A Design Processor

Masters Degree Project

by

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The undersigned certify that they have read, and recommend to the faculty of Environmental Design for acceptance, a Master's Degree Project entitled

A Design Processor

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Abstract

"A Design Processor" explores the application of the computer as a design tool for industrial designers and architects. Using a design process model, a list of tasks associated with design was created. These tasks were then used to outline potential system requirements.

Computer-related technologies which satisfied the various task demands were explored, with those technologies which best suited the task selected. A further consideration was the exploitation of technologies for more than one application, in the interest of economy.

Technological constraints, human factors considerations, production technology, and system flexibility were each explored in the design of this product. The result of this work is the design of a portable computer system which will enable the designer to explore design in a manner which is both appropriate and intuitive.

Keywords

Architecture, Computers, Design, Industrial Design, Model, Sculpture, Sketch

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Introduction

> *"The computer is a tool, a complex man-made artifact that can stretch our limits and can extend our reach."*
>
> Baecker and Buxton, 1987 [1]

The application of the computer in the fields of architecture and industrial design has grown rapidly in recent years. Through the development of specialized software, the designer is now able to utilize the power of the computer in the execution of many tasks within the design process.

However, existing systems require that designers work within the confines of their configurations, which are not always appropriate to the task at hand. Although useful, they do not allow designers to work in a way which could be considered as being natural to the task. Rather, designers are required to alter their methods of working in order to accommodate the system. In order to utilize the computer in the fields of architecture and industrial design more effectively and to reduce the constrains on the designer, the development of a computer system designed specifically for use by architects and industrial designers is required.

The problem of creating a computer system suited to user tasks is not a new one. There has been a great deal of work, both theoretical and real-world, that has attempted to address the issue of system usability, and how the strengths of the computer might be better exploited.

In 1945, Vannevar Bush developed a theoretical tool called the "Memex". The "Memex" would be able to store great volumes of books, records, and communications that could be consulted with great speed and flexibility. "Sketchpad", developed in 1963 by Ivan Sutherland of MIT, explored the generation, organization, and manipulation of pictures through the use of a light-pen. Alan Kay's "Dynabook", a theoretical tool in the form of a notebook, examined the manner by which humans and media interact -- that the essence of a medium is very much dependent on the way messages are imbedded, changed, or viewed. The "Dynabook", viewed as a medium itself, could be all other media if the imbedding and viewing methods were sufficiently well provided. It would in effect be a "Super-medium". The "Dynabook" was developed in the late 1960's.[2]

Regardless of the task, any new tool created to aid in the execution of that task is not neutral. By changing tools, the manner in which the task is executed changes as well. Whether this is good or bad is, I believe, up to the end-user to decide. For some, the introduction of a new tool offers new methods of exploration and experimentation. For others, new tools mean a movement away from tradition and familiar ways of working. Technology does not necessarily dictate its own acceptance.

This tool is not meant to replace those which exist, although it may if users choose to. Rather, I envision it as being simply an alternative to existing methods. The tool proposed is meant to assume the role which the end-user dictates; it may completely replace all other methods of work, it may be used alongside existing methods, or it may not be used at all.

The primary goal of this project is to provide a tool which allows the designer to exploit the power of the computer, while being afforded the opportunity to work in a manner which is preferred and natural to the design process. The tool created must first be technologically feasible within the next five years, rather than a utopian solution. But more importantly, the tool's usability must take precedence over all other factors -- being a servant to the user first, and an object second.

The scope of this project is restricted to the industrial design of the system. This includes issues concerning the definition of the users and their associated task requirements, technological constraints, human factor concerns, and production technologies. Issues regarding graphical user interface design, software, or operating system design are not included within this project.

The presentation is organized in a manner which follows the process of the product's development, from user definition to detail design. The specifics of the final design solution are left to attached appendices.

The first chapter focuses on the definition of the user and the process of design. By specifically defining the user, it is possible to identify what tasks are to be considered in the product's design.

Chapter two defines the tasks and sub-tasks which may be performed by the user in the process of design. It is the information from these first two chapters that has driven the product design.

The conceptual development of the product is addressed in chapter three. The possible methods of accomplishing the defined tasks, a variety of solutions, and their relative success in terms of the stated goals are examined.

