

SECTION 1 - THE RAAF FACILITIES ORGANISATION AND FUNCTIONS

CHAPTER 1

THE BRANCH OF THE DIRECTOR GENERAL FACILITIES - AIR FORCE (DGF-AF)

INTRODUCTION

101. At Department of Defence (Air Force Office), the Branch of the Director General Facilities - Air Force (DGF-AF) is tasked with the administration of all Facilities matters pertaining to the RAAF. DGF-AF has dual responsibilities, ie, to Chief of Air Force Development (CAFD) and to the First Assistant Secretary Facilities (FASF). Administratively, the Branch is located within the Facilities Division of Department of Defence (Central). Its establishment comprises both Service and Public Service personnel (civil engineers, technical officers, draftsmen and administrative staff).

102. The Branch is responsible for all programming aspects, in respect of New Works, Repairs & Maintenance, Furniture & Fittings and Property. Within these responsibilities, the Branch represents Air Force Office as the specialist on Facilities matters within the Department of Defence forums. The Branch is involved with other Government Departments through liaison in the normal course of activities.

103. Other responsibilities include the Master Planning of all RAAF establishments, the location, design, construction and evaluation of airfields, and associated engineering services.

104. The organisation of the Branch is graphically illustrated at Annex A and a summary of the duties and responsibilities of DGF-AF is contained at Annex B.

ORGANISATION

105. The Branch is organised on a functional basis, comprising three Directorates, ie:

a. Directorate of Facilities Planning and Programming (DFPP). This Directorate has three Planning Sections (WPLANS 'A', WPLANS 'B', WPLANS 'C') and a Works Programming Section (WPROG). Within designated geographical regions, the Planning Sections are responsible for the Master Planning, development, and co-ordination of staff work associated with all Facilities matters pertaining to the RAAF establishments responsible within their respective areas. The WPROG is responsible for the submission of estimates and the preparation and administration of financial programmes relating to Medium and Major New Works, Minor New Works, Repairs & Maintenance, Acquisitions, and Furniture & Fittings.

b. Directorate of Facilities Engineering and Services (DFES). This Directorate has three Sections: The Civil Engineering Section (WCE), the Mechanical and Electrical Engineering Section (WMEE), and the Drawing Office (WDO).

c. Directorate of Works Policy. This Directorate is responsible for the formulation of works policy and its promulgation and implementation through the RAAF Facilities Manual DI(AF) AAP 3300.001, Air Force Temporary Instructions (Facilities) and Air Force Facilities Directives. The Directorate is also responsible for the Branch administration including all aspects of personnel management and training.

FUNCTIONS

Works Planning Sections (WPLANS)

106. Each of the three Planning Sections is responsible for the co-ordination of all Facilities matters in relation to the RAAF establishments within their assigned geographical areas (eg PLANS 'A' for Queensland). This includes participation in the preparation of Master Plans and the formulation of development proposals.

107. Planning Sections may assist in the production of AFWRs and, at the appropriate stage of procedures, are tasked with the preparation of the Functional Design Brief (FDB) required for all Medium/Major New Works proposals. Where these contain civil, mechanical and electrical engineering features, such proposals are processed in conjunction with WCE or WMEE, as applicable. Planning Sections also evaluate all requests for repairs and maintenance, housing acquisitions and disposals. Where necessary, Planning Sections participate in deliberations with other Federal Government Departments, State authorities and Local Government. Each Planning Section is also responsible for the preparation of Cabinet Submissions, and for giving evidence before the PWC in respect of Major New Works proposals.

108. WPROP Sub-section. The WPROP Sub-section is responsible for all property matters, including the preparation and management of the annual Acquisitions Programme and maintenance of the Master Property Assets Register. It also provides the input for the acquisitons and leasing components of Air Force Office draft estimates. Additionally, this Sub-section is the coordinator of all requests for siting approvals and for the provision of facilities numbers for all new structures.

Works Programming Section (WPROG)

109. This Section is responsible for the preparation of financial estimates in respect of the Facilities - related votes and for the preparation and administration of the annual programmes for Minor/Medium/Major New Works, R&M, Rent and Furniture and Fittings (F&F). WPROG also monitors the Acquisition and Housing Programmes in a coordinating role and is responsible for all aspects of Defence housing pertaining to the RAAF in liaison with the Defence Housing Branch.

Civil Engineering Section (WCE)

110. This Section is responsible for the management of all civil engineering projects, R&M aspects pertaining to such projects and the provision of specialist engineering advice. The range of activities include aircraft pavements, aprons, roads, navigation aids, bombing ranges, water supply, sewerage systems and drainage. WCE is further tasked with the development of new Bases (eg, Tindal) and of so-called 'bare' Bases (eg, Learmonth, Derby).

Mechanical and Electrical Engineering Section (WMEE)

111. This Section is concerned with aviation fuel storage, electricity supply, emergency power plants, air-conditioning, energy conservation, boilers, heating and fire protection. WMEE manages all projects in the mechanical and electrical engineering field and provides specialist advice as required.

Drawing Office (WDO)

112. The Drawing Office operates within two sub-sections. Activities include Survey Drafting, the RAAF aspects of Defence (Areas Control) Regulations and some areas of operational charting. WDO is also responsible for the implementation of the RAAF Survey Programme in liaison with the Australian Survey Office of DOLGAS, and generally meets the needs of the DGF-AF organisation in the preparation of all drawings required by the various Sections in day-by-day operations. The Sections is equipped with plan printing and microfilm equipment and maintains a large data base of plans and facilities.

Air Force Works Liaison Officers (AWLOs)

113. In respect of all facilities matters arising within defined geographical areas of responsibility, AWLOs exercise authority as the field representative of DGF-AF. At Formation level, the AWLO complements the existing works organisation by the provision of specialist advice and service. Functional control of AWLOs is vested in DGF-AF and exercised through the relevant Plans Cell Section Head, whilst administrative control is delegated to the Commanding Officer of the Support Units to which the AWLO is posted or attached (except in the Northern Territory, where the OC DARWIN is the Administrative Controller for AWLONT). The duties of the AWLO are detailed in Section 1 Chapter 2.

Single Manager Responsibilities

114. The Director General is the nominated specialist and Single Manager within DOD for:

a. airfield pavement and aprons projects;

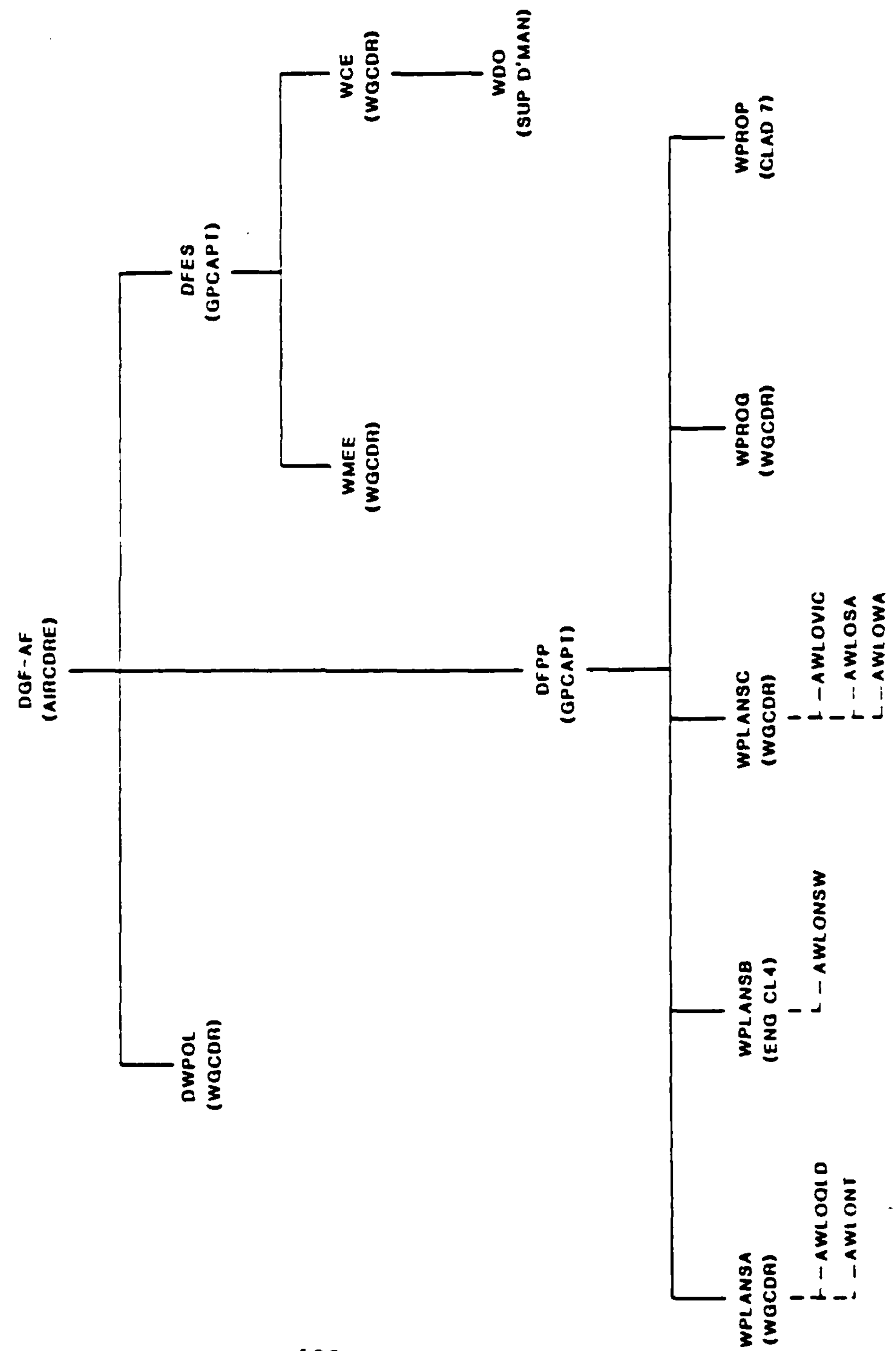
b. aviation fuel storage; and

c. control of Defence (Areas Control) Regulations.

Annexes: A. Organisation of the DGF-AF Branch

B. Duties and Responsibilites of the Director General Facilities - Air Force (DGF-AF)

ORGANIZATION OF THE BRANCH OF THE DIRECTOR GENERAL FACILITIES – AIR FORCE (DGF-AF)



RESPONSIBILITIES OF THE DIRECTOR GENERAL FACILITIES - AIR FORCE (DGF-AF)

1. The Director General Facilities - Air Force is responsible both to the Chief of Air Force Development (CAFD) and the First Assistant Secretary Facilities (FASF) for the provision of specialist advice on the development of plans, policies and procedures relevant to the administration and management of the RAAF Facilities function, and their implementation. He is also responsible to CAFD for the overall direction and provision of Facilites Services within the Air Force.

2. In particular, DGF-AF is responsible for:

a. the provision of an interface between Air Force Office, the Facilities Division and other departments/external organisations in respect of RAAF Facilities matters;

b. the development, promulgation, implementation and review of RAAF Facilities plans, policies and procedures;

c. the evaluation of environment issues affecting RAAF establishments;

d. the master planning for the long-term development of RAAF establishments, specific accommodation planning, and the siting of non-technical facilities;

e. the examination, and sponsorship of New Works, Property, Housing, Repairs and Maintenance (R&M), and Furniture and Fittings (F&F) proposals;

f. the co-ordination and development of RAAF Facilities proposals from the stage of endorsement of requirements through to their construction, handover and evaluation, i.e.:

(1) definition of User Requirements (Air Force Works Requirements);

(2) preparation of Functional Design Briefs and Project Briefs DF1, DF2, DF3;

(3) preparation of cost estimates for Financial Divisions 237, 239, 245, 246, 248, 250 and 252;

(4) preparation of submissions to FASF, the Minister, Department of Local Government and Administrative Services (DOLGAS)), Department of Finance (DOF), Department of Arts, Heritage and the Environment, Department of Housing and Construction (DHC), Cabinet and the Parliamentary Standing Committee on Public Works (PWC);

(5) the monitoring of DHC design and construction; and

(6) the evaluation of completed facilities.

g. the formulation and management of RAAF Facilities programmes;

h. in respect of approved programmes, the discharge of Coordinator responsibilities, exercising expenditure delegation and control, and monitoring the progress of projects;

i. the management of Air Force property, including acquisition, leasing, hiring and disposal trasactions, and approvals to vary the functional use of facilities;

j. the maintenance of a Master Property Assets Register;

k. the co-ordination of RAAF housing requirements;

l. the provision and management of RAAF Facilities Services including New Works, Property, Housing, R&M, F&F, Unit Works Services, Civil Engineering Services and Mechanical and Electrical Engineering Services;

m. the provision of professional and technical advice to other Branches, Directorates and Commands on Facilities planning, design and construction and on civil, mechanical and electrical Engineering Services;

n. all policy/design matters concerning aircraft pavements, fuel storage and the administration of Defence (Areas Control) Regulations;

o. the coordination of the supply, siting and use of prefabricated facilities;

p. the coordinating of the investigation, design and construction of RAAF Special projects (which are not the responsibility of DHC) and for overseas facilities;

q. the supervision of the installation of plant and workshop machinery, in liaison with the appropriate Technical Officers;

r. the development of RAAF bombing and gunnery ranges (Defence Practice Areas);

s. the provision, through appropriate programmes, of certain supply items and civil engineering stores;

t. the contributing to the formulation of Joint Service and RAAF operational plans; and

u. planning and policy formulation to meet RAAF responsibilities for the provision of engineer works services in operations in accordance with JSP(AS)2A.

3. DGF-AF is a member of the following permanent Committees:

a. the Air Force Works Priority Committee (WPC);

b. the Air Force Programmes & Estimates Advisory Committee (AFPEAC);

c. the Air Force Requirements Committee (AFRC); and

d. the Defence Facilities Advisory Group (DFAG).

4. When so directed by CAS, DGF-AF represents Air Force Office as witness at hearings conducted by the Parliamentary Standing Committee on Public Works (PWC) in relation to Air Force Office-sponsored Major New Works projets.

DGF-AF RESPONSIBILITIES FOR THE SUPPLY OF EQUIPMENT/PLANT

In respect of his Vote Coordinator role for Divisions 239-03 and 245 DGF-AF is responsible for funding the supply of the following equipment, in accordance with appropriate Scales of Entitlement:

a. The initial supply of furniture and furnishings to newly constructed buildings;

b. Built-in furniture for incorporation in New Works projects;

c. Floor coverings, including carpet squares, body carpets, carpet runners, linoleum, vinyl sheeting and floor tiles, but excluding bedside rugs;

d. Curtains, blinds and fittings;

e. Furniture for public rooms of messes and airmens recreation/canteen centres (except billiard tables, which are obtained in accordance with DI(AF) SUP 18-21);

f. Furniture and furnishings for married quarters, including domestic refrigerators;

g. Commercial refrigerators and cool rooms (including portable pre-fabricated refrigerators), quick freeze blast cabinets, fixed deep freeze cabinets (subject to approval by the Departments of Defence and the Treasury), fixed ice making machines, water coolers and industrial and mortuary refrigeration;

h. Fixed messing equipment including stoves; hot presses, vegetable peeling machines and dish washing machines;

i. Fixed barracks equipment including sinks, troughs and washing machines of all types;

j. Fixed lighting, heating, cooling, ventilating and airconditioning equipment (DI(AF) SUP 18-14 refers);

k. Fixed electrical equipment and fittings as prescribed in DI(AF) SUP 18-14;

l. Fire fighting appliances and euipment intended for the protection of fixed equipment and installations (excluding fire hoses, fire extinguishers, and items fitted to mobile fire fighting appliances or used for the protection of aircraft);

m. Fixed equipment and built-in furniture in RAAF hospitals and sick quarters;

n. Office furniture, including drawing office furniture, mobile steel shelving (Compactus type), office safes and filing cabinets including steel cabinets fitted with combination locks, but excluding Type A cabinets;

o. Fixed workshop, hangar, storage and airodrome equipment and facilities, ie fixed lifting devices including rail type hoists, storage bins and mobile steel shelving, fixed cranes and weigh bridges, refuelling installations generating sets, frequency converters;

p. Moorings, mooring buoys and components; and

q. Prefabricated demountable houses.

NOTE:

(Fixed equipment referred to in this paragraph does not include that installed in or fitted to vehicles, trailers or other portable facilities).

APPENDIX B

LAYOUT OF AN AIR FORCE WORKS REQUIREMENT (RAAF)

Extract from the RAAF Facilities Manual
DI(AF) AAP 3300.001
Annexes A and B to
Chapter 4 of Section 8

TYPICAL LAYOUT OF AN AIR FORCE WORKS REQUIREMENT

(Only centre headings are mandatory)

AFWR ...../19.... FOR ....AT RAAF BASE ....

INTRODUCTION

1. The introduction should provide a precis of the background to the problem and thus identify the purpose of the AFWR.

EXPLANATION AND JUSTIFICATION

Current Situation

2. Statement of the facts pertaining to the present situation, eg how and why the problem has arisen; present consequences and how the RAAF establishment is presently coping; if interim action has been taken to alleviate the problem and why such action is inadequate in the long term.

3. The paragraphs in this section should include all relevant data, description, explanations and, if applicable, supporting specialist advice.

4. Statements of 'inadequacy' must be justified with quantitative data. Where applicable, reference should be made to inspection reports or other relevant documentation.

Future Situation

5. A statement, with supporting data, as to whether the situation is expected to remain static or to change. If a foreseeable development rather than an existing situation is to be resolved, details of the anticipated change of circumstances, eg change of role, increase in ROE, establishment, etc are to be given.

6. A statement as to whether contingency requirements have a valid bearing on the proposed solution.

7. A statement of the consequences if positive action is not taken to resolve the problem.

AIM

8. The stated aim should be the logical course of action determined from careful evaluation of the existing problem, as detailed in the preceding paragraphs. It should be stated in the following manner:

> "The aim of this AFWR is to evaluate the extant and enduring facilities requirement of ...."

ANALYSIS OF THE REQUIREMENT

(What is Needed to Achieve the Aim)

9. The 'requirement' is the proposed solution to the problem. The following factors must be covered, as applicable:

   a. Activities to be accommodated (eg workshops, stores, married quarters, etc);

   b. Established personnel to be accommodated;

c. Division of personnel between Sections;

d. Location of the facility/works and siting criteria;

e. Real Estate, eg land acquisition, leasing;

f. Related Projects. Projects in progress, approved or planned and their timing; and

g. Timing/Priority. Reasons for timing and priority rating.