In chapter four, the final design of the product is discussed: system functionality, the selection of technologies, the system configuration, and the relationship between these issues.

Chapter five demonstrates the ways in which the system may be used through a design scenario. This scenario discusses the options available to the designer at each task phase and how the designer may move from task to task.

The specifics regarding the final design are located within the appendices. Human factor considerations, production technology, and dimensioned drawings are each assigned to an individual appendix.

The outcome of this project has been the design of a portable computer system which addresses the task requirements found within the design process. The system is made up of five components; a stylus, keyboard, digitizer, projector and a screen. Combining these components allows the user to perform those tasks normally associated with design. The components are integrated into a system case, effectively creating a single tool with a variety of functions.

It is the tool's flexibility that allows the architect or industrial designer to move through the design process in a manner which is natural and unencumbered by the technology. The emphasis on the tool's functionality makes the process efficient and only through the selection of appropriate technologies is this tool feasible.

1) Ronald M. Baecker and William A.S. Buxton, Readings in Human-Computer Interaction, (Los Altos: Morgan Kaufman, 1987), p. 40.

2) Baecker and Buxton, pp. 7-23.

Chapter 1
The User and the Design Process

> *"The designer has available seemingly infinite possibilities for task, function and dialogue definition, a flexibility of choice that may be a two-edged sword when it comes to improving the ease of system use."*
>
> Hammond, 1987[1]

Initially, I believed that the flexibility of the computer made possible a design project that could be directed to all types of users -- it could be all things to all people. Although theoretically possible to some degree, to attempt to satisfy such a broad user base could make the project unmanageable.

A selection of a user group needed to be made in order that a specific set of tasks could be selected. Designers, specifically architects and industrial designers, were selected as that user group. They were selected as members of a common group because of the many similarities in the manners in which they work.

After examining the paper entitled "An Experimental View of the Design Process" by Joseph Ballay (1987) and conducting a further exploration of design process literature, there was an indication that the designer would be an appropriate user for this project. The designer performs a broad variety and large number of tasks throughout the design process and would place considerable demands on any computer system.

The design process can be very complex. A designer's ability to organize, monitor, and control this process is a critical factor in the success of the product and the efficiency with which it is designed. The tasks of organizing, monitoring, and controlling the design process are critical -- as important as the actual 'design work' itself.

What is required of this system is the ability to address the issues within the process of design. The computer should be able to maintain the design process, provide tools to enable the design, and manage the information pertinent to the design problem.

Further, the tool used should be flexible enough to allow for a personalization of the design process. The type and use of design tools should be flexible as well as being able to define the terms of information storage, retrieval, and presentation.

Optimally, this product should provide a machine that meets these common needs of the designer while allowing the user to "customize" the way they work. This would enable the user to establish a personalized process, increasing efficiency without altering the process of design.

1.1 The User

For this project the user group will be defined as those persons who use a computer in the design of built forms -- architects and industrial designers. This tool is intended to aid in the execution of all tasks associated in the design process, from criteria formulation to the final presentation of the design. Therefore all potential users within this group will be referred to as designers.

How designers work will be instrumental in establishing the criteria for the design of this product. Although the likelihood of two designers working in an identical manner is small, some basic similarities in the design process can be found. These common points can then provide the basis to determine a number of basic tasks within the design process. For this project, the model of the design process by Ballay(1987) will be used. (Figure 1)