10. Special Works Requirement. This paragraph should detail any unusual or special works aspects of the problem which may affect the selection of the best solution and/or the Indicative Cost, eg:

a. Type of Construction. Conventional, prefabricated, modular, stating the reason for selection and making reference to the expected life cycle of the facility;

b. Future Extension. Anticipated and/or possible future activities to be accommodated;

c. Special Integral Equipment. Statement of what is required and who is to provide it (eg DHC, contractor, RAAF, etc) and design implications;

d. Environmental Control. Purpose, capacity and areas to be controlled, special conditions to be met and justification of the requirement;

e. Services Scales and Standards of Accommodation (SSSA). Statement as to whether existing SSSA apply or whether variations are proposed, or are already under consideration.

f. Other Unusual Requirements and Special Fixtures. Statement of details of any unusual requirements/special fixtures which are not normally provided; and

g. Existing facilities. Statement as to whether any existing facilities or parts thereof are required to be removed from the proposed site.

ALTERNATIVE WAYS OF MEETING THE REQUIREMENT

11. It is imperative to show that feasible alternatives have been considered. These should be examined and evaluated with regard to suitability, cost, value of work, timing, etc. From these, by comparison, the best available solution should be selected as the 'preferred option'. Where no alternatives are available, this must be stated.

Option 1 - State the proposed method of meeting the requirement. eg Construction of a new facility located .... etc

12. Each option should be described in general terms, but must clearly outline the extent of work involved. The evaluation of the option must refer both to its advantages and disadvantages.

13. Works Planning Implications.

a. Master Plan. Statement as to whether the option is part of the approved Master Plan and whether any other facilities are affected;

b. Property Requirements. Statement as to whether acquisition is required and if any problems are foreseen; and

c. Disposal of existing facilities or assets, where applicable.

14. Associated Implications. Statement as to whether the proposal has implications for:

a. RAAF. (Eg effect on human resources or organization);

b. Other Services. (Army or Navy works, operations, establishments or activities);

c. Other Commonwealth Departments or Agencies;

d. State or Local Government. (Eg compliance with local council policy, zoning regulations, or by-laws); and

e. Non-Government Agencies, Businesses or Private Citizens. (Any known circumstances which could affect the proposal).

15. Environmental Impact. Statement as to whether or not an Environmental Impact Statement (EIS) for this type of project will be required. If affirmative, aspects such as the effect on the natural or human environment, eg chemical pollution, noise level, etc are to be discussed. (Where the originator of an AFWR is uncertain as to whether an EIS is required, advice should be sought from DGAW-AF).

16. Staging. If the project could be completed in stages, this should be stated. However, each stage must constitute a self-sufficient functional entity, capable of fulfilling its intended purpose upon completion, in spite of being part of a whole.

17. Indicative Cost. An Indicative Cost for the project is to be included.

Option 2 - State this proposal for meeting the requirement. (eg "Modification of existing Building ....)"

18. Each succeeding option is to be fully evaluated under separate headings. All relevant aspects are to be included as for Option 1.

Comparison of Options

19. The comparison should include reference to all the essential/desirable factors and consideration of any significant implications relative to each option.

20. Selection of the Best Option. Statement that Option No .... is the selected solution because it is:

a. the cheapest (in the year of expected authorization or in respect of life-cycle costing);

b. the easiest to construct in the time available;

c. the most cost-effective;

d. the only one that ensures the operational capability;

e. the only one available; and

f. any other reason, as applicable.

THE REQUIREMENT

21. The requirement should be summarized as follows:

"The Department of Defence (Air Force Office) requires .... at RAAF Base .... to ...." eg,

"The Department of Defence (Air Force Office) requires the construction of a new Base Squadron Headquarters Building at RAAF Base FLYOVER to replace the existing condemned building, (Building 153)."

General Design Concept

22. Under this heading, a short description of the general design concept for the proposed facility is to be given. However, the design concept and detailed specifications will be stated in the Functional Design Brief (FDB).

23. Layout Sketches. Simple layout sketches may be provided to assist in the selection of the desired siting and the interrelationship of activities to be accommodated. Attached notes should indicate the personnel numbers to be accommodated and/or working in the individual areas.

24. Annexes. If appropriate, extracts from the Master Plan, flow charts, photographs illustrating the existing problems, photographs/drawings of similar facilities existing elsewhere, etc. should be attached.

Target Dates and Approvals

25. Critical Dates of Related Items. Statement of the anticipated or required delivery dates for other source equipment associated with the project or to be accommodated in the proposed facility.

26. Selection of Target Date. Statement of the desired target date and the parameters determining its selection. The implications of non-attainment of the target date, if applicable, should be explained.

27. Status of Approval. Where applicable, reference should be made to already approved proposals related to the requirement, eg major capital equipment projects.

28. Security Classification. AFWR's are normally unclassified documents. However, where certain aspects of the project have security implications, these should be identified for appropriate classification of the document.

29. Annexes to the AFWR should be selected as appropriate, eg:

a. Tabulation of data;

b. Photographs illustrating the problems;

c. Photographs of similar existing facilities;

d. Extract of Master Plan; and

e. Conceptual sketches.

QUESTIONS TO BE CONSIDERED IN FRAMING THE AFWR

Explanation of the Aim

Have all relevant facts been explained?

Has the problem been clearly identified?

What significant changes in circumstances gave rise to the problem, or are anticipated?

How is the RAAF establishment currently coping?

Are there some activities that can be re-arranged, reduced or discontinued?

Have inabilities to perform arisen?

Why cannot current interim arrangements be continued?

Why is the existing facility inadequate, insufficient or unacceptable?

What are the economic considerations?

What is the nature and extent of any existing security/safety/health hazards?

Are there operational considerations, eg change or role, ROE, etc?

What are the implications if no action is taken?

ANALYSIS OF THE REQUIREMENT

Description of the Facility

What are the generic types of the facilities involved (eg, workshops, stores, married quarters, land acquisitions, leasing, etc)?

Where will the facility be located (eg, Defence establishment/nearest town. Reference - title, source, date - to the main paper(s) most relevant to selection of location)?

Reasons for the Requirement

Who is it mainly for (eg, names of main user units or organisations)?

What Defence objectives, capabilities, functions or activities is the facility mainly intended to support?

What other Defence objectives, capabilities, functions or activities will the facility significantly support?

How significantly will performance of the activities, functions etc be improved by the facility?

What are the main deficiencies of the facilities currently supporting the objectives, capabilities, functions or activities concerned (eg, deficiencies with respect to:

- functional efficiency
- capacity

- quality (eg, technical or other standards)
- location
- maintenance costs
- environmental problems)?

PLANNING AND OPTIONS

When is the facility wanted
(eg, operational, equipment or other target dates or commitments determining the facility's timing)?

How many personnel will use the facility
(eg, permanent and temporary users; average/minimum/maximum numbers)?

What will the capacity of the facility be
(eg, maximum number of persons, vehicles, aircraft etc. to be accommodated/supported, at normal and peak levels of operation)?

What are the long term plans for use or development of the facility (and any assets replaced, but retained for other purposes), and what is their basis
(eg, manpower or other growth projections; Master Planning; long-term functional or capability studies)?

What significant social, economic or other environmental effects is the facility likely to have?

What consultations have occurred with other relevant Departments or organisations in relation to the public effects of the proposed facility?

How might public effects of the facility influence its longer term use or development
(eg, longer term interactions between the facility and urban growth)?

ALTERNATIVE SOLUTIONS

What alternatives to the proposed facility have been considered with respect to:

- supporting the relevant Defence objectives, capabilities, functions or activities (eg, sharing other Service or commercial facilities)
- location
- scope of the facility
- timing of proposal (ie start and/or rate of development)
- life cycle costing

and what are the main disadvantages/advantages of those alternatives?

Can the existing facility be modified or re-located to meet the requirement?

Could any other facility be utilized?

Does the AFWR fully demonstrate the need for the requirement?

COSTS AND PROGRAMMING OF THE FACILITY

What is the estimated capital cost of the facility, and date and basis of that estimate
(eg, Defence estimate; DHC Indicative Cost, Preliminary Estimate; DAS estimate of acquisition or leasing costs etc)?

What is the life cycle cost of the proposed facility?

What other costs will be involved
(eg, equipment, furniture and fittings, R&M on proposed facility etc)?

What cost savings will be achieved
(eg, net reductions in R&M expenditure, ie. R&M on replaced facility less R&M on proposed facility)?

What is the estimated value of Defence assets which could be disposed of after establishment of the facility, and what is the basis of that estimate
(eg, disposal plans; DAS valuations)?

What expenditure is proposed on the facility in each year of the FYDP?

SELECTED SOLUTION

Why was it chosen?

Is there an initial capital outlay advantage as well as a saving through to end-of-life?

If it is possible to use existing facilities, why is it better to build a new one?

What additional benefits might be gained from the chosen solution?

Will it fulfill current and foreseeable needs?

Will it enhance the Defence capability to meet contingencies?

Will it affect or be affected by any other ongoing or proposed project?

What are the consequences if the proposal does not proceed?

Why is it essential to meet the proposed target date?

APPENDIX C

LAYOUT OF A FUNCTIONAL DESIGN BRIEF (RAAF)

Extract from RAAF Facilities Manual
DI(AF) AAP 3300.001
Annex E to
Chapter 4 of Section 8

File Reference ....

FUNCTIONAL DESIGN BRIEF FOR

AT RAAF

DEFENCE BRIEF CERTIFICATION

"I certify that where elements of this works proposal relate to the provisions of Services' Scales and Standards of Accommodation (SSSA), the relevant provisions contained in that document have not been exceeded."

....
Air Commodore
Director General
Accommodation and Works-Air Force

Amendment Status

Original Issue

Amendment 1

Amendment 2, etc

Introduction

1. This Functional Design Brief details the requirement for .... at RAAF ....

Location

2. The facility is to be located within the .... zone/location shown on the Master Plan/Site Plan attached at Annex A.

Site Requirements

3. Immediate landscaping and access paths to this facility are to be incorporated in the design together with car parking facilities for.....Service vehicles and for......private vehicles in accordance with SSSA.

4. In the preparation of the project cost estimates, DHC is to allow for the demolition of any buildings and/or the relocation/termination of engineering services to the site, if required.

General Design Concept

5. Where appropriate, the architectural character of the facility should take account of adjacent buildings and the natural environment. Recognised construction techniques for passive resistance to forced entry are to be employed in this facility.

6. The final design must take best advantage of the site and incorporate all economies possible with regard to floor area and construction, yet still retain the necessary functional requirements and work flow pattern.

7. Future extension of the facility is not envisaged at this stage: however, the facility is to be designed to permit future extension should it become necessary.

8. Use of a pre-constructed, modular unit building system should be considered, where appropriate.

9. The facility is to be designed to accord with the DHC Technical Directive AE TD 108.

10. A Functional Relationship Diagram for the facility is attached at Annex B.

Personnel

11. The facility will/will not be permanently manned. An establishment figure of.....personnel is to be used for planning purposes. Provision is required for female amenities based on....% of the establishment.

Activities to be Accommodated

12. The RAAF requires a permanent facility which will accommodate the following activities:

Room Schedule

13. The following rooms are to be incorporated in the building:

Room No	Function	No of Personnel	Approx Area (m2)
1			
2			
3			
4, etc.			

Room Data Sheets are provided at Annex C.

Energy Conservation

14. Alternative Designs. During the preparation of preliminary design concepts and preliminary estimates of costs, DHC is requested to identify designs/materials/energy systems which might be considered on a through-life costing basis as alternative design solutions, bearing in mind the aim of energy conservation.

15. Building Operation. At the time of the handover/takeover of the facility, DHC is requested to provide an energy budget for the building. This would comprise an identification of the energy systems within the building, the methods of operation, recommendations for their control in relation to energy conservation, and annual budgets for operating costs assessed by DHC as reasonable targets.

Electrical Services

16. General Wiring. The wiring is to be installed/upgraded to conform with the wiring rules AS 3000.

17. Lighting. General and supplementary lighting is to be provided/upgraded to accord with the recommendations stated in AS 1680 for the various tasks.

18. Security Lighting. External security lighting controlled by photo-electric cell with a manual override is to be provided around the building to provide shadow free illumination.

19. Escape Lighting. The requirement for emergency escape lighting is to be investigated by DHC. If required, it is to be installed in accordance with AS 2293, Part 1.

20. Power. Standard 240/415V 50 Hz and other non-standard 60 Hz, 400 Hz, 28V DC power supplies are generally required for the various tasks in the building. In some cases, existing converting equipment and socket outlets in situ may satisfy the requirements. Unless otherwise stated, all outlets and converting equipment are to be supplied and installed by DHC. In certain circumstances where converting equipment and non-standard outlets are supplied by RAAF, the wiring is to be carried out by DHC.

21. Emergency Power. The emergency power required for the facility is...% of the nominal load during periods of mains failure. All essential socket outlets will be identified during design discussions. In addition, in areas where essential work is being carried out, limited lighting is to be provided.

Fire Protection

22. The final protection system offered must be approved by Department of Defence (DGAW-AF/WMEE) early in the design stage. The following is required:

a. A closed head sprinkler system is to be installed throughout the facility with all alarms transmitted through a FIB to the Base Central Supervisory System.

b. Fire points are to be provided throughout. Each fire point is to consist of a small bore hose reel and hand held fire extinguishers.

c. Hand held fire extinguishers (RAAF supplied) are to be installed by the contractor, as specified by the Base Fire Officer in consultation with DHC.

d. External hydrant coverage is required and must be capable of providing a minimum of....litres/sec total from a maximum of ..... hydrants in the vicinity of a fire. The maximum spacing along the mains is to be...metres between hydrants.

e. Mains Power Isolating Switch - The electrical switchboard or an isolating switch, painted post office red is to be located adjacent to the FIB or main entry door to enable the supply to the building to be isolated in case of a fire. The switch is to be suitably protected against unauthorised use.

f. Fire exit doors - All required fire exit doors should be operable from within the building, with normal single handed operation and without recourse to a key.

Note: Prior to finalizing this paragraph, Fire Protection requirements for a particular facility should be checked through DGAW-AF/WMEE.

Protective Security (as applicable)

23. The building will have only one external personnel access door which is lockable from the outside. All other external access doors are to be lockable only from the inside.

24. Physical Security. Physical hardening of the external doors and windows is not required for this building. Also, no special security lock-up measures, either internally or around its perimeter, are envisaged for this building. However, normal precautionary measures should be adopted for a facility of this nature.

25. Security Devices. All security alarms installed within the building are to be monitored through a satellite security panel and connected to the Base Master Security Panel.

Note: Prior to finalizing this section, Protective Security requirements for a particular facility should be checked through DGAW-AF/WMEE.

Water Reticulation

26. Hot and cold water is to be supplied via single outlets to all hand basins, showers, the tea preparation area and the cleaner's sink. Cold water is required to all cisterns and the refrigerated water fountain. Cold water hose taps are required in the ablutions and externally for gardening purposes.

Compressed Air

27. Dry industrial compressed air is to be reticulated from a compressor in the plant room to the following areas:

The air pressure is to be...kPa providing....m3/min FAD from each outlet simultaneously with 33% diversity. The reticulation system is to be fitted with a DHC supplied pressure gauge, regulator and oil trap unit. The outlets shall be compatible with 1/4" BSP JAMEC fittings.

Environmental Controls

28. Noise Attenuation. The building is to be designed to achieve an acceptable noise reduction from external noise sources. A dB(A) reduction of..............is required.

29. Pollution Control. Pollution control measures are to be incorporated as necessary to ensure that all relevant Commonwealth, State and Local Government regulations are adhered to.

30. Thermal Loads. The thermal load within the building is made up of the following:

a. Personnel.

b. Machinery.

Specific details of thermal loads are given in the Room Data sheets.

31. Air Treatment. A ventilation system complying with AS 1668 shall be provided to achieve the following parameters:

a. temperature ..... degrees Celsius to ..... degree Celsius.

b. relative humidity ..... percent RH to ..... percent.

c. positive internal pressure of ..... Pa is required in Room Nos .....

d. filtration with filters having duty cycle average efficiencies of not less than 15%, 95% and 85% against test dust No 1, 2 and 3 respectively when tested in accordance with method 5 of AS 1132.

32. Ventilation. All toilets, showers and change rooms should have a mechanical ventilation system capable of providing at least ten changes of air per hour. The mechanical ventilation system is to accord with AS 1668.

33. The noise level of the ventilation system shall generally comply with the appropriate values specified in AS 2107.

34. Heating. Heating to a minimum of 17°C (for workshops) and 19°C (for offices) is required in the following rooms:

35. Environmental Clearance. The administrative procedures of the Environment Protection (Impact of Proposals) Act 1974 have been satisfied/are being pursued.

Special Equipment

36. The types of special equipment that are to be:

a. RAAF supplied and installed,

b. RAAF supplied and DHC installed, and

c. DHC supplied and installed,

are listed in the Room Data Sheets at Annex C.

Design Features

37. The following design features and finishes are to be incorporated in the design of the facility.

a. Finishes. Low maintenance finishes compatible with the function of the area concerned are to be used wherever possible.

b. Floor Levels. Continuous floor levels are required throughout the building.

c. Floor Finishes. Heavy duty vinyl sheeting with welded joints is preferred in all but the wet areas and areas approved for carpets unless otherwise specified. Wet area floors are to have an impervious hard wearing non-slip surface such as ceramic tile or equivalent and are to be graded to floor drains.

d. Walls. All internal wall surfaces are to be finished with materials that can withstand frequent cleaning.

e. Ceilings. Except where specified to cater for special requirements, ceiling heights are to accord with accepted building practice.

f. Doors. Doors are to be of standard commercial width except where otherwise specified. All doors are to be key lockable with the exception of toilets, lunchrooms, changerooms and tearooms unless otherwise specified. Doors to 'high use' areas are to be fitted with kick plates. All doors are to be fitted with door stops.

g. Windows. Window frames are to be constructed of low maintenance material suitable to the type of facility. All opening windows are to be fitted with flyscreens.

h. Master Keying. Doors which are to be master-keyed will be nominated at a Design Monitoring Meeting.

i. Telephones. Ducts with draw wires are to be installed to all points where telephones are required. The location of telephone points are listed on the Room Data Sheets. Actual locations will be determined at a Design Monitoring Meeting.

j. Industrial Safety. Non-combustible materials should be used wherever practicable. All fittings and associated equipment are to be recessed, where practicable, or positioned so that obstruction to corridors and occupied areas and contact damage to fittings will be minimal.

k. Colour Scheme. The internal colour scheme is to be in accordance with the recommendations of the Department of Labour and Industry 'Colour in Factory and Office' and AS 1433. The final colour scheme is to be approved by the RAAF Project Officer.

m. Signs and Notices. Signs and notices required throughout the facility are detailed at Annex D.

Keys and Keyboard

38. A metal clad and securable keyboard with provision for all keys is to be DHC supplied and co-located within the building, as near as practicable to the main access door. Two keys for each lockable door are to be provided. Each key is to be individually tagged with a metal disc on which the door identification number is to be clearly stamped. Construction keying is to be utilized prior to transfer of the facility to the user.

Design Documentation

39. Sketch Plans. Sketch plans of the proposed floor layout, fire protection, electrical services and hydraulic services are to be forwarded to DGAW-AF for concurrence.

40. Documentation. Documentation for this project is to be reviewed with this Department at the 50% and 90% completion stages.

41. Tender Documents. Three copies of the completed tender documents are to be forwarded to DGAW-AF for final review and concurrence prior to the calling of tenders. These documents will be treated as "Commercial-in-Confidence"

Annexes: A. Zone/Location Plan

B. Functional Relationship Diagram

C. Room Data Sheets

D. Schedule of Signs and Notices

ROOM DATA SHEET

Room No. and Name	NO
Net Area	m^2 APPROX
Function	
Location	AS PER RELATIONSHIP DIAGRAM
Noise Output	
Thermal Loads	
Occupancy	
Finishes - Walls	
" - Floor	
" - Ceiling	
Environmental Control	
Special Equipment	
Telephones	
Other Services	
Special Features	
Furniture and Fittings	
Comments	

APPENDIX D

ADMINISTRATIVE SPACE STUDY FOR
SCOTT AFB
BASE COMPREHENSIVE PLAN

This material is an extract only. The entire document can be obtained from HQ USAF/LEEVX, Mr Phil Clark. Not all figures and tables referred to in this extract have been included.

Pages 199 to 212 include the purpose and scope of the study, show tabulated space allocations and requirements, and define renovations, demolitions, and new construction required.

Pages 213 to 218 is the Administrative Space Requirements Survey which was sent to all Unit and Squadron Commanders at Scott AFB. It was instrumental in the success of the study.

FINAL SUPPLEMENT

ADMINISTRATIVE SPACE REQUIREMENT SUPPLEMENT
TO THE
BASE COMPREHENSIVE PLAN

for

DEPARTMENT OF THE AIR FORCE
HQ 375 Aeromedical Airlift Wing
Scott Air Force Base, Illinois

Prepared by

HARLAND BARTHOLOMEW & ASSOCIATES, INC.
St. Louis, Missouri

Contract No. F11623-84-C0073

December, 1985

TABLE OF CONTENTS

ADMINISTRATIVE SPACE REQUIREMENTS

Purpose and Scope

The Administrative Space Requirements Study is a planning tool used to help locate administrative functions and buildings in the Base Comprehensive Plan. The scope of the study is to determine how much administrative space will be required to accommodate each organization or unit, and where that space should be located to carry out mission and functional requirements. This report presents findings based upon an analysis and tabulation of space requirements and functional interrelationships. In addition to the quantitative data on future space requirements, the study addresses long-term suitability of present administrative space in relation to functional and locational requirements, particularly for functions now housed in scattered locations and in nonpermanent facilities. The study also presents recommendations for the long-range provision of administrative facilities which will satisfy the space and functional requirements. Data presented in this report has been used to develop land use and facility recommendations for administrative functions in the Base Comprehensive Plan.

Planning Criteria

The primary objective for the study is to provide adequate administrative space for each unit and organization to carry out its mission in the optimal location which maintains necessary functional relationships within the organization and with other closely associated organizations. Several preliminary planning criteria which support this objective has been identified as guidelines for the study.

1. The study assumes that the present organizational structure will be carried forward except for those changes already approved and in process.

2. The study should provide a reasonably permanent solution for each organization's space requirements, but with a maximum amount of flexibility built in to allow for unexpected change in assignments, organization or mission.

3. All units or elements within a command should be located within the same building or building group, except where specific functional considerations allow or require a separate location.

4. The study should provide for co-location or locations in close proximity to promote functional relationships between closely associated organizations.

5. The study should recognize the growing importance of special purpose space to support administrative functions, especially in the areas of data processing and employee training.

6. The study should be directed to providing space in permanent facilities for all administrative functions, with the quality of administrative space meeting contemporary standards for an office environment.

7. Planning for future administrative space should be based upon the sum of:

a. General Administrative Space equivalent to 135 square feet of gross building area per employee working in general office space.

b. Special Purpose Administrative Space as specified in Air Force Regulation 86-2.

This amount of space must satisfy current functional requirements, and also provide for common building elements (e.g., hallways and mechanical areas). Space requirements derived from applying these criteria are intended only to guide long-range planning; future planning and development for a specific facility must be based upon more detailed analysis of the particular space requirements.

Administrative Space Requirements Survey

In June 1984, an administrative space survey was distributed to all unit and squadron commanders as the initial step in obtaining data on future administrative space requirements. The survey asked for information about the unit's mission, organizational and functional relationships, number of authorized administrative personnel, contractor and special purpose space requirements, and space deficiencies. A copy of the Administrative Space Requirements Survey is included as Appendix A. The data provided by the individual units and organizations in their response to the survey were tabulated, reviewed and correlated with other available data. These results were then used to prepare a final summation of space requirements and diagrams of functional/locational relationships.

Space Requirements

Using the current planning criteria for administrative space requirements (135 square feet of gross building area per general office employee plus special purpose space requirements), the summation of space requirements, based upon the survey responses, indicates a total administrative space requirement of 1,188,419 square feet of gross building area.(1) The total is well in excess of the total of 1,025,000 square feet of administrative space available according to the Real Property Inventory and facility plans, and nearly three times the present total of adequate administrative space at the base.

(1) The administrative space requirements include all space classified in Category Group 61 - Administrative Facilites as specified in Air Force Regulation 86-2; administrative space requirements which are classified as a part of training, operational or other facilities have not been included in the study.

Functional/Locational Requirements

As part of the Administrative Space Requirements Survey, units were asked to identify other organizations or units at Scott AFB which should be co-located (in the same building) or located in close proximity. Because maintaining desirable functional relationships is a major objective in planning for future administrative space requirements, all interrelationships specified in the survey response are treated as primary planning requirements. All of the interrelationships specified in the survey response were charted and then used to construct diagrams of ideal functional relationships which could then be used in analyzing existing and proposed arrangements and locations of administrative function. The diagrams shown in Figures 1 through 3 provide a comprehensive overview of the functional relationships between units as well as the relative number of personnel within the related units. In addition to those relationships between units shown in the diagrams, the study assumes that there are close functional relationships within each of the units and that, as stated in the planning criteria, all elements within a unit should be located within the same building or building groups (except where specific functional requirements make a separate location desirable).

Relationships which require co-location of units exist principally in two functional areas: between units of the 375 AAW and 375 ABG responsible for base administration; and among operational units such as the 57 AFS, 11 AAS and ASMRO. Relationships which require close proximity but not co-location are broader in scope and include a network of relationships among HQ MAC, HQ AFCC, HQ AWS, 7 WW, 23 AF, HQ 375 AAW and HQ 375 ABG. Functional relationships among other tenant organizations are limited, although there are exceptions such as the close working relationship betw.en DECCO and DCOAC.

Based upon initial analysis of the functional locations relationships, the significant requirements appear to be:

1. Co-location of closely related units responsible for base administration.

2. Co-location of operating units carrying out interrelated missions.

3. Co-location of all related units within each organization's headquarters (including MAC, AFCC, AWS and 23 AF).

4. Close proximity between organization headquarters of MAC, AFCC, AWS, 23 AF, 375 AAW and 375 ABG.

Location of Existing Administrative Space

Existing administrative space at Scott AFB is located in nearly 50 buildings, which range in size from over 300,000 square feet of gross area to less than 1,200 square feet of gross area. The bulk of administrative space is located within buildings classified as administrative facilities, although administrative space is also located in a number of operational facilities. As part of the Administrative Space Requirements Study, existing administrative space at the base was identified by location and gross area for each unit or organization. (See Table 1.) The gross area figures shown for each unit are derived from the Real Property Inventory and occupancy plans provided by each facility manager, and are intended to provide a relative measure for analyzing the present location of space occupied by each organization or unit and its arrangement in relation to functional requirements.

Figures 4 through 8 illustrate the present arrangement of administrative facilities for all organizations at the base. Space occupied by the 375 AAW and 375 ABG is scattered, with a relatively high degree of separation. To some extent, this corresponds to functional requirements, with separation of base administration and services, but there are also closely related administrative functions which are separated by substantial distances. The headquarters of the two major commands (MAC and AFCC) are relatively concentrated in arrangement of space, although some major elements of HQ MAC (data automation and communications) are located in the South Drive area away from related units and facilities. Generally, the other tenant organizations have space within a single building, or adjacent buildings located to maintain their desired interrelationships with other organizations.

Adequacy of Administrative Facilities

The existing 52 administrative facilities provide a gross floor area of just over 1,000,000 square feet, which would accommodate approximately 84 percent of the total requirement of 1,188,419 square feet of administrative space. However, only one-third of the existing space is located in permanent structures which are presently suitable for long-term administrative use. The remaining space is considered unsuitable for long-term administrative use because it is located in:

1. Buildings of temporary construction: 28 buildings with 302,423 square feet of floor area. These are mostly World War II-era buildings which have already exceeded their 25 years' economic life span. Also in this category are various "modular" structures which have been used to provide for critical space deficiencies, but cannot be considered adequate as long-term facilities.

2. Buildings of semi-permanent construction: nine buildings with 135,118 square feet of floor area. These are of wood frame construction, built between 1952 and 1955, and are generally obsolescent for administrative purposes. However, some of these facilities may be suitable for other uses.

3. Buildings of permanent construction which are improperly located or configured for long-term administrative use: seven buildings with 47,635 square feet of floor area. These are smaller buildings, some of which have been converted from an earlier nonadministrative use and not properly configured for

Table 1

SUMMARY OF ADMINISTRATIVE SPACE REQUIREMENTS

Scott Air Force Base, Illinois

Organization	Symbol	Existing Space Allocation: Building No.	Gross Sq. Ft.(1)	Category(2)	Condition(3)	Administrative Space Requirements (category group 61): General Office Staff(4)	General Office Space Sq. Ft.(5)	Special Purpose Space: Sq. Ft.	Description(6)	Additional Space Sq. Ft.(7)	Total Space
375th Aeromedical Airlift Wing											
Command Section	CC	3	17,690 (8)	P	1	8	1,080	1,920	Auditorium		3,000
Deputy Commander for Operations	DO	3 509	1,080	S	3	8	1,080				1,080
History	HO	7	582	P	1	2	270				270
Public Affairs	PA	3	(8)	P	1	11	1,485			108	1,591
Safety	SE	3 1522	(8) (9)	P S	1 3	12	1,620	2,000	Traffic Safety		3,620
Deputy Commander for Aeromedical Evacuation	SG	3	(8)	P	1	28	3,780	100	EDP		3,780
Social Actions	SL	3190	2,982	F	3	12	1,620	1,298	TNG		2,918
Deputy Commander for Resource Management	RM	3	(8)	P	1	9	1,215	150	Control Center	135	1,500
Resource Plans Division	LGX	3									
Comptroller Division	AC	10 4001	18,331 930	F P	2 2	135	18,225	4,468			22,693
Contracting Division	LGC	861	8,463	F	1	68	9,180	1,030	TNG	665	10,210
Deputy Commander for Maintenance	MA	433 350	6,833 3,910	P F	1 3	114	15,390	867 226	TNG EDP	945	16,319
375th Consolidated Maintenance Squadron	CAMS	351 441	2,977 3,683	F F	3 3			781	Other		

Organization	Symbol	Existing Space Allocation: Building No.	Gross Sq. Ft.(1)	Category(2)	Condition(3)	Administrative Space Requirements (category group 61): General Office Staff(4)	General Office Space Sq. Ft.(5)	Special Purpose Space: Sq. Ft.	Description(6)	Additional Space Sq. Ft.(7)	Total Space
375th Supply Squadron	LGS	4001	20,995	P	2	121	16,335	1,600	EDP		17,935
		457	740	T	3						
375th Transportation Squadron	LGT	43	1,815	P	1	29	3,915	250	EDP	1,485	
		530	3,383	T	1			4,653	TNG, Ready Room		18,003
		1522	5,904 (9)	S	3			7,500	Freight Office		
		3660	1,625	S	3						
Staff Weather	WE	No Separate Requirement									
375th Air Base Group											
Command Section	CC	1512	520	T	2						
		3									
HQ Squadron Section	CCQ	3	9,866 (10)	P	1	6	810				810
Base Administration	DA	3				11	1,485				39,391
		1900	3,764	S	1			3,989	BITC/DOC Security		
		3277	6,081	T	3			5,730	Documentation Br		
		700	17,463	P	1			11,910	Pub Distrib		
								16,280	Field Print Plant		
Communication	DC	No separate space requirement (see 1974 TPG)									
Civil Engineering	DE	528	10,220	S	3	136	18,360	200	EDP	400	2[illegible]129
		530	3,987	T	3			4,525	Drafting		
		531	1,977	T	3			2,604	Other		
		532	1,655	T	3			1,040	Contractor		
		533	1,740	T	3						
		1522	5,468	S	3						
Personnel	DP	10	19,785	T	2	163	22,005	14,362	EDP, Cust Serv	258	54,647
		52	8,568	P	2			16,150	TNG		
		3190	8,024	T	3			1,872	Other		
		3192-98	7,108	T	3						
Disaster Preparedness	DW	56	9,871	P	2	7	945	3,167	TNG	135	7,095
								1,080	ST		
								1,768	Other		
Staff Judge Advocate	JA	861	7,043	T	1	12	1,829	460	LIB		6,256
								1,380	Courtroom		
								575	Reception		
								1,012	Other		
Morale, Recreation & Welfare	SS	1533	5,834	T	3	25	3,375	800	EDP		4,175

Organization	Symbol	Existing Space Allocation: Building No.	Gross Sq. Ft.(1)	Category(2)	Condition(3)	General Office Staff(4)	General Office Space Sq. Ft.(5)	Administrative Space Requirements (category group 61): Special Purpose Space Sq. Ft.	Special Purpose Space Description(6)	Additional Space Sq. Ft.(7)	Total Space
Services Squadron	SV	3	(10)	P	1	21	2,835				2,835
		150	672	P	1						
		1510	1,755	S	2						
		1512	455	S	2						
Headquarters Military Airlift Command	HQ MAC	1600	261,315	P	1	2,953 (12)	398,655	41,809	EDP	12,638	503,618
		1521	3,349	S	1			12,829	TNG		
		1522	33,197	S	3			963	Library		
		4	5,119	P	2			745	Vault		
		9	2,688	T	3			4,144	Contractor		
		61	6,045	P	1			5,160	Reservation Control		
		150	4,850	P	1			17,144	Printing, Publications		
		700	17,144	P	1			9,531	Other		
		859	27,020	T	1						
		861	17,916	T	1						
		865	14,937	T	3						
		1575	42,906	P	1						
		1605	4,704	T	1						
Headquarters, Air Force Communications Command	HQ AFCC	40	152,669	P	2	1,450	195,750	1,030	Library	12,150	212,780
		3190	3,080	T	3			1,350	ST		
		1533	2,313	T	3			1,300	EDP		
		10	2,806	T	2			1,200	Other		
		35	3,640	T	1						
Defense Commercial Communications Office	DECCO	3189				227 (13)	30,645	8,150	EDP		47,348
								450	Library		
								350	Draft		
								5,053	ST		
								2,700	Other		
			51,500	T	3						
Defense Communication Agency Operations Center, Allocations and Engineering Directorate	DCOAC	3189				40 (13)	5,400	150	TNG	810	7,003
								32	Vault		
								611	EDP		
Headquarters 23rd Air Force	HQ 23AF	4	35,516	P	2	196	26,460	2,773	Command/Control Centers		33,817
Headquarters Aerospace Rescue and Recovery Service	HQ ARRS							973	Vaults		
								1,032	SCIF		
								801	CAT Room		
								1,778	Other		
1842nd Electrical Engineering Group	1842 EEG	3190	25,914	T	3	211	28,485	784	Drafting	2,592	40,786
								8,460	System Test		
								465	Library		

NOTES TO TABLE 1

(1) Existing space allocation is derived from Real Property Inventory and checked against gross square footage measured from building plans provided by facility managers. Gross square feet includes common building areas, and actual ratio of gross to net square feet will be different for each facility.

(2) P = permanent building; S = semipermanent building; T = temporary building.

(3) Condition categories are:
- 1 = Usable as is for designated function.
- 2 = Usable, but requires alteration/maintenance/repair to raise to Condition Code 1.
- 3 = Forced Use, a facility which cannot practically be raised to Condition Code 1 for the current designated use.

(4) General office staff is total administrative staff less personnel working within special purpose space and personnel working on second or third shifts.

(5) General office space is calculated at 135 square feet of floor area per general office employee.

(6) Abbreviations for Special Purpose Space are:
- EDP = Central data processing (word processors/personal computers are not considered special purpose space).
- TNG = Training rooms/classrooms
- ST = Special equipment storage
- LIB = Library

(7) Additional space is space required to accommodate projected increase in staff FY 85-87 plus special purpose space specified to meet additional requirements.

(8) Total gross area of 17,690 square feet allocated to HQ 375 AAW includes space occupied by CC, DO, PA, SE, SG, RM, and LGX.

(9) Gross area of 5,904 square feet allocated to 375 AAW/LGT also includes space occupied by 375 AAW/SEG.

(10) Total gross area of 9,866 square feet allocated to HQ 375 ABG includes spaces occupied by CC, CCQ, DA and SV.