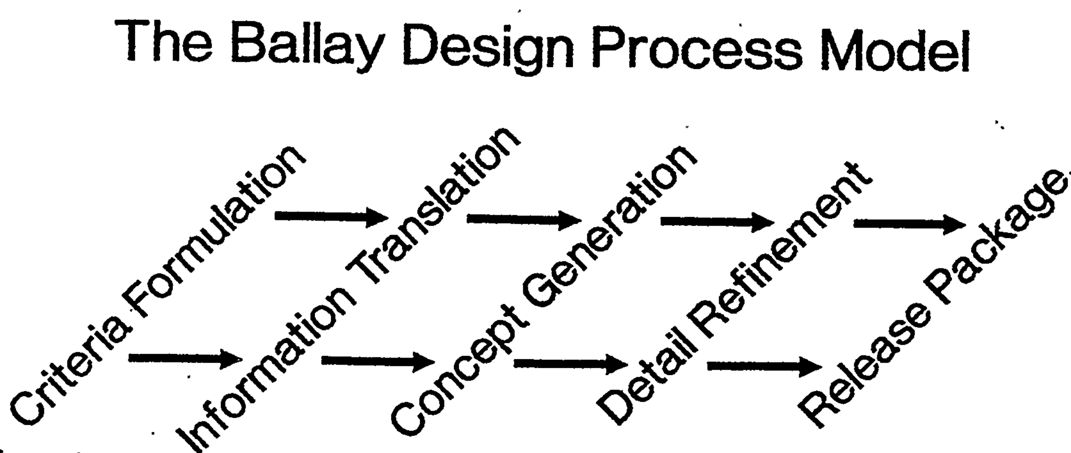


Figure 1

In his model, Ballay refers specifically to the industrial designer. However this model is applicable to design in general. Differences within certain segments of the process between different design endeavors do exist. Consequently, these will be reflected in each portion of the process with varying levels of importance.

1.2 The Design Process Model

1.2.1 Criteria Formulation

Criteria formulation involves the collection and analysis of information for the establishment of design criteria. This step of the process occurs in a number of ways and is dependent upon the type of design endeavour, the designer him/herself, and the level of external constraints placed upon the process.

In many ways, the design being executed possesses a number of inherent constraints. Architects and industrial designers are likely to have considerable external influences, each having concerns particular to their design endeavour. Construction costs, available technologies, and client tastes are each an example of constraints external to the designer.

Regardless of the endeavour, the designer must be able to organize the information in order to establish design criteria. This information will come from a variety of sources and will exist in several formats. After collecting this information, the designer must organize the information so that it can be distilled and prioritised. Without some form of clear organization, there is a possibility and likelihood the criteria established will be ill-defined.

Once the criteria have been established, this new body of information itself must be well organized, easily accessible throughout the design process, and presented so that relative importance of each criteria can be understood. This is of particular importance where the number of criterium is large, external in nature, and of great variety.

1.2.2 Information Translation

This phase of the design process "reflects the designer's significant sub-problem of translating the information he receives,such as written briefs, drawings, and specifications, into a format or mode that is useful in the problem-solving process" (Ballay 1987)[2]. How a designer accomplishes this is largely dependent on personal preference and available technologies. Examples of this transfer might be the conversion of component specifications into CADD files, or the creation of a three-dimensional representation of a site from topographical maps.

1.2.3 Concept Generation

Concept generation is a broad area within the design process. This is the phase of the process where issues concerning fit, function, ergonomics, and aesthetics are explored. Certainly not all of these concerns are addressed by all design endeavors, but they are representative of the major components of most projects. This is the phase of the process where problem-solving takes place -- where invention is born.

As in the transfer of information, how a designer develops concepts is largely based on personal preference and available resources. The designer should be able to decide the level of inclusion, coherence, and precision of this process, dependant upon the task at hand.

Inclusion - is the amount of information about a form that is represented in a sketch. It can be thought of as the level of detail or as the "grain size" of the information of the sketch.

Coherence - is the degree to which different pieces of information agree with or support another. It reflects whether the partial solutions or sub-problems have been reconciled to one-another.

Precision - is the dimensional refinement with which an intended configuration is represented. [3]

Ballay further states that the concept generation stage should remain loosely structured for as long as possible in order to maximize the opportunity for invention.

"Through exclusion, incoherence, and imprecision, the designers provide their sketches with enough ambiguity so they can take advantage of inventive opportunities right up to the end of the design process."

Ballay, 1987[4]

Concept generation should therefore attempt to remain as loose as possible in both the organization and methods of development. Therefore, the methods used for concept development must allow for that "looseness". Sketches, rough models, brainstorming, and other techniques of invention are possible only if the medium chosen is appropriate for that type of work.

Whatever technique is chosen, it should be intuitive, simple, and non-precious. There should not be a perception on the part of the designer that any part of the concept development is difficult to reproduce or remove. Preciousness of a medium, especially when it occurs early in the design process, is likely to lead to a preliminary termination of the concept generation phase.[5]

1.2.4 Detail Refinement

In Ballay's model, detail refinement is comprised of two phases of the Jones (1970) model[6]; Details and Structures, and Appearance decisions. This was established because Ballay's study showed these two phases running parallel to each other, rather than sequentially, and as such would be best served by one category.