(11) Requirement calculated as 1.5 times the net square foot requirement in AFM 86-2, Ch. 13, Sec C.

(12) Includes administrative staff of HQ Airlift Communications Division which merged with HQ MAC/AD on 1 January 1985 to form HQ MAC/SI; does not include staff working in special purpose space in Building 1600.

(13) Includes Contractor personnel.

(14) Included in HQ Military Airlift Command.

Table 2

SUMMARY OF FUTURE ADMINISTRATIVE FACILITY REQUIREMENTS

Existing Facilities To Remain

Building No.		Area (Gross Square Feet)
3		29,483
4		39,379
40		164,950 [1]
433		16,500
700		34,607
1575		46,536 [1]
1600		304,525
4001		21,925
	Total	657,905

Existing Facilities To Be Removed

Building No.		Area (Gross Square Feet)
9		2,688
10		41,850
35		3,640
37		3,816
41		4,070
350		823
351		2,977
441		3,683
457		740
509		2,800
528		10,220
530		3,987
531		1,197
532		1,655
533		1,740
859		52,900
861		41,882
865		14,937
1521		48,413
1522		50,540
1533		8,147
1605		4,705
1900		4,897
3189		51,500
3190		44,140
3192-98		6,496
3277		6,081
	Total	420,523

Table 2 (Continued)

Existing Facilities To Be Converted To Nonadministrative Use

Building No.	Area (Gross Square Feet)
7	1,225
43	4,869
50	9,701
52	8,568
56	9,871
61	6,551
150	2,795
1510	1,755
1512	975
1534	13,926
3660	14,550
Total	74,786

Future Construction

Facility Name	Area (Gross Square Feet)
HQ AFCC	218,000
DECCO/DCOAC	72,000
Consolidated Computer Facility Addition	88,000
HQ MAC Addition	50,000
Consolidated Personnel/ Finance Facility	87,000
Base Civil Engineering Facility	27,000
Base Communications Facility	23,000
Communications Engineering Facility	53,000
Vehicle Operation Mgt. Facility	6,400
Traffic Management Facility	12,500
Total	636,900

(1) Includes space now occupied by nonadministrative facilities.

Table 3

FACILITY DEFICIENCIES

Scott Air Force Base, Illinois

CAT CODE	FACILITY	DEFICIENCY	SOURCE
112 211	TAXIWAY, PARALLEL	76,700 SY	MCP
116 667	PAD, CALIBRATION	2,061 SF	MCP
116 672	PAD, ACFT WASH RK	2 EA	AFM 86-2
123 335	VEH FL STN	9 OL	AFM 86-2
131 116	COMM RECEIVER	4,000 SF	F-TAB
131 132	SAT COMM TRML	7,000 SF	MCP
134 375	RAPCON CEN	6,034 SF	MCP
136 661	LIGHT, RUNWAY APPROACH	1,500 LF	MCP
141 783	TRML, AIR FREIGHT/PASS	67,000 SF	MCP
149 962	CONTROL TOWER	1 EA	AFM 86-2
171 158	BAND CENTER	9,000 SF	AFM 86-2
171 443	RESERVE STORAGE	7,500 SF	INTERVIEW
179 477	GRENADE LAUNCHER RANGE	1 EA	INTERVIEW
211 111	HG MAINT	33,846 SF	
211 152	ACFT MAINT FCLTY	64,500 SF	MCP
211 157	FIELD MAINT FCLTY	40,000 SF	MCP
211 161	COR CON UTIL STOR	240 SF	AFM 86-2
217 712	AVIONICS SHP	10,000 SF	AFM 86-2
218 712	ACFT SUP EQUIP SHP	11,250 SF	AFM 86-2
218 852	SURVIVAL EQUIP SHP	3,582 SF	AFM 86-2
219 943	BCE PAV GRND FCLTY	6,000 SF	AFM 86-2
219 944	BCE FCLTY	55,000 SF	MCP
219 944	BCE MAINT SHOP	14,109 SF	AFM 86-2
422 257	MUNITIONS STOR FCLTY	5,409 SF	MCP
442 515	MEDICAL STOR	15,655 SF	AFM 86-2
442 758	RETAIL SALES FCLTY	20,000 SF	MCP
442 769	HOUSING SUPPLY STOR	4,000 SF	INTERVIEW

Table 4

PROPOSED FACILITIES

Scott Air Force Base, Illinois

PLAN REF. NO.	CAT CODE	FACILITY	DEFICIENCY	EXPLANATION
	112 211	TAXIWAY, PARALLEL	76,700 SY	MCP 91 (Plus Related Fclty)
	116 667	PAD, CALIBRATION	2,061 SF	MCP 91 (Moved by Taxiway)
	116 672	PAD, ACFT WASH RK	2 EA	Co-Locate with 311 161
	123 335	VEH FL STN	9 OL	
	131 116	COMM RECEIVER	4,000 SF	Expand Bldg 1089
	131 132	SAT COMM TRML	7,000 SF	MCP 86
	134 375	RAPCON CEN	6,034 SF	MCP 88
	136 661	LIGHT, RUNWAY APPROACH	1,500 LF	MCP 91
	141 783	TRML, AIR FREIGHT/PASS	67,000 SF	MCP 91 (On Apron)
	149 962	CONTROL TOWER	1 EA	
	171 158	BAND CENTER	9,000 SF	Renovate Bldg 56
	171 443	RESERVE STORAGE	7,500 SF	FY 86
	179 477	GRENADE LAUNCHER RANGE	1 EA	Landfill Site
	211 111	HG MAINT	33,846 SF	
	211 152	ACFT MAINT FCLTY	64,500 SF	MCP 90
	211 157	FIELD MAINT FCLTY	40,000 SF	MCP 91
	211 161	COR CON UTIL STOR	240 SF	Co-Locate with 116 672
	217 712	AVIONICS SHP	10,000 SF	
	218 712	ACFT SUP EQUIP SHP	11,250 SF	
	218 852	SURVIVAL EQUIP SHP	3,582 SF	
	219 943	BCE PAV GRND FCLTY	6,000 SF	Consolidate BCE Fclty
	219 944	BCE FCLTY	55,000 SF	MCP 90
	219 944	BCE MAINT SHOP	14,109 SF	AFM 86-2
	422 257	MUNITIONS STOR FCLTY	5,409 SF	MCP 88
	432 283	COLD STOR BSE	3,698 SF	Move from Comm Ctr

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 375TH AIR BASE GROUP (MAC)
SCOTT AIR FORCE BASE, ILLINOIS 62225

11 JUN 1984

REPLY TO ATTN OF: DEER (Ms. Watkins, 2926)

SUBJECT: Administrative Space Survey

TO: ALL UNIT AND SQUADRON COMMANDERS

1. We are asking for your assistance in gathering requirements data for your administrative space at Scott AFB. The scope of our data must encompass all organizations, whether Air Force, DOD, tenants or regularly assigned contractor personnel. The data collected will be incorporated into a base-wide Administrative Space Study and used in our Base Comprehensive Plan for future development. Additionally, the data will be used to support our proposals for construction of additional administrative space or for relocation/realignment of existing organizations. You are encouraged to employ your best personnel in the completion of this survey as this data will be used to plan and program your current and projected administrative space requirements.

2. A survey package is attached for completion and return to the above office no later than 30 Jul 84 along with your endorsement. (In addition, we ask that your project officer contact this same office upon receipt of this package.)

GEORGE R. DIXON, Colonel, USAF
Commander

1 Atch
Administrative Space Survey

GLOBAL IN MISSION — PROFESSIONAL IN ACTION

ADMINISTRATIVE SPACE REQUIREMENTS SURVEY

INSTRUCTIONS AND DATA DESCRIPTION

The information/data we request consists of completing the 1984 Data Worksheet. Please call 375 ABG/DEER, Extension 2926, so that we may verify your receipt of this package. In addition we request that your unit commander review and endorse the completed package before it is returned to us.

1984 DATA WORKSHEET

1. Name or designation of your unit or organization.

2. What is the parent organization or headquarters to which your organization reports? ______________________________

3. Briefly describe your organizational mission. Note: If your organization has a prepared mission statement, such as for press releases, simply include it as an attachment to your submission rather than making a response here.

____

____

4. Is there another organization(s) or unit(s) at Scott Air Force Base with which your organization should be co-located in the same building or located in close proximity? If so, please enter the name of that organization.

____

a. Please indicate the below listed conditions which should be met regarding your organization and the unit(s) or organization(s) cited in part 4 by striking out the conditions which do not apply.

(1) Co-located/Close Proximity (Strike out one)

(2) Location is: Mandatory/Preferred (Strike out one)

b. Briefly explain the reason why your organization must be located in proximity or co-located with the unit(s) or organization(s) cited in part 4a.

5. Administrative Space Requirements are based on two considerations. These are the requirements for special purpose space (addressed further on) and space for personnel working in an office environment. To determine the number of personnel in your organization for whom we must provide office space, please complete the following calculation. Note that this data must be based upon personnel authorized (from your Unit Manning Document) not the number of personnel on board or assigned.

a. Total administrative personnel authorized: _____

b. Authorized personnel working exclusively within special purpose space. Include all shifts. _____

c. Subtract b from a and enter result: _____

d. Adjustment for shift personnel: Determine the number of authorized personnel working on a second or third shift who use exactly the same administrative space as the personnel present during the normal duty day and enter here: ______

e. Subtract d from c and enter here: ______

6. The product of line 5e. represents the number of personnel in your organization that must be provided office space. If there is a known change in your personnel authorization, within the next 3 years, which will occur due to mission change or other causes, please indicate below:

a. The number of personnel to be gained or lost. ______

b. When will this change occur? ______

c. What is the cause of this change?

____

____

7. Provision for contractor personnel. Is your organization obligated by contract or agreement to provide administrative space for contractor personnel such as Field Engineers or others?

a. If so, and the amount of space for contractor use is specified in the agreement, identify the contractor and the total area (in sq. ft., please) which we are obligated to provide.

Contractor(s)	Area Specified (SF)

TOTAL CONTRACTOR AREA ______________

b. If a specified area is not called for in the contract, please provide the following information regarding contractor personnel.

Maximum number of Contractor Personnel Present During Any Shift ______

Name of Contractor or Company ______________________________

Point of Contact for Contractor:

NAME: ______________________________ TELEPHONE NUMBER ______________

SPECIAL PURPOSE SPACE:

This term applies to areas that are required to meet special administrative needs. Auditoriums, libraries, training rooms, drafting rooms and rooms housing electronic data processing (EDP) and associated equipment are examples of this type of space. Be sure when identifying EDP equipment that you allow sufficient space as required by manufacturer's instructions.

Example: Special Purpose Requirements:

Aeromedical Evacuation Operations Support: 250 SF. Provides space for current and near-term programmed Electronic Data Processing and telecommunications equipment used in support of command and control activities. (Please use the attached worksheets for your calculations)

NOTE: Current Air Force Regulations do not include word processing equipment nor mini-computers (desk top terminals) as part of the definition of Special Purpose Space. By separate calcalation indicate the count and the amount of space (SF) used by this type equipment in your organization.

	Count	SF
Word Processing Equipment	____	____
Mini-computer	____	____

DEFICIENCIES/FORCED USE:

To identify the shortfalls of administrative space and special purpose space, tell us the amount of additional square footage needed to adequately support your existing function and/or any future expansion. For example, identify areas of forced use within a building, file cabinets in stairwells, distribution or storage in hallways, etc. Briefly describe each requirement and tell us how much total space is needed to adequately support these forced-use areas. Again if there is any anticipated growth in the areas identified as special purpose, indicate what changes are expected in equipment and estimate the square footage needed to house it. Also include as a deficiency any function which would take place if there were adequate space but due to present limitations is not performed.

Example:

Deficiencies/Forced Use:

Storage cabinets located in hallway: 30 SF. Due to the crowded office condition, storage cabinets are located in hallway resulting in hazardous conditions. (Please use attached worksheets for your calculations)

3

DEFICIENCIES/FORCED USE AREAS

FUNCTION	AREA AMOUNT (SF)	DESCRIPTION

SPECIAL PURPOSE REQUIREMENTS

FUNCTION	AREA AMOUNT (SF)	DESCRIPTION

APPENDIX E

COMPUTER APPLICATIONS FOR SPACE PLANNING AND MANAGEMENT

The following is a review of Space Planning computer software and of computer systems developed and/or used by current US Architect-Engineer firms in the areas of Space Planning and Space Management.

Space Planning Computer Software

1. ALDEP (Automated Layout Design Program) was developed by International Business Machines (IBM) and documented by Seehof and Evans (48) in 1967. It uses a square grid floor plan representation and attempts to assign modules to grid locations such that adjacency requirements are met (39:441). Francis and White (23), Gaither (25), and Mitchell (39) outline the process.

A building outline must be input, to set boundaries for the layout. ALDEP randomly selects a department or activity and places it in the layout. A relationship chart, input as a triangular matrix,

> is scanned, and a department having a high closeness rating to that already located is placed in the layout. This process is continued until either all departments have been placed or no departments available for placement have a high closeness rating with departments already placed. In the latter situation, a department is randomly selected from those available for placement. ... The selection process continues until all departments are placed. The score for the layout is determined by totalling for adjacent departments the numerical values assigned to the closeness ratings (23:102).

Each repetition of the process produces a different solution. The designer determines the number of alternatives required and evaluates them in terms of total score and any other criteria not considered by the program. The assigned closeness ratings are:

$$A = 4^3 = 64, \quad E = 4^2 = 16, \quad I = 4^1 = 4,$$
$$O = 4^0 = 1, \quad U = 0, \quad X = (-4)^5 = -1024$$

where A, E, I, O, U, and X are as defined by Muther in Systematic Layout Planning (43), see Figure 1 in Chapter II. A minimum allowable score can be set such that only alternatives with an acceptable score are printed out. It is customary to set the minimum score for the first run at zero and use the maximum score for all alternatives generated as the minimum acceptable score on the next run (23:103). The program is also designed to avoid extreme zig-zagging of activity borders (23:104). Seehof and Evans expand on the scoring system:

> The layout score is the summation of the preference value for adjacent departments. For each module (grid square) of the building, the preference value of the eight surrounding modules is added to the layout score. Then the preference value is set to zero so that it is added only once to the layout score. (48:693)

A sample problem is shown below (23:103-108). A space requirements table and relationship matrix (Figure E1) are input for 10 departments, and three successively better maximum score alternatives are produced from three consecutive program runs (Figures E2, E3, and E4). A fourth run did not produce a higher score alternative. Note that unallocated spaces are shown with zeros on the printouts.

2. CORELAP (Computerized Relationship Layout Planning) was developed by Lee and Moore between 1965 and 1967. In their journal article bearing the program's name (35) they compare the program to ALDEP and highlight the advances made by

(a)

Department	*Required Area*	*No. Squares*
111	120.000	12
112	340.000	34
113	410.000	41
114	130.000	13
115	60.000	6
116	570.000	57
117	170.000	17.
118	450.000	45
119	1,400.000	140
120	1,250.000	125

Departments available for random placement = 10

(b)

111	S									
112	U	S								
113	U	U	S							
114	I	O	I	S						
115	U	O	U	I	S					
116	U	U	U	I	E	S				
117	U	U	U	O	U	U	S			
118	U	U	U	I	I	E	U	S		
119	U	I	A	I	U	U	A	E	S	
120	E	O	U	O	U	U	U	U	U	S

Figure E1. ALDEP Data Input for Sample Problem (a) Floor Space Requirements for a Ten Department Facility (b) Relationship Chart in Matrix Form (23)

TRIAL LAYOUT   11A SCORE = 414

TOP FLOOR

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	10	1	1	1	1	9	9	9	9	8	8	8	8	0	0	0
0	10	10	10	1	1	1	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	1	1	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	1	1	9	9	9	9	7	7	9	9	0	0	0
0	10	10	10	10	1	2	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	2	2	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	2	2	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	2	2	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	2	2	9	9	9	9	7	7	8	8	0	0	0
0	10	10	10	10	2	2	9	9	9	9	9	7	9	9	0	0	0
0	10	10	10	10	2	2	9	9	9	9	9	9	8	8	0	0	0
0	10	10	10	10	2	2	9	9	9	9	9	9	8	8	5	5	0
0	10	10	10	10	2	2	9	9	9	9	9	9	8	8	5	5	0
0	10	10	10	10	2	2	9	9	9	9	9	9	8	8	5	5	0
0	10	10	10	10	2	2	9	9	9	9	9	9	8	8	6	6	0
0	10	10	10	10	2	2	3	9	9	9	9	9	9	3	5	5	0
0	10	10	10	10	2	2	3	3	9	9	9	9	8	9	5	5	0
0	10	10	10	10	2	2	3	3	9	9	9	9	8	8	6	6	0
0	10	10	10	10	2	2	3	3	9	9	9	9	8	8	6	6	0
0	10	10	10	10	2	2	3	3	9	9	9	9	8	8	6	6	0
0	10	10	10	10	2	2	3	3	9	9	9	9	8	8	6	6	0
0	10	10	10	10	4	2	3	3	9	9	9	9	5	5	5	5	0
0	10	10	10	10	4	4	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	4	4	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	4	4	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	4	4	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	4	4	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	4	4	3	3	9	9	9	9	5	5	5	5	0
0	10	10	10	10	3	3	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	3	3	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	3	3	3	3	9	9	9	9	6	6	6	6	0
0	10	10	10	10	3	3	3	3	9	9	9	9	6	6	6	6	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure E2. ALDEP Output for Sample Problem: Trial 1 (23)

TRIAL LAYOUT — 168 SCORE = 420

TOP FLOOR

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	3	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	3	9	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	9	9	9	9	9	9	8	8	6	6	10	10	10	10	2	2	0
0	9	9	9	9	9	9	8	4	6	6	10	10	10	10	2	2	0
0	9	9	9	9	9	9	4	4	6	6	10	10	10	10	2	2	0
0	9	9	9	9	9	9	4	4	6	6	10	10	10	10	2	2	0
0	9	9	9	9	9	9	4	4	6	6	10	10	10	10	2	2	0
0	9	9	9	9	9	7	4	4	6	6	10	1	10	10	2	2	0
0	9	9	9	9	7	7	4	4	6	6	1	1	10	10	2	2	0
0	9	9	9	9	7	7	4	4	6	5	1	1	10	10	10	10	0
0	9	9	9	9	7	7	7	7	5	5	1	1	10	10	10	10	0
0	9	9	9	9	7	7	7	7	5	5	1	1	10	10	10	10	0
0	9	9	9	9	7	7	7	7	5	1	1	1	10	10	10	10	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure E3. ALDEP Output for Sample Problem: Trial 2 (23)

TRIAL LAYOUT — 15C SCORE = 422

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	7	7	9	9	9	9	6	6	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	6	6	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	6	6	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	6	6	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	6	6	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	6	6	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	6	8	6	6	10	10	10	10	0	0	0
0	7	7	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	7	9	9	9	9	9	8	8	6	6	10	10	10	10	0	0	0
0	9	9	9	9	9	9	8	8	6	6	1	10	10	10	0	0	0
0	9	9	9	9	9	9	8	8	6	6	1	1	10	10	0	0	0
0	9	9	9	9	9	9	8	8	6	6	1	1	10	10	10	10	0
0	9	9	9	9	9	9	8	8	6	6	1	1	10	10	10	10	0
0	9	9	9	9	9	9	8	8	6	6	1	1	10	10	10	10	0
0	9	9	9	9	9	3	8	8	6	6	1	1	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	1	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	6	6	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	5	5	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	5	5	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	5	5	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	4	4	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	4	4	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	4	4	2	2	10	10	10	10	0
0	9	9	9	9	3	3	8	8	4	4	2	2	10	10	10	10	0
0	9	9	9	9	3	3	3	3	4	4	2	2	10	10	10	10	0
0	9	9	9	9	3	3	3	3	4	4	2	2	10	10	10	10	0
0	9	9	9	9	3	3	3	3	4	2	2	2	10	10	10	10	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure E4. ALDEP Output for Sample Problem: Trial 3 (23)

CORELAP. While the program is based on a heuristic algorithm, as is ALDEP,

> it is a path-oriented analysis of the layout problem which builds systematically by adding one department upon another until a final layout is achieved, whereas ALDEP's method of arriving at a final layout is not path oriented. This is to say, each randomly generated layout has no connection with the previous layout (35:196).

Muther, the developer of SLP, assisted in the development of CORELAP. Like SLP, CORELAP "arrives at the logical block plan layout; however, it can in no way be construed to be optimum in the strict mathematical sense" (35:196).

The major differences to ALDEP are as follows (23:108-115):

a. A building outline is not required;

b. It is possible to place a constraint on the length to width ratio of the final layout;

c. Departments can be pre-assigned, but only along the layout perimeter.

d. The following numerical values are assigned to the closeness ratings:

A = 6, E = 5, I = 4, O = 3, U = 2, X = 1

Total Closeness Rating (TCR) for department i is defined as

$$TCR_i = \sum_{j=1}^{m} V(r_{ij})$$

where

$V(r_{ij})$ is the numerical value assigned to the closeness rating for departments i and j, and

m is the number of departments

The order of placement is based on the highest TCR with items already located in the layout.

e. CORELAP arranges departments in the layout differently. ALDEP employs a vertical scan routine to restrict the irregularity of the shape. CORELAP evaluates a number of possible locations for a rectangular shaped department, as well as a number of different rectangular shapes for the department. Its evaluation is based on the total length of common boundaries with highly rated adjacent departments.

An example of CORELAP input and output is at Figures E5, and E6. The relationship chart used is at Figure 1 in Chapter II. CORELAP was designed for application to the layout of large manufacturing plants. However, it has been used on all facility types. Lee and Moore state that

> In the design of a new plant, it makes no sense whatever to 'stuff' a layout into an existing building only to pay the cost in inefficiencies as long as the layout is in use. A new building needs to be built to maximize the effectiveness of the process it houses. The CORELAP program is designed to provide this information (35:200).

An interactive form of CORELAP has been developed which has significantly improved the designer's abilities to relocate activities manually.

3. <u>CRAFT</u> (Computerized Relative Allocation of Facilities Technique) was developed by Buffa and Armour in 1964, before either ALDEP or CORELAP. It was intended for use in design of layouts where material handling costs were a major consideration. It employs a heuristic improvement algorithm which seeks to minimize material handling costs.

Input includes flow data (quantity of goods passing between departments), material handling cost data, an initial

Department	Area
11	500.00
12	400.00
13	600.00
14	7000.00
15	600.00
16	400.00
17	500.00
18	400.00
19	500.00
20	300.00
21	400.00
22	1000.00
23	400.00
24	500.00
25	1100.00
26	1100.00
27	600.00
28	300.00
29	1100.00
30	400.00
31	200.00
32	400.00
33	200.00
34	1800.00
35	1200.00
36	1200.00
37	7000.00

(a)

(1) Department Number	(2) Number of Unit Squares Required	(3) Side of the Largest Square in (2)	(4) Remainder Col (2) − [Col (3)]²	(5) Total Closeness Rating (TCR)
29	11	3	2	81
30	4	2	0	79
36	12	3	3	77
34	18	4	2	75
19	5	2	1	75
15	6	2	2	74
37	70	8	6	74
32	4	2	0	73
14	70	8	6	70
18	4	2	0	70
33	2	1	1	70
35	12	3	3	69
11	5	2	1	67
13	6	2	2	67
31	2	1	1	66
16	4	2	0	64
12	4	2	0	63
21	4	2	0	62
28	3	1	2	61
23	4	2	0	60
17	5	2	1	59
27	6	2	2	59
24	5	2	1	56
22	10	3	1	55
26	11	3	2	54
20	3	1	2	54
25	11	3	2	38

(b)

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	29	29	29	29	0	0
0	0	29	29	29	29	0	0
0	0	0	29	29	29	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Output of First Department, 29, Entered into Layout.

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	29	29	29	29	34	34	34	34	34	0	0
0	0	29	29	29	29	34	34	34	34	34	0	0
0	0	0	29	29	29	34	34	34	34	0	0	0
0	0	0	0	0	0	34	34	34	34	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

Output Showing Arrangement of Second Department, 34, with Department 29.

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	32	32	0	0	0	0	0	0	0
0	0	0	0	32	32	0	0	0	0	0	0	0
0	0	29	29	29	29	34	34	34	34	34	0	0
0	0	29	29	29	29	34	34	34	34	34	0	0
0	0	0	29	29	29	34	34	34	34	0	0	0
0	0	0	0	0	0	34	34	34	34	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

Output Indicating where Third Department, 32, Is Added into the Layout.

(c)

Figure E5. CORELAP example. (a) Departmental Area Requirements (b) Computation of Total Closeness Ratings (c) Output Showing Successive Addition of Three Departments (35)

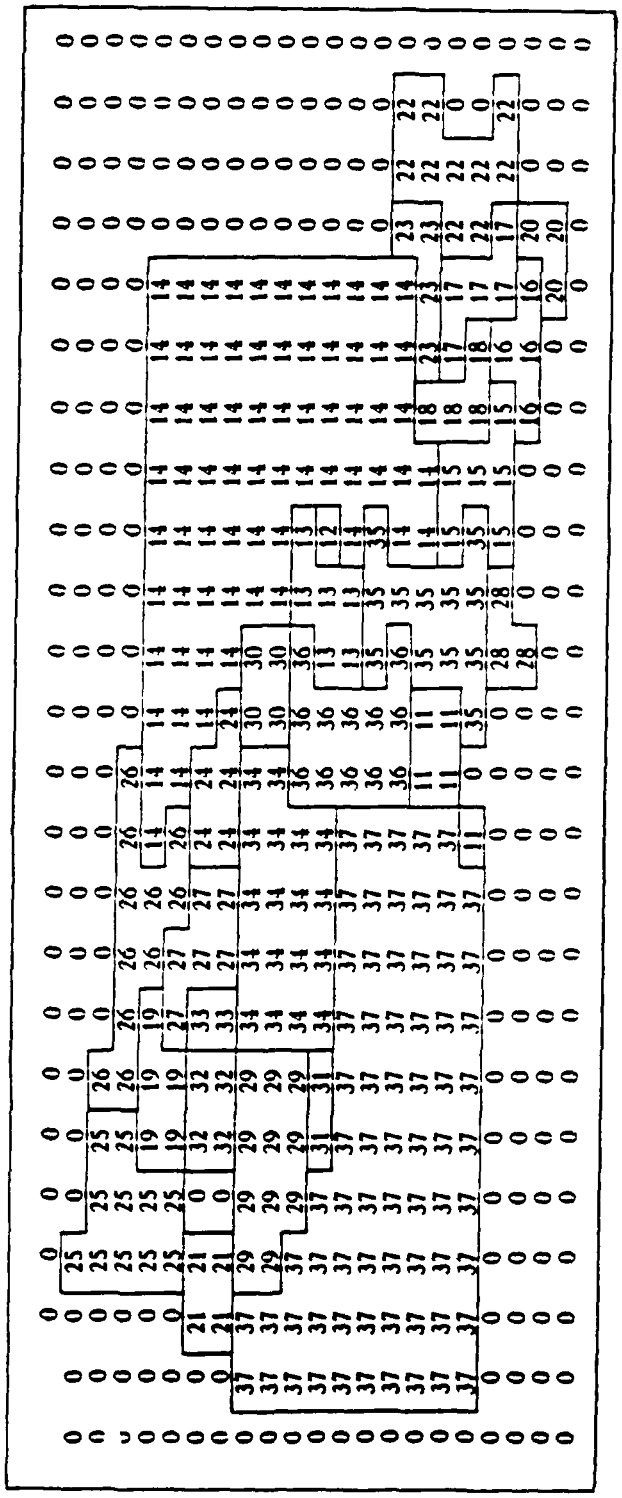


Figure E6. CORELAP example - Final Block Layout Output. Zeros Refer to Unallocated Space (35) layout, and number and locations of fixed departments. It seeks an optimum design by making improvements in the layout in sequential fashion. It is sometimes referred to as a quantitative layout program, and ALDEP and CORELAP (which are based on activity relationships) are referred to as qualitative layout programs (23:125). Francis and White describe the process:

> CRAFT first evaluates a given layout and then considers what the effect will be if department locations are interchanged. If improvements can be made by making pairwise exchanges, the exchange producing the greatest improvement is made. The process continues until no improvement can be made by pairwise exchanges. Only departments with common borders or of the same area are considered for exchanges of location (23:125-126).

Vollmann has broadened the application of CRAFT to layout of non-manufacturing activities and offices, but the basic material flow algorithm has remained constant (57;58).

4. SEARCH (System Evaluation of Architectural Criteria) was designed by the US Army Corps of Engineers Construction Engineering Research Laboratory (CERL) in 1975 to automate the checking of plans for their Military Construction Program (MCP) for functional compliance with project briefs (39:478). In 1983 it was combined with other stand-alone systems to produce the CAEDS (Computer Aided Engineering and Architectural Design System). CAEDS supports the entire facility design process, starting from the initiation of requirements and continuing through to the preliminary and final design phases. It also produces working drawings and

cost estimates, and contains in its database extensive standard facility designs.

The SEARCH module includes walking distance, acoustic separation, line of sight, handicap accessibility, as criteria for evaluating alternatives. It cannot design layouts. The SKETCH module is used to develop custom layouts or to modify standard layouts, and provides a wide array of standard architectural details.

Other modules in the CAEDS system are: DIS (Design Information System) which reviews project information from an automated DD 1391 database for identification of projects which can use standard designs as a starting point; BLAST, which analyses alternative designs for energy efficiency; and CACES, which estimates construction costs direct from design drawings.

CAEDS was used in the preliminary design stages of 200 projects in the 1984 US Army MCP. A review of the entire CAEDS system was made by J. Spoonamore, one of the SEARCH module developers, in <u>CAEDS Computer Aided Engineering and Architectural Design</u> (53).

5. The <u>Harness hospital design system</u> was developed in 1972-3 under the sponsorship of the United Kingdom (UK) Department of Health and Social Security. Mitchell describes the system:

> A Harness hospital is assembled by arranging standardized, pre-designed hospital departments along a circulation spine. Rules of assembly are defined for this kit-of-parts, so that the range of potential arrangements suitable for a given situation is well-defined and relatively small (39:101).

The system automatically generates layouts according criteria input by the planner or designer.

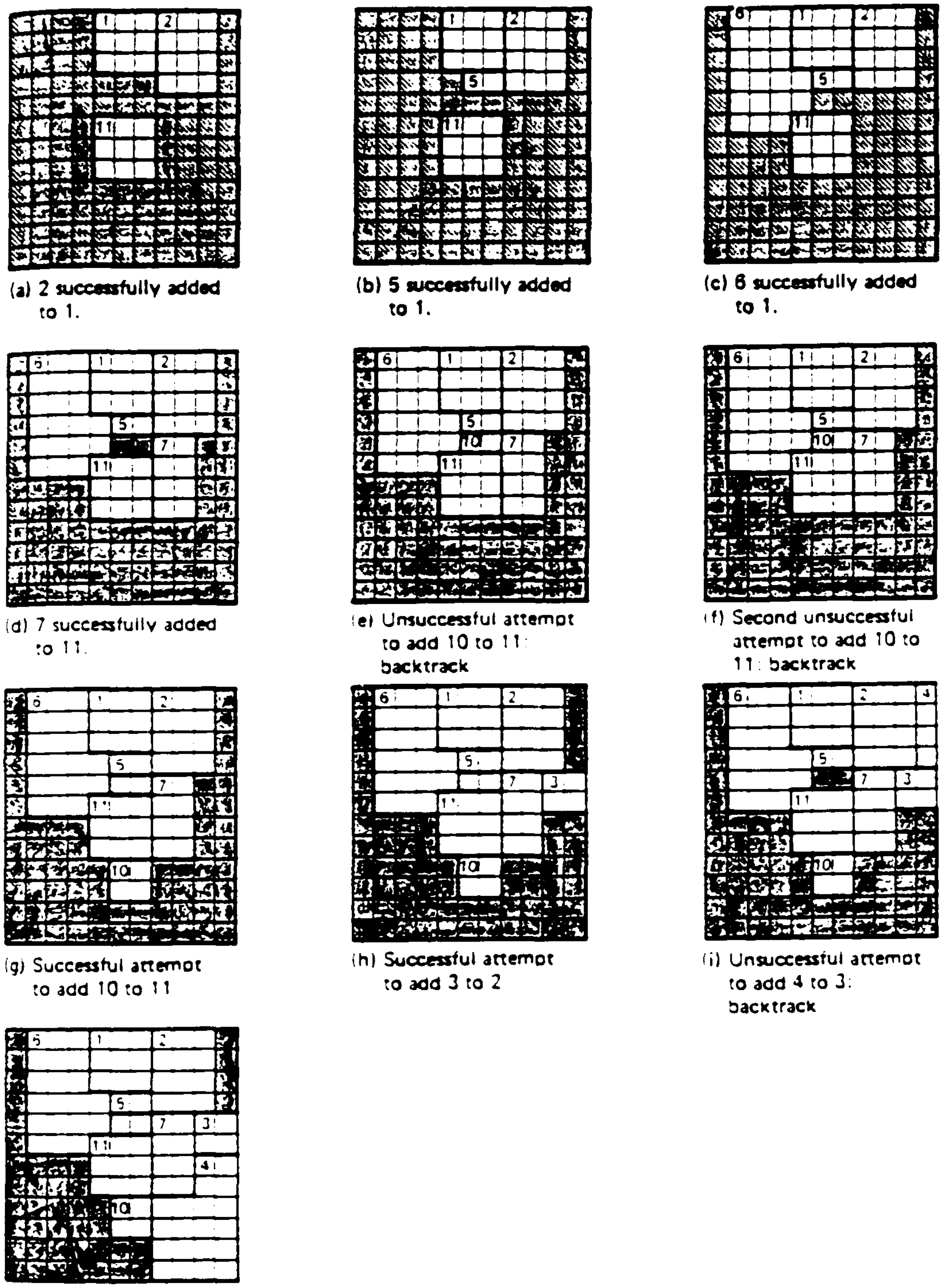
6. CEDAR 3, developed in 1975 for use by the UK Government Property Service Agency, is intended for use at the sketch design stage, to "facilitate the comparison alternative building geometrics and site layouts with respect to capital and running costs" (39:102).

7. The DOMINO floor plan layout program, developed by Mitchell and Dillon in 1972, locates spaces with defined size (number of grid modules) and shape into a defined building envelope. Tasks are formulated as quadratic assignment problems. The criteria used are distance and traffic volume between departments. It has been applied to open office and department store planning.

Spaces are placed until no space in the a particular required location remains. The order of locating activities is by the Ordered Score method. A process called 'backtracking' is then employed automatically, whereby the space which was last located is relocated so that other spaces may be added (39:465). An example is provided at Figure E7. The program attempts to add new spaces to the perimeters of located spaces to which there are high interactions. Backtracking is necessary if there is insufficient room for the added space at the chosen perimeter location. A new perimeter location is then selected and tried.

7. The DPS (Design Problem Solver) program was developed in 1975 to arrange furniture and equipment in a room in accordance with a constraint graph specifying proximity, separation, and other requirements. The program attempts to place each item in the room one by one so that no constraints are violated. There are diagnostic procedures to tell the designer the reason why any item cannot be placed (39:466).

8. LOKAT was developed in 1972 and reviewed by a Bernholtz and Fosburg in an article entitled Spatial Allocation in Design and Planning (7). It deals with two and three dimensional spatial allocation and can handle many matrices treating many different qualitative and quantitative criteria in one problem. Matrices can be weighted to reflect the importance of various criteria. It has been applied to multi-story office building layout redesign, manufacturing plants, a hospital, a law faculty building, and housing unit layout. It can generate alternatives and/or evaluate existing layouts, can design with or without the input of preset activity locations, building envelope and utility constraints, elevators, stairwells, and lobbies.



(a) 2 successfully added to 1.

(b) 5 successfully added to 1.

(c) 6 successfully added to 1.

(d) 7 successfully added to 11.

(e) Unsuccessful attempt to add 10 to 11: backtrack

(f) Second unsuccessful attempt to add 10 to 11: backtrack

(g) Successful attempt to add 10 to 11

(h) Successful attempt to add 3 to 2

(i) Unsuccessful attempt to add 4 to 3: backtrack

(j) Successful attempt to add 4 to 3

Figure E7. 'Backtracking' with DOMINO. (39)

With multi-story facilities, it can produce the best arrangements on each level according to whatever relationships and constraints are input by the matrices. It will also evaluate and score each alternative on an overall basis and according to each criteria (7). Grant states

> the decisions and sophistication built-in are design decisions, not operations research nor mathematical nor programmer decisions. The inherent internal design flexibility is thus at a maximum (26:30).

Many more space planning systems and software packages have been developed over recent years. The following are just some; CIRCUL, HIDECS 2 (Hierarchical Decomposition Techniques), CASAT (Computer Aided Space Allocation Technique), BUREX, IMAGE, MATCH, PLAN, SPACE, PLANET, Regal CAD, SPACE-PLAN, RELATE, and ALGOL, GPSS, SIMSCRIPT, and SIMULA, are minicomputer programs.

The last three of these are simulation programs. AutoCAD, VersaCAD, CADkey, and EasyCAD, are four software packages built specially for personal computers (PCs) and are readily available. The USAF has shown an interest in purchasing CAD systems and training personnel to use them (2). HQ USAF Space Command is currently purchasing ten PCs specially configured to run AutoCAD. Zenith Z-100 and Z-248 personal computers are available on GSA contract, as is CADkey. AutoCAD is not available on GSA contract. USAFA runs an introductory course in CAD, using AutoCAD, in its Civil Engineering program. This course is in drafting only and does not cover design techniques such as space planning.

Software that can be used for space management is more readily available. Database Management System (DBMS) and spreadsheet software are widely available for the PC, and all are easy to use and menu driven. Two of the more common spreadsheet programs are Lotus 1-2-3 and Supercalc. They are used mainly to tabulate data in rows and columns, to manipulate quantitative data contained in the tables, and to produce graphical representations of the data. The most common, quality DBMS programs are Dbase, Rbase, and Reflex. These programs allow data to be formatted as desired, selected, sorted, and produced in reports, as does WIMS.

Perhaps the most applicable software to real property space management are the integrated software packages such as Javelin, Enable, Symphony, and Ability, which combine DBMS, spreadsheet, graphics, business management, word processing, and telecommunications capabilities. All are PC packages, menu driven, and are supported by a great deal of documentation and commercially produced 'How To' literature.

A/E Firms Using CAD for Space Planning

A 1984 study by Graphic Systems, Inc. (Cambridge MA) found that U.S. design firms own about two PCs each. Also in 1984 there was a 63% growth rate in the PC CAD market, which is substantially higher than the growth of the mini-computer and main frame market (31:10). The increasing use of small systems is the trend in CAD, but it is the mini computer that appears still to hold the edge in space planning capabilities (31:10).

American Bridge uses Regal CAD to plan future space requirements for its clients. It allows quick and accurate alterations to be planned and documented as building tenants come and go and office space changes function. The interior design, and construction plans, for the first 10 floors of Tower 49 in mid town Manhattan in seven weeks using this system. It was also utilized to plan the layout of 650,000 SF of clerical space in the Mellon Bank's corporate headquarters building in Pittsburgh PA. For rent and leasing purposes, the system can automatically calculate areas of the most complex office layout. Regal CAD possesses a powerful database capability which is integrated with the graphics, allowing changes to layouts to be reflected instantaneously in the database's area quantities.

Bobrow/Thomas and Associates has developed a space programming package called User Needs Information (UNI) which assists the firm's medical planning department in space planning, room design criteria, and equipment requirements. It has been used extensively in small projects involving the rework of existing facilities. Different layout schemes can be produced quickly for final selection by the client.

Bohm-NBBJ use the SIGMA Design III CAD system which includes an advanced space planning package. The system uses color graphics to display adjacency strengths. Spaces can be picked up from a template and placed in a layout plan manually by the designer, or the process can be automatic, whichever is preferred.

The Collison Partnership do all interior design for Nordstrom Inc. stores, a major chain of high fashion retail clothing stores located throughout the western U.S. During the design of a store various schemes for the layout are studied. Although a department's shape may change with each scheme, its area is relatively fixed. The firm's CAD system can manipulate many departments through a variety of schemes in a short period of time with the system quickly providing area take-offs for each, regardless of shape.

Design Logic provides computer support services for professional, corporate, institutional, and government clients for architecture, engineering, and facilities programming and management. It offers space planning service including: monitoring of space usage, equipment and furniture locations and inventory; space planning statistics; staff and area projections; descriptions and summaries of space requirements; space, furniture, and equipment layout.

Goleman and Rolfe Associates, Inc. uses a CalComp IGS 500 CAD system for space planning of office buildings, and to provide area calculations for prospective building tenants. Area calculations are done on spreadsheet. By identifying those areas of the plan which constitute building services and corridors, the computer can produce a spreadsheet indicating gross building area, net rentable area, net tenant usable area and utilization efficiency, and multi-tenant minimum corridor net usable area and efficiency. All this is done automatically from the drawings.

Hellmuth Obata Kassabaum (HOK) runs a large nationwide network of VAX 11/780 and VAX 11/750 mini-computers to support all facets of architectural and engineering design and planning. All software is developed in-house to suit their requirements - HOK SPACE and HOK NEEDS collect and organize qualitative and quantitative information about clients' space needs, and HOK LAYOUT is used to find the best solution for placing interrelated activities vertically (stacking) and horizontally (blocking).

The Hnedak Bobo Group (HBG) uses an Intergraph 730 system produced by the Digital Equipment Corporation (DEC), which is basically a VAX 11/730 minicomputer enhanced by Intergraph's graphics processing boards. All software is created by Intergraph, and includes a Space Planning and Facilities Management package (SPFM). The package links graphics to a large database to plan layouts, generate reports of inventories, do furniture take-offs, and area calculations.

Lombard-Conrad use the Supercalc spreadsheet program and an Architectural Interactive Design System (AIDS). A user survey is conducted to determine department needs for space, equipment, and furniture, and perceptions of relationships with other departments. The spreadsheet is used to inventory all spaces. Bubble diagrams are developed from the relationship data using computer graphics, and reviewed with the client prior to developing schematic layouts with AIDS.

Medical Planning Associates uses VAX 11/750s with a DEC all-in-one Office Automation package. Space programming is performed using spreadsheet software, and schematic layout design is performed using the SPACE program.

Yearwood and Johnson Architects, Inc. use VAX 11/751s and Intergraph CAD software to create block diagrams from relationship matrices. RTKL Associates use a mix of VAX 11/751 and 11/780 with WANG peripheral hardware, and Intergraph IGDS graphics with AIMS-3 databases for space programming. H.A. Simons (International) and Sippican Consultants International similarly use the VAX 11/780 Intergraph fully developed turnkey system for space planning and programming.

Harwood K. Smith and Partners (HKA) use CalComp equipment with the CalComp Facilities Planning and Management /Stacking and Blocking Activity (FPMSASABA). It includes a strong database which contains general planning criteria and project data, the spaces required, and functional activities. Desired adjacencies and preferred locations are input interactively in a matrix which is generated by the system from the database. A base block diagram for each level of the building is automatically created from the matrix.

Individual activities can then be manipulated, regardless of their degree of space utilization. The SABA program can be invoked at any time to give the computer solution, but designer freedom is maintained. Each layout is scored objectively according to strengths of relationships between adjacent spaces. The system has been used for space planning of office buildings in downtown Dallas TX.

Raymond E. Hege is a one-man architectural design firm. He uses an IBM PC with VersaCAD for general architectural drafting and basic level space planning. While not having the level of space planning capability of the mini-computer systems and software developed by Intergraph and CalComp, the PC system and software cost is substantially lower. CAD can be used productively by even the smallest firms for true design.

APPENDIX F

SURVEY LETTER TO MAJOR COMMANDS

Air Force Institute of Technology (AU)
School of Systems and Logistics
Wright Patterson Air Force Base, OH 45433-6583

AFIT/LS (5-6569) Mar 1987

AFIT Thesis Topic: An Analysis of Methods for Maximizing the Utilization of Space in USAF Facilities.

HQ SAC/DE	HQ AFLC/DE	HQ ATC/DE
HQ TAC/DE	HQ AAC/DE	HQ SPACECMD/DE
HQ MAC/DE	HQ AFCC/DE	HQ USAFA/DE
HQ USAFE/DE	HQ AFSC/DE	HQ PACAF/DE

Dear Sir,

I am an Officer in the Royal Australian Air Force (RAAF) and am currently enrolled in the Graduate Engineering Management program at AFIT, WPAFB. I am a qualified Civil Engineer and have been working in the RAAF Facilities branch since 1976. My experience in managing the construction, modification, and maintenance of facilities at many Australian bases has prompted my interest in the long term utilization of facility space. I have chosen this subject as my AFIT thesis topic and request your assistance by providing some information on the processes used by Base Civil Engineers and Major Commands to ensure that available facility space is fully utilized.

I have studied the AFRs dealing with real property accounting and facility design and have visited Mr Dick Jonkers (HQ USAF/LEERB) and Mr Phil Clark (HQ USAF/LEEV) to obtain their interpretations of some. Maximizing facility utilization is a theme which recurs in many regulations - AFRs 86-2, 87-2, 87-22, and 88-15 to name a few. Real Property Management regulations refer specifically to the need for constant monitoring of existing facility usage.

AFR 87-2 requires that current and accurate data be kept by Base Civil Engineers (BCEs) on accommodation requirements and facility usage, and "if such data reveal that one or more facilities are not being put to maximum use, a management analysis of the use will be made" (para 2). Furthermore, it requires that the BCE make an annual presentation to the Base Facilities Board on facilities usage versus requirements, both satisfied and unsatisfied. He must detail where space shortages and surpluses exist and propose methods of best using the available space (para 2). This responsibility is extended to MAJCOMs as well. They should continually validate and evaluate assets and requirement data developed by bases, and ensure maximum effective use of all existing assets, through periodic base facility use surveys or other available means. [They should] make every effort to compress space assigned to activities, to ensure maximum effective use and conformity with criteria in AFM 86-2. (para 2)

The regulations all stress the importance of utilizing existing building space effectively, but none deal with practical methods of doing this. Could you please take the time to answer the following questions on Command policies in this area, and on current practices at bases under your command:

1. Are 'management analyses' of facility usage actually carried out, and if so, what format do they take? Are they usually base or Command instigated?

2. What indicators are used to signal that space within a facility may be under-utilized?

3. Are bases given any guidelines by Command on how to ensure space is utilized effectively?

4. Is it be possible to determine whether or not a BCE is managing facility space well? Are there any accepted 'hard' measures of effectiveness used by your Command such as an area/personnel ratio? What do IG teams look for?

5. What major projects have recently been undertaken by bases under your Command (such as Master Planning, Base comprehensive Planning, and buiding renovations) which have required a complete re-allocation of existing building space in one or more facilities? Have A&E firms specializing in Space Planning usually been contracted to determine the optimal arrangement of functions in these existing building, or has some of this work been done in-house?

6. What in-house design methods are being used to 'compress' space, both for new facilities and when modifying those existing? Are the definitive drawings from AFM 88-2 being used on a regular basis? Do BCE architects and planners commonly use Bubble Diagrams, Relationship Charts or some other tool to lay out functions on a floor plan?

7. Which bases under your command use any form of Computer Aided Architectural Design software (such as AutoCAD, VersaCAD, EasyCAD or CADkey) to layout floor plans? Do you or your bases have any plans to introduce such software as either a WIMS application package (through WANG) or as a package for Z-100 or Z-248 stand alone PCs?

I am also interested in compiling a list of planning factors involved in the redistribution of building space. Surplus space, when identified, must be matched with outstanding space requirements and a decision made as to which requirement will be satisfied. On the other hand, if an urgent requirement exists and no surplus space has been identified, a decision must be made as to how that requirement can be satisfied quickly. Often there will be insufficient time to program and construct a facility. Operational requirements may also dictate that the function must be accommodated close to existing support facilities, ruling out leasing as a feasible solution. In situations such as these,

1. Are Commands notified of the problem? If so, what advice would be given to the base?

2. What factors influence base management's decision on how to reallocate existing building space to accommodate the requirement? Are the BCE's architects, planners, or real property personnel requested to conduct space planning analyses in order to identify where space can be made available with minimum effect on users?

3. If such analyses are made, is it usually on an as-required basis to solve a specific problem, or progressively to ensure that space utilization is continually monitored?

I believe that WIMS (and BEAMS, for those bases still to receive WIMS) have fully automated Real Property accounting. In order to support the space planning activities of BCE architects and planners, what type of data do you see being required? (Note: By this I mean such things as: accurate records of building users; room functions; numbers of personnel working in individual facilities; functional relationships -things that are not usually found on a building floor plan and which often change over time). Is this type of data available to architects and planners in existing computerized or manual databases?

Your responses to these questions will enable me to gain a better perspective of the MAJCOM/DEs' perceptions of the importance of Space Planning in maximizing the utilization of Air Force facilities. I will also be conducting a survey of CONUS base BCE personnel involved in either designing floor layouts for new facilities or allocating space in existing facilities. Your responses will help me to complete the survey instrument. I can be contacted on AV 785-6569.

JOHN P. QUINN, Squadron Leader, RAAF

APPENDIX G

SURVEY QUESTIONNAIRE

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

Reply
attn: LSG

Survey Instrument (USAF Survey Control No 87-61, expiry 1 Aug 87)

BCE Building Designers and Real Property Managers

1. A graduate student of the Air Force Institute of Technology is investigating the utilization of space in Air Force facilities. The Air Force constructs, occupies and controls many millions of square feet of additional building space each year. New construction dollars are becoming more scarce, but the cost of accommodating people and increasingly more complex equipment is rising. In order to satisfy as many user requirements as is possible with the funds available to the Air Force each year, the use of space must be well planned and facilities must exhibit functional and architectural flexibility. The purpose of this study is to examine the methods and information systems currently used by facility designers and real property space managers to allocate building space efficiently and thereby extract the maximum value from each dollar spent on new construction.

2. As you are actively involved in the planning and/or design of Air Force facilities, your response to the enclosed questions is vital in determining the characteristics of those information systems and methods which have proven to be effective in planning, designing, and managing building space.

3. Your participation in this study is entirely voluntary and your input will be handled with strict confidentiality. Responses will be code numbered to preserve anonymity and any further communications between the researcher and respondents will be treated as personal. We encourage your support for this study and request that your response be mailed in the envelope provided by 12 June 1987. Any questions concerning any aspect should be direct to Squadron Leader John Quinn (Facilities Officer, Royal Australian Air Force), AFIT/LSG, AUTOVON 785-6569.

John M. Halliday, Lieutenant Colonel, USAF
Assistant Professor of Logistics Management
School of Systems and Logistics

2 Atch
1. Questionnaire
2. Envelope

Survey Instrument to Determine the Perceptions of Base Real Property and Building Design Leaders on the Utilization of Space in USAF Facilities

INSTRUCTIONS - PLEASE READ CAREFULLY BEFORE ANSWERING QUESTIONS

1. Place all answers on these sheets. There is no separate answer sheet. Further instructions are given throughout the survey on where to write your responses.

2. When a selection from alternative responses is requested, place your selection in the left margin in the circle provided.

3. Some questions require a subjective response, based on your feelings or your experience. Others are factual, and refer to actual methods and standards used at your installation.

4. You will be invited to comment on questions or issues progressively. Please feel free to write anything you wish. Above all, frankness and honesty are requested. Thank you.

****

PART 1 - LAYOUT DESIGN AND UTILIZATION MONITORING METHODS

Listed below are a series of statements that represent possible feelings that you may have about Air Force design and real property regulations, and about the value of Space Planning. Use the following rating scale to indicate your own feelings.

1 = Means you strongly disagree with the statement.
2 = Means you moderately disagree with the statement.
3 = Means you slightly disagree with the statement.
4 = Means you neither agree nor disagree with the statement.
5 = Means you slightly agree with the statement.
6 = Means you moderately agree with the statement.
7 = Means you strongly agree with the statement.

◯ 1. Design regulations provide adequate guidelines for ensuring that architects/planners minimize space wastage in floor layout.

◯ 2. Functional relationships are the most important criteria in building layout design.

◯ 3. I rely on my intuition to come up with an initial conceptual floorplan layout when designing a new building or reallocating space in an existing building.

4. The use of standard designs (AFM 88-2) does not permit designers to tailor a facility to the needs of individual users.

5. Real Property regulations adequately cover how to monitor building usage.

6. Real Property personnel in my organization are responsible for determining required changes to the physical layout of functions within existing buildings.

7. Space utilization studies of existing facilities are carried out regularly, even if there are no requirements to satisfy.

8. Our Real Property records do not indicate how efficiently a user is using the space that he has been allocated.

9. Architect or engineer assistance is provided only on request by Real Property personnel, which is usually if building modifications are required, or if the functional layout problem is particularly complex.

10. If space is known to be underutilized or used for some unapproved or wasteful purpose, action is usually taken to reallocate it.

QUESTIONS 11 to 13: Choose the response which best describes your experience:

12. Which of the following tools do you use most, when laying out floorplans?

1. Some type of computer software.
2. Bubble diagrams.
3. Functional Relationship chart (matrix).
4. AFM 88-2 standard designs.
5. Linear or non-linesr programming.
6. Intuition and experience.
7. Other. Please specify - ______________________________

13. If you use (or have used) CAD for floorplan layout, which software packages do you use (or have you used) most?

1. CADkey on a PC.
2. AutoCAD on a PC.
3. VersaCAD or EasyCAD on a PC.
4. WANG AutoCAD on WIMS.
5. Some other CAD software on PC.
6. A computer programming language such as BASIC, PASCAL, or FORTRAN.
7. Linear or non-linesr programming software.
8. I don't use a computer at all for this.

11. How does your organization assess if a user's space is under-utilized and if his allocation could possibly be reduced?

1. Known occupancy against the allowances of AFM 86-2.
2. Known occupancy and equipment space requirements.
3. Visiting buildings and making a subjective assessment.
4. Personal knowledge of base facilities and the relative efficiency of their usage.
5. Other criteria. Please specify - ______________________

____

PART 2 - EFFECTIVENESS OF THE SYSTEM

Use the following rating scale to indicate your own feelings about how effectively USAF building space is used and managed.

1 = Strongly disagree
2 = Moderately disagree
3 = Slightly disagree
4 = Neither agree nor disagree
5 = Slightly agree
6 = Moderately agree
7 = Strongly agree

14. My organization manages the use of installation building space as well as possible, considering the constraints imposed.

15. The USAF manages the utilization of its building space well.

16. Our real property records usually track building usage well.

17. Space surplus to a user's requirements can be readily identified.

18. In most cases, surplus space can be modified to satisfy some outstanding requirement.

QUESTIONS 19 & 20: The two following questions may require assistance from other personnel to extract data from Real Property records. Please answer to the best of your ability, using the scale shown below:

1. Less than 20,000 square feet (SF).
2. Between 20,000 and 40,000 SF.
3. Between 40,000 and 60,000 SF.
4. Between 60,000 and 80,000 SF.
5. Between 80,000 and 100,000 SF.
6. Over 100,000 SF.

19. My base has a list of building space **surpluses** totalling approximately:

20. My base has a list of approved but currently **unsatisfied requirements** for building space totalling approximately:

PART 3 - DATABASES

Use the following scale to best describe the capability of your Real Property and New Requirements records to support decisions involving the utilization and re-distribution of building space.

1 = Strongly disagree
2 = Moderately disagree
3 = Slightly disagree
4 = Neither agree nor disagree
5 = Slightly agree
6 = Moderately agree
7 = Strongly agree

21. New requirements data is usually detailed enough to allow Real Property personnel to look for a suitable accommodation.

22. Summary data on all outstanding requirements is available from a single source, without having to look through individual hardcopy project files.

23. The data we keep on utilization of existing building space is accurate enough to tentatively match a requirement to it.

24. Available building space is readily identifiable from real property records.

25. Our records list functions located within all buildings.

26. Surplus space is usually identified by building users.

27. Up to date building usage data is usually available when needed by planners and designers.

28. It is important to have current data on the number of personnel working in a facility, and the layout of equipment.

29. Real Property records do not contain enough information to conduct a detailed analysis of efficient space usage within facilities.

30. Space that is known to be mis-used or wasted is recorded as such, either in real property reports or on file, for possible future re-allocation should the need arise.

QUESTIONS 31 and 32: Use the following scale:

1. Yes - WIMS.
2. Yes - Database Management software on PC.
3. No - Manual records.

31. Is the Real Property database in your office computerized?

32. Is the building information database in your office computerized?

33. How is the data that is used to assess efficient utilization kept up to date? Choose the most appropriate response.

1. Collected by BCE personnel by regular building visits
2. Product of regular BCE surveys of building managers.
3. There is no 'system' for collecting such data.
4. Other. Please specify method - ____________________

____

____

COMMENTS:

PART 4 - SPACE ALLOCATION CONTROL

Use the following rating scale to indicate how the allocation of space is controlled at your installation.

1 = Strongly disagree	5 = Slightly agree
2 = Moderately disagree	6 = Moderately agree
3 = Slightly disagree	7 = Strongly agree
4 = Neither agree nor disagree	8 = Not applicable

34. It is primarily the BCE's responsibility to ensure that building space is utilized effectively.

35. It is the Facilities Board's (FB) responsibility to ensure that building space is utilized effectively.

36. Major tenants on this installation are reasonably free to decide how they will use space within their allocated buildings.

37. BCE personnel systematically visit every base facility to reassess utilization.

38. The BCE actually decides how space will be allocated.

39. The FB makes the decisions on the allocation of space.

40. The BCE implements the FB's decisions.

41. The BCE influences the FB's decisions - they usually accept his recommendations.

42. We have a Space Allocations Panel (or similar) composed of tenant representatives, which acts as a forum for analyzing space shortage problems, identifying possible solutions, and recommending action.

COMMENTS:

PART 5 - CONSTRAINTS TO MAXIMIZING BUILDING UTILIZATION

Use the following scale to rate your perceptions of factors which possibly reduce the effectiveness of your organization's efforts to utilize its building space well.

1 = Strongly disagree	5 = Slightly agree
2 = Moderately disagree	6 = Moderately agree
3 = Slightly disagree	7 = Strongly agree
4 = Neither agree nor disagree	8 = Not applicable

43. Structurally unsound or maintenance-intensive buildings are often renovated and used beyond their intended design life.

44. It is often impractical to physically separate a user's 'surplus' space from his 'approved' space such that it can accommodate another requirement.

45. It is easier to fund the renovation or modification of an existing old building to satisfy a new requirement, albeit unsound or maintenance-intensive, than to obtain MCP funds to construct a new facility.

46. It is often difficult to assess if space within a building is utilized well.

47. Insufficient funds are available to modify all surplus space to make suitable for other requirements.

48. The effective utilization of building space is more important than building habitability, should the two conflict.

49. Building modifications associated with space re-allocation often cause disruptions to user operations.

50. The negative operational effects of disruptions caused by space re-allocations are outweighed by the benefits of utilizing space more effectively.

51. Allocating one facility to more than one organization often causes problems for all users.

PART 6 - PLANNING FACTORS IN THE DISTRIBUTION OF BUILDING SPACE

QUESTIONS 52 & 53 : Use the following scale to indicate the per person net office space space allowance used in each case.

1. Less than 75 SF
2. 75 SF
3. 80 SF
4. 85 SF
5. 90 SF
6. More than 90 SF

52. What "net office area per building occupant" (as defined at AFM 86-2, para 13-3) is used at your base for planning space requirements for new administrative facilities?

53. What "net office area per building occupant" is used at your base for managing and redistributing space in existing administrative facilities?

QUESTIONS 54 to 61: Use the following scale to best rate the following statements about possible criteria that may be used by your organization when either designing space layouts for a new facility or redistributing space within an existing one.

1 = Strongly disagree
2 = Moderately disagree
3 = Slightly disagree
4 = Neither agree nor disagree
5 = Slightly agree
6 = Moderately agree
7 = Strongly agree

54. Activities within a building should be located according to their need for proximity.

55. Building modifications associated with space re-allocation are more economical than new construction.

56. Net usable space should be maximized. Circulation and low use areas should be minimized.

57. Building design should include features that minimize the potential cost of future extensions or modification.

58. Open plan designs maximize the ease involved in the possible future rearrangement due to changing functions and relationships.

59. Open plan design should be used for office and work areas wherever possible.

60. Building layout should maximize the orderly flow of personnel through the building and minimize unnecessary traffic through main working areas.

61. The availability of suitable space for renovation will usually enable a requirement to be satisfied quicker than by new construction.

PART 7 - PLANNING STEPS TAKEN TO SATISFY REQUIREMENTS

Use the following scale to rate your feelings about requirement review practices in your organization.

1 = Strongly disagree	5 = Slightly agree
2 = Moderately disagree	6 = Moderately agree
3 = Slightly disagree	7 = Strongly agree
4 = Neither agree nor disagree	8 = Not applicable

62. When a new requirement for space is received it is staffed first by Real Property personnel.

63. The requirement is checked against AFM 86-2 to ensure that the request is in accordance with space entitlements.

64. Space already allocated to a low priority use is sometimes re-allocated to a new requirement with a higher operational priority.

65. A cost analysis is usually done to assess whether to renovate existing space, extend an existing facility, construct a new facility, or lease space - whichever are feasible.

66. Real Property personnel always attempt to find suitable space available within existing facilities before recommending new construction.

67. Prior to deciding if an identified surplus space is suitable for a particular requirement, a site visit is usually made.

68. The prospective user of a re-allocated space takes an active role in assessing its suitability for his requirement.

69. Which of the following possible responses best describes the criteria used to make decisions on whether to renovate, lease, or construct a new facility?

1. A cost analysis of all possible alternatives.
2. The relative availability of MCP and O&M funds.
3. Base politics.
4. The best interests of mission fulfillment.

PART 8 - BACKGROUND DATA

The following questions relate to your duties, experience, and professional qualifications. Please choose the most appropriate of the responses provided:

70. In what field was your undergraduate training?
    1. Architecture.
    2. Town/City/Urban Planning.
    3. Civil or Structural Engineering.
    4. Mechanical Engineering.
    5. Engineering other than those above.
    6. Building Sciences.
    7. Not included above. Please specify - ____________________
    8. No undergraduate training.

71. In which area does your primary duty lie?
    1. Architectural design of individual facilities.
    2. Real Property accounting and space management.
    3. Engineering Management.
    4. Other. Please specify - ______________________________

72. How many years total experience, including non-AF, have you had in the activity checked at Question 71?
    1. 1 yr or less.
    2. Between 1 and 2 yrs.
    3. Between 2 and 3 yrs.
    4. Between 3 and 4 yrs.
    5. 4 yrs or more.

****

<u>THANK YOU</u> FOR YOUR TIME IN PARTICIPATING IN THIS SURVEY. IF YOU WOULD LIKE TO MAKE ANY FINAL COMMENTS PLEASE DO SO BELOW. **WHEN YOU HAVE FINISHED, PLEASE PLACE THIS QUESTIONNAIRE INSIDE THE ENVELOP PROVIDED AND SLIP IT IN THE NEXT OUTGOING MAIL.**

<u>COMMENTS</u>:

APPENDIX H

COMPUTER LISTING OF RESPONSES TO SURVEY QUESTIONNAIRE

KEY to DATA RECORDS

```
    Sub-population
    Identifier

Unit      Ques    Ques         Ques       Ques            Ques
Code      70-72   1-10,12,     14-20      21-33           34-42
                    13,11

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          667518123  5674265675  25664571

            Ques         Ques         Ques
            43-51        52-61        62-69
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522 825 275 66652264 6656612 3555713663112 572677726
527675565 3376777677 57767774
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161771571 5475777775 77777761
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      777545553 4472776661 77747773
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AD-A188 273 AN ANALYSIS OF METHODS FOR MAXIMIZING THE UTILIZATION 4/4
OF SPACE IN USAF FACILITIES(U) AIR FORCE INST OF TECH
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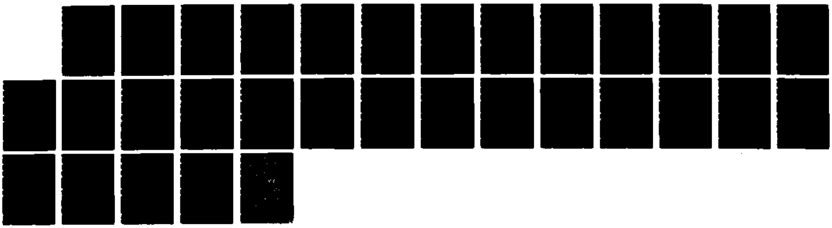
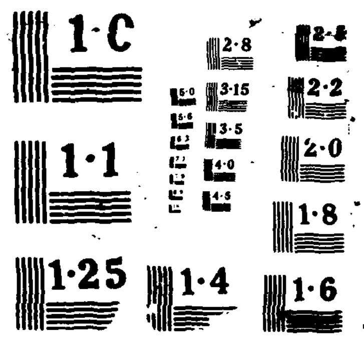
UNCLASSIFIED SEP 87 AFIT/GEM/DEM/87S-19 F/G 13/13 NL

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APPENDIX I

SELECTED COMMENTS BY SURVEY QUESTIONNAIRE RESPONDENTS

The survey questionnaire is in Appendix G. These comments by respondents are listed by question. Their general comments on the issues covered by the questionnaire are listed separately at the end of this appendix.

The comments in this appendix reflect the views of some respondents and do not necessarily represent the views of the author or the position of the Air Force Institute of Technology or the United States Air Force.

Question 3.

Real Property does not participate in this.

Question 4.

Don't really use.

Don't have to use.

Question 5.

I believe the uniqueness of each Command's space usage would make it very difficult to do so.

Provided the XR organization stays out of the issue.

Question 6.

Reduced to only a record keeping function as a result of XR involvement.

Question 7.

[Space utilization studies are not carried out regularly] due to the shortage of personnel.

We try to, but its an easy thing to let slip - not adequate personnel.

Question 9.

DEER only reports space allocation/usage. They have no expertise in functional layout, which is part of the design process and done by architects.

Assistance is always available, not only "on request".

Question 10.

If we ever found any it would be reported probably.

Question 11.

Combination of above and objective analysis of special requirements.

Combination of all.

DEEP does this.

When user complains he has too much space.
All of the above and anything else we can get.

Question 12.

Real Property does not lay out floorplans.

Use AFM 88-2 plus direction of the base architectural plan and architectural compatibility.

User requirements/needs.

Combination of 2,3,4, and 6.

Initial floorplans are not developed by Real Property personnel.

Question 13.

Expecting a computer sometime in 87.

Are in the process of procuring AutoCAD for WANG PC's.

We are in the process of adding CAD to our organization.

Question 14.

Space is used extremely well - not managed.

Questions 19, 20.

Space requirements, for the past 10 years that I have been the Chief Architect, have far exceeded the space available. XR or whoever makes long-range plans has failed to keep up. Part of our base was closed a few years back and the personnel in that area were moved to the main part of the base. This caused us to have to convert some warehouses to office space and to put up temporary modular buildings. We still have not caught up to the space needs. Also parking is a big problem on this base. I think in the long run some multi-level parking will have to be constructed.

Question 21.

User requests/demands never seem to match authorizations. Much leg work and dealing with politics is required.

Question 24.

Vacant buildings - yes! Others [in-use] - no.

Question 26.

Never.

Question 31.

WANG computer is now being installed. Software expected approximately September 87 - will improve markedly on database.

Still use cards with measurements and other info as well.

Question 33.

The efficient utilization of space is only reassessed when shortages arise. Surveys are sent to buildings which may be involved in trading or augmenting space. After users justify space their surpluses are used for reallocation action.

Space inventories are prepared for specific uses - such as project documents for minor construction or MCP.

Buildings are surveyed when reviewing requirements for additional space, add-ons, changes in use - all done by DEEP. DEER periodically measures buildings and reviews occupancy.

All buildings are visited by section, space use surveys are made - 3 year program.

Analysis made of appropriate facilities/requirements case by case.

Collected by BCE personnel regularly and again are needed prior to alterations or new construction.

A new space committee concept made up of all organizations commanders.

Space utilization is a function of the "power" structure.

There is no specific system which can be enforced; just a "hodge-podge" of information.

We never to seldom use Real Property information in the design or renovation of buildings. In general the Design section does not act on space mayyers but reacts to users' requests for more space through our Programming department (DEEX).

Question 34.

Should be a BCE responsibility.

Question 35.

The FB is utilized to assign space based on the recommendations of the Real Property Officer based on utilization studies.

If not, they should be.

Yes, with data from the BCE.

Question 36.

The Fire Department would require fire corridors and fire escapes. Also, if the Engineering Section is designing a layout, all AFM and code requirements would be met.

Question 37.

Manpower does not allow.

We try. Manning requirement for Real Property section needs to be rewritten to allow us manhours to accomplish this.

Question 38.

No, it's the space utilization panel.

Question 42.

Space use is discussed in a Facility Board Working Group meeting, then brought to the FB.

The HQ TAC area has a space board for there assigned buildings. The base proper is covered by a Lieutenant who surveys and recommends moves.

The Deputy Base Commander makes the decision on space; the FB validates that decision some time later.

We are now implementing such a committee.

Real Estate Working Group.

We need one.

Real Estate Working Group chaired by RM.

Space management is done by XRX personnel at the ALC level. BCE/Real Estate may be asked for "homework" info, statistical data, etc., but space decisions are primarily worked out above the Air Base Group level.

We have utilized "space use" board for major mission beddown changes in the past - Wing C/V does not support on an on-going basis.

Facilities/space are/is allocated via FUB, but FUB at this time is basically the ESG/CC. With a different personality, the FUB may actually decide. Space utilization (how allocated space is used) is up to the organization occupying the space.

We have a pre-FB panel which decides on space allocation.

The Base/Wing Commander makes many decisions and Real Property changes the records. Real Property is headed by a GS-9 who is generally not in the decision-making process.

I think it's a good thing to have.

The panel meets and works well but listens to the "power" structure.

The panel is ineffectual. Lack of data and participation negate its effectiveness.

Question 52.

Office systems furniture criteria.

90 SF for average employee, but up to 150 SF for high grade executives.

Question 53.

Functionality of available space is the key to this question. Many times we cannot hold to smaller figure (90 SF).

No standard amount. Based on needs.

Typically use "net floor area" and let unit work within those limits.

We are actually so crowded that mission need is totally determining factor.

No consideration. Just look at total space.

Question 55.

It depends on the mission of the user.

Depends on extent of need.

Question 57.

Reg's don't allow it, nor funding.

Questions 58, 59.

But users do not like this. Customer satisfaction is more important.

Some offices need walls (eg., supervisors). Also, most employees need a privacy wall at least 5 or 6 ft high to prevent interruptions in their work (eg., noise, telephones).

Question 61.

Both usually take an inordinate amount of time.

Self help is a massive player in this arena.

Especially if new construction is > $200 K. ie., MCP.

Question 62.

Requirement determination is performed by planning and programming (DEEP). Often it is first directed by the user to DEER.

Simoultaneously with programmers.

Most requirements for space increase that I know of start at the FB, then to Programming, then to Design.

Question 66.

RP not actively involved in this phase.

Question 70.

All of my real estate experience has been acquired through on-the-job training.

Question 71.

Officers first policy - my primary duty is with PRIME BEEF, according to Air Force policy. Between going to PRIME BEEF meetings, recalls, Exercises, SAME meetings, and other obstacles, I sometimes have time to perform architectural design duties.

General Comments.

Space moves are generally unpalatable to [building] occupants. Many have spent a lot of time and money self-helping areas for themselves and are reluctant to give it up. Political pressure on the BCE is usually used to generate moves or non-moves by organizations.

Real Property (DEER) usually plays only a book-keeping role and is not a player in space allocation. The programming office (DEEV) receices requests for space/ facilities/ renovation and acts on them with little or no interaction with DEER.

Good questions. A lot of design is performed by A-E's. How much data does the base direct to the A-E in terms of space? Is the A-E left on his own to come up with the requirements?

Problems always exist in real property management. Requirements validation by DEEP are performed necessarily when the need arises. Manpower doesn't allow other options. DEER data is not always current or correct and cannot be accepted at face value. AFM 88-2 needs a comprehensive update/rewrite. Changes have been reactive. Facility users have been elevating requirements to Command levels for approval without presenting complete picture; politically motivated changes occur.

See Deputy Assistant Secretary of Defense (Installations), Principles of Excellent Installations, which preaches to design what they [users] want; not to pay attention to directives as long as law is not violated.

More realistic and useful category codes are neede to clearly identify space use; ie., common use area for hallways, latrines, etc., admin space for each organization by name.

Real Property is under-manned and incorrectly staffed for much of the work they are required to perform - essentially, a lot of emphasis is on the program. Just enough manpower to keep it minimally functional but not enough to be pro-active and not merely reactive. Real Property should be the protagonist to ensure the most efficient utilization of facilities to serve the missions of the Air Force.

This questionnaire should have been divided into two - one for Real Property and one for Design.

Many space utilization decisions are made outside of established channels due to direction of some projects through DEEP. Some reallocations of space are made due to sudden changes in mission requirements and time is not available to accomplish the changes in compliance with established procedures.

Personalities determine who makes the decisions. Personal politics influence many decisions. Perhaps the "focal point" for Real Property action should be at the highest level... Base Commander's office... to get required input.

Cannot accurately answer the questions. Have only been in the job 90 days.

Personnel and lack of adequate grade structure are largest detriment to a functional DEER staff and facility utilization.

I don't know very much about the Real Poperty field of USAF.

Rewrite AFM 86-2; need a category code for common use areas (halls, walls, latrines).

At our base, Environmental and Contract Planning do most of the space requirements work with our help, as our other position has not been manned due to lack of funds.

I noticed that Real Property was referred to quite often in this questionnaire. We in the Design section have very little interaction with Real Property personnel. They may have input in the early stages of a project or after it is built, but we as facility designers do not coordinate very often with them.

APPENDIX J

RESPONSES BY MAJOR COMMANDS TO SURVEY LETTER

The survey letter to MAJCOM/DEs is in Appendix F. Questions from the survey letter are examined one at a time and all responses to a particular question are grouped. Some responses are paraphrased due to their original length, but their intent has been preserved. HQ AFLC responses are taken from notes made by the author during personal interviews.

Question 1

Are 'management analyses' of facility usage actually carried out, and if so, what format do they take? Are they usually base or Command instigated?

HQ USAFE. USAFE is instituting an effort to validate and evaluate assets and requirements data developed by its bases. Command level Real Property personnel will "walk throgh" through all base facilities with BCE real property personnel and change data presented in the real property inventory (the 7115 report) as required. This team will also develop, in conjunction with other BCE and responsible base offices, a consolidated list of base facility requirements. A subjective assessment of the effectiveness of each facility's space utilization will be made by the team and space deficiencies and shortages will be calculated. USAFE began a similar program in the early 1970's but was discontinued after a few years of good progress due to lack of funding. Some of the observations of this team were highlighted in Chapter II.

HQ SAC. HQ SAC does not participate in space utilization studies. It does not know the extent of analysis carried out by BCEs on SAC bases. It has delegated this monitoring responibility to base commanders. Bases usually have a real estate wirking group which reports to the Facility Utilization Board (FUB). HQ SAC does get involved in a base's space utilization when a new mission, weapon system, or rebasing action is proposed for the base. It participates in a site survey to determine the new facility requirements, identify existing facilities that are underutilized in order to reduce the extent of new construction, and to site new facilities. However, they act in an advisory role only and usually honor the base's wishes.

HQ ATC. Space utilization surveys are base instigated and occur only when a user identifies a space deficiency. The extent of HQ ATC's participation is unknown.

HQ AFSC. Management analyses are carried periodically and for specific project purposes. A General Services Administration (GSA) report is produced semi-annually and requires accounting for all administrative space on an installation. A government work space management report is prepared every two years. A management analysis of facility usage is prepared when missions expand, when outside users request space on base, or construction projects require personnel and equipment to be relocated. They are usually base instigated.

HQ TAC. The base Facilities Board has the delegated authority to determine the use of facilities on its installation. HQ TAC Facility Requirements project officers are tasked to visit their assigned bases at least once every two years to review facility assets, requirements, usage, and deficiencies. They recommend action to best utilize existing facilities to minimize deficiencies, but bases are not compelled to follow this advice.

HQ AFLC. Management analyses are carried out only when there exists a requirement for space that the Real Property Section cannot place from utilization records or specific knowledge of facility underutilization. Analyses are carried out in support of major projects, such as a weapons system beddown or an organizational relocation. At Wright-Patterson AFB, HQ AFLC occupies approximately 1,000,000 SF of building space. The base FB permits HQ AFLC to manage its use of this space. HQ AFLC has its own FB and Space Allocation Panel (SAP) for this purpose. Both meet regularly to resolve space ownership disputes and to discuss new user requirements. Many AFLC bases operate SAPs but to date there has been no stated Command requirement to do so.

Question 2.

What indicators are used to signal that space within a facility may be under-utilized?

HQ USAFE. When the "team" walks through a facility it subjectively assesses the utilization of available space and applies a percentage effectiveness factor. For example, a factor of 72% applied to a 20,000 square feet building indicates that theoretically 5,600 square feet could be made available for another function or for another user.

HQ SAC. Base indicators are unknown. SAC relies on the 7115 report to accurately signal deficiencies, shortages, and effectiveness of space utilization. It also uses, for the evaluation of proposals for construction, renovation, or alteration projects, the DD 1391c Existing Facilities/Deficiency Detail Data Sheet (which is included in project documentation). SAC form 246 is also prepared by bases for facilities in each category code to identify a base's facility requirements. SAC feels that these reports provide sufficient information for SAC/DE to make judgments on the effectiveness of a base's facility utilization.

HQ ATC. If requirements are maintained accurately, the "Space Use of Real Property Facilities, PCN: SF 100-185" report will display an overage based on the requirement.

HQ AFSC. The GSA and government work space management reports will reveal space under-utilization. In addition, most base Real Property Officers frequently review personnel strengths and equipment versus space occupied. Inventories on a three-year cycle verify that facilities exist as stated, that sizes are accurate and that population densities comply with regulations.

HQ TAC. The HQ TAC response did not indicate what indicators are used to evaluate space utilization from periodic facility use surveys. However, for the evaluation of project proposals TAC relies on the DD Form 1391c to prove the base is a good steward of the existing space.

HQ AFLC. Two reports (167 and 7115) are used to track building utilization. Report 167 is produced by BEAMS. It gives the facilities occupied by each user organization, for each facility breaks down the space occupied by each section of the user organization, and gives a gross building area for each user. The 7115 breaks space usage down further, into category codes. It has provision for listing 'vacant space', but this column is 'never' used unless a building has been "pickled" (a term given for the complete removal of all furniture and fittings prior to demolition) or has been gutted by fire. Otherwise, if unused or underutilized space exists in a facility, it is not recorded. Users do not report such space. An update of AFR 87-2 apparently directs bases to keep a record of a user's actual requirements (from AFM 86-2 space allowances by function) as well as his actual allocations. With these appearing side by side in the 7115 report, under or overutilized space would be easier to detect.

Question 3.

Are bases given any guidelines by Command on how to ensure space is utilized effectively?

HQ USAFE. In its new effort, combined command and base Real Property teams will recommend ways of utilizing space more effectively once they have walked through a facility.

HQ SAC. No. Authority is fully delegated; no guidelines on methods of achieving maximum utilization are given to bases.

HQ ATC. No. Bases use their own judgment.

HQ AFSC. No. Guidance implements AFRs and GSA regulations.

HQ TAC. No guidance, but much HQ TAC evaluation of project proposals, especially where new weapons systems are concerned.

HQ AFLC. No, but bases are encouraged to form Space Allocation Panels to resolve space issues outside of the FB.

Question 4.

Is it be possible to determine whether or not a BCE is managing facility space well? Are there any accepted 'hard' measures of effectiveness used by your Command such as an area/personnel ratio? What do IG teams look for in this area?

NOTE: The first part of this question is similar to question 2. Responses to the other parts only are given.

HQ USAFE. No response.

HQ SAC. When reviewing proposals for construction projects, SAC uses AFM 86-2 to determine allowable spaces. For administrative space, Engineering Technical letter 86-12, Pre-wired Work Stations and Systems Furniture is used to more efficiently use space and reduce the actual area/personnel ratio to below the allowable limit. Bases are required to stay within the specified space criteria unless they can justify otherwise. IG teams make a subjective assessment only, looking at the 'quality' of space - whether working conditions are cramped.

HQ ATC. Area/personnel ratios as directed in AFM 86-2 are used. The IG looks only for updates of facility records. If they have been updated, the base passes.

HQ AFSC. Actual area/personnel ratios are well below space allowances due to accommodation shortages. Most BCEs must make maximum use of all facilities to accommodate all base functions.

HQ TAC. For new facilities, area/personnel ratios are used. Lower ratios are used for administrative facilities where systems furniture is appropriate.

HQ AFLC. Effective utilization of a base's building space is not monitored by Command. This is a base responsibility. No 'hard' measures are used.

Question 5.

What major projects have recently been undertaken by bases under your Command (such as Master Planning, Base comprehensive Planning, and buiding renovations) which have required a complete re-allocation of existing building space in one or more facilities? Have A&E firms specializing in Space Planning usually been contracted to determine the optimal arrangement of functions in these existing building, or has some of this work been done in-house?

HQ USAFE. No response.

HQ SAC. Information not available.

HQ ATC. Regards Base Comprehensive Planning (BCP), HQ TAC has found few if any A-E firms who have the experience and background to do complete space utilization surveys. The firms will determine valid building requirements; however, the base will determine space requirements.

HQ AFSC. Five bases are currently undertaking BCP efforts. ASD is currently doing a Facility Utilization Study. All studies are involving optimal arrangements of functions has to date been accomplished by A/E firms.

HQ TAC. Combat Support Centers, Vehicle Maintenance Complexes, Base Civil Engineer Complexes, and Base Supply Warehouse Complex projects have had strong emphasis in TAC in the Militrry Construction Program (MCP) in an attempt to consolidate like functions, make effective use of existing resources, and to replace World War II wooden facilities. Much effort is made by BCE personnel to coordinate moves and to identify existing facilities for conversion or disposal. TAC Programs personnel and Staff users participate in Command level validation of these projects. A-E space planning firms are not utilized for this purpose.

HQ AFLC. Although not part of AFLC, a large quantity of ASD Research and Development facilities at Wright-Patterson AFB were recently converted to administrative space due to various programs being contracted out. A complete survey of requirements and existing spaces was required to plan this project.

AFLC runs a Quality of Life (QOL) program to improve the living and working conditions of its personnel and dependents. HQ AFLC has funded a $15-18 million project at McClellan AFB, to renovate 540,000 SF of surplus warehouse space for use as open office administrative facilities. The facilities will incorporate computer rooms, some individual offices, conference rooms, and rest areas. Funding for this project was far easier than had an item for new construction been proposed for inclusion into the MCP.

Base Comprehensive Planning (BCP) efforts by AFLC have tried to consolidate the facilities of units which have become fragmented over time. For example, at WPAFB the 906th TAC Fighter Wing's test beds for the F-16 and F-4, and the 4950th Flight Test Wing's facilities for the C-135 and C-141, are currently fragmented throughout all three base areas. BCP studies have looked at the functionality of operations and have recommended planning guidelines to bring all elements of these functions together.

Question 6.

What in-house design methods are being used to 'compress' space, both for new facilities and when modifying those existing? Are the definitive drawings from AFM 88-2 being used on a regular basis? Do BCE architects and planners commonly use Bubble Diagrams, Relationship Charts or some other tool to lay out functions on a floor plan?

HQ USAFE. No response.

HQ SAC. Systems furniture is commonly used to compress space requirements. Definitive drawings are available for use by bases but in most cases design of facilities is done by private design firms which may or may not use them. The extent of their use is unknown.

HQ ATC. In old facilities no attempt is made to compress space unless a facility undergoes a major modification. Systems furniture is required to be used in such cases and for new facilities. Open office concepts are used extensively. Definitive drawings are seldom used.

HQ AFSC. Systems furniture is commonly used. Definitive drawings are seldom used. Few BCE's have personnel capable of using bubble diagrams, relationship charts, or time and motion study techniques. This type of design is usually accomplished by A-E firms.

HQ TAC. TAC has developed its own definitive drawings for unique TAC facilities such as Squadron Operations Facilities, Aircraft Maintenance Unit (AMU) Facilities, large and small fighter hangars, and an aircraft Corrosion Control Facility. TAC is currently working with HQ USAF on the space requirements for flightline Parts Stores and Shop Service Centers to complement the AMUs. For other facility types, BCE architects and planners work with functional managers to layout optional floor plans within allowed gross areas.

HQ AFLC. Facility flexibility is seen as important in design by some of the HQ AFLC/DE personnel interviewed. Generic, multi-purpose buidings with high ceilings, large spaces capable of being partitionned off, capable HVAC systems, and a solid, simple structure, could be renovated for a variety of uses as requirements change. It is felt that this type of construction may decrease long term facility construction and maintenance costs.

Question 7.

Which bases under your command use any form of Computer Aided Architectural Design (CAAD) software (such as AutoCAD, VersaCAD, EasyCAD or CADkey) to layout floor plans? Do you or your bases have any plans to introduce such software as either a WIMS application package (through WANG) or as a package for Z-100 or Z-248 stand alone PCs?

HQ USAFE. No response.

HQ SAC. CAAD software is used to produce architectural working drawings at some bases. Vandenberg AFB and Grissom AFB currently have CAAD systems. Details of their specific usage are unknown. CAAD was recently used in projects to upgrade the Command Section offices at HQ SAC.

HQ ATC. Reese and Chanute AFBs use AutoCAD while Randolph and Lackland AFBs use Intergraph. Most bases will buy CadKey or AutoCAD as Z-248 PCs become more available.

HQ AFSC. Brooks AFB and Arnold AFS have access to CAAD resources. There is no Command plan to introduce Computer Aided Design (CAD) of any type as a WIMS application package.

HQ TAC. Two un-named TAC bases are in the early stages of acquisition of a CAD system. Two other bases are in a preliminary investigation stage. Applications at other bases are being examined at TAC. To date these systems have not been used to lay out floor plans.

HQ AFLC. No architectural design input was received from AFLC. However, DEER advised that Real Property personnel in some BCE organizations do assess functional layouts of facilities in order to 'fit in' new requirements. Most Real Property Sections have a Space Management Officer whose responsibility it is to find accommodation for requirements needing space, if it is possible. If space can be found, but building modifcations are required, Real Property solicits the help of BCE architects.

Questions 8, 9, and 10.

General. If an urgent requirement exists and no surplus space has been identified, a decision must be made as to how that requirement can be satisfied quickly. Often there will be insufficient time to program and construct a facility. Operational requirements may also dictate that the function must be accommodated close to existing support facilities, ruling out leasing as a feasible solution.

Question 8.

In situations such as these, are Commands notified of the problem? If so, what advice would be given to the base?

HQ USAFE. No response.

HQ SAC. Command is only notified when a project is proposed by the base to alleviate the problem. In these cases, Command would evaluate the need for urgent action and, if agreed, hasten funding. If the base handles the problem locally Command would not be advised.

HQ ATC. Commands may be notified, but bases are tasked with developing and implementing solutions. Typical solutions were not specified by HQ ATC. If the base can not solve a problem, Command will assist.

HQ AFSC. Command is notified of the problem if, and only if, the base cannot solve it. In an emergency, allowable population densities may be increased to permit the accommodation of more personnel and functions within available space. Temporary facilities, such as trailers and pre-engineered structures are frequently acquired to satisfy urgent requirements.

HQ TAC. HQ TAC is frequently required to provide urgent additional space within short time frames. Detailed investigation of reallocation options are made, but often the lease/purchase of portable/modular facilities is required to meet short term, short notice requirements. SAC is against the use of trailers and other portable structures whenever possible, and long term requirements require long term permanent facility solutions.

HQ AFLC. No input.

Questions 9, 10.

What factors influence base management's decision on how to reallocate existing building space to accommodate the requirement? Are the BCE's architects, planners, or real property personnel requested to conduct space planning analyses in order to identify where space can be made available with minimum effect on users?

If such analyses are made, is it usually on an as-required basis to solve a specific problem, or progressively to ensure that space utilization is continually monitored?

HQ USAFE. Such space studies are for project purposes but combined "walk-through" efforts will soon be a regular monitoring feature.

HQ SAC. Factors determining reallocations of space are deficiencies versus excesses based on validated requirements and base space utilization records. Base management would reallocate based on need. Space studies are usually carried out for project purposes only, and not on a regular basis.

HQ ATC. Factors are space availability, funding, functional relationships, direction by (priorities of) base leadership. Real Property personnel do space studies of this nature, but only when required.

HQ AFSC. Factors are mission requirements and the equitable allocation of space (between users). The BCE's architects and planners are tasked to assist the Real Property Officer in the performance of such space studies on an as- required basis.

HQ TAC. The primary factor is mission requirement. Detailed analyses of space for urgent reallocation to support a new requirement are made when required.

HQ AFLC. For major weapons system beddowns, AFLC employs Site Activation Task Forces (SATAFs). The SATAF will not be disbanded until the beddown is complete and all 'teething' problems have been resolved. Some of its responsibilities are to determine existing facilities at the intended base which could be made available to accommodate the system, where existing tenants of those facilities would go, and what new construction was necessary. The SATAF is dedicated to ensuring that all aspects of the beddown (not only facilities) run smoothly. SATAFs are usually told by the base FB which buildings are available for use. SATAFs do not have the ability to seize facilities from a base.

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New facilities are expensive. Before new construction is chosen by an organization as the solution to a facility space deficiency, every effort should be made to satisfy the requirement within existing facilities. This may require rearranging interior layouts, reassessing the actual space needs of users, reallocating space, and making building alterations to permit more effective space utilization.

If new construction is necessary, the interior layout should be systematically designed with functional relationships and long term flexibility in mind. This study examines methods used by the United States Air Force (USAF) and Royal Australian Air Force (RAAF) to 'manage' facility space and to 'plan' facility space. It compares the general effectiveness of methods used by the USAF, and determines what effect the quality and accessibility of building information and space utilization data has on a base's effectiveness in utilizing its facility space. The practices of Base Civil Engineering (BCE) Design and Real Property Sections in the planning and management of facility space were solicited from key BCE personnel.

The use of the computer as both a space management and interior design tool is explored. Computer algorithms, programs, and systems developed and used by private US organizations for space planning and management, are examined for potential use in Air Force Civil Engineering (AFCE).

Recommendations are made for both the RAAF and USAF to improve their utilization of existing facility space. Specific design tools, rather than intuition, should be used to plan floorspace layouts. Utilization studies should be conducted periodically, not only when a deficiency arises. Databases should be examined and updated constantly to ensure facility managers and designers have the best information possible on which to base decisions on how building space can be best used.

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