The detail refinement stage involves taking the information from previously defined concepts and resolving the issues concerning engineering and aesthetics in concrete terms. Typically, this may involve as few as one or as many as five concepts.

In order to help the designer in this phase, it is important that information from the concept generation phase should be easily translated into its final form. The easier it is for conceptual information to be translated, the more efficient the designer becomes. Rather than starting final drawings from scratch, information from the sketch images and models should be usable as underlays.

1.2.5 Release Package

The assembly of the final package of information, images, and/or models is what Ballay describes as the release package. As in the detail refinement phase, there will be differences among the varying design endeavors as to what this package will comprise. For architects and industrial designers, this package might include two and three-dimensional CADD images, renderings, models, and a written description.

Regardless, this phase requires the designer to organize this information so that it may be easily understood by others. Further, the quality of the presentation of this information often influences the perception of the quality of the design being presented. Therefore, the media of presentation must be of a high standard.

1.2.6 Process Flow

This model by Ballay, although complete in its components, is somewhat restrictive in terms of the freedom of movement through the process. Ballay has represented the process as linear, without movement back and forth between the process phases. Admittedly, his model was achieved through empirical means -- the observations of several designers working alone on a specific product. The designers did not perform interim presentations, nor were they provided with any external feedback throughout the process. He states that there was little iteration within the experimental context, but he does not state that iteration outside of the experimental conditions would not exist.

Under normal conditions, iteration would likely take place in varying degrees throughout the process. Movement between the phases is to be expected as information is acquired and updated. This evolution often requires the designer to re-evaluate previous material. This information may be generated from within the process, as the designer makes discoveries along the way. As Joseph Ballay states:

> ***"Because the partially completed product is continually changing, the task environment is continually changing."***
>
> Ballay, 1987[7]

1) Nick Hammond, et.al., "The role of cognitive psychology in user-interface design", in Applying Cognitive Psychology to User-Interface Design, ed. Margaret M. Gardiner and Bruce Christie (Chichester: John Wiley and Sons, 1987), p. 14.

2) Joseph M. Ballay, "An Experimental View of the Design Process", System Design: Behavioral Perspectives on Designers, Tools, and Organizations, (Elsevier Science Publishing Co., Inc., 1987) p. 30.

3) Ballay, p. 37.

4) Ballay, p. 42.

5) Ballay, p.42.

6) Balley, p. 28

7) Ballay, p. 32.

Chapter 2
Design Tasks

As the previous section indicated, there is a group of tasks associated with each phase of the design process. Through the creation of an inventory of tasks and sub-tasks, the requirements of this product can be determined. The following task sequence was established using the Ballay model, interviews with designers, and personal experience. The Ballay model was used to generate a general task outline, while interviews with other designers and personal experience was used to generate the more specific sub-tasks. The majority of these tasks are common to both architects and industrial designers, although there are some tasks which are unique to each profession.

2.1 Getting the Job

This phase of the designer's process is not included within the Ballay model, nor was it included by many designers who were interviewed for this project.[1] Although not inherently part of the design process, getting the job is the first step around which a process exists, and so I felt that the inclusion of this section was important. The makeup of this section was created from my own experience as an industrial designer.

2.1.1 The Presentation

2.1.1.1 The Portfolio

Typically, the designer and potential client will meet to discuss the project and the designer's ability to achieve an attractive and appropriate solution. The portfolio, a compilation of information which best communicates the designer's skills, is of primary importance in demonstrating the designer's skills to the potential client. The portfolio is typically a book of some configuration containing two-dimensional images (drawings, photographs, etc.) which highlight the designer's achievements in previous projects.

2.1.1.2 The Slide Presentation

When the client audience is large, the portfolio is often presented in the form of a slide show. This presentation may then be tailored to the client's specific interests and requirements.

2.1.1.3 The Resume´

The resume´ is used to augment the portfolio presentation. Within the text of the resume´ information not present in the portfolio is presented, such as educational background, a list of previous clients, and references.

2.1.2 The Proposal

If the client is interested in contracting the services of the designer after the initial presentation, a specific proposal is then developed. The proposal includes information such as defining what service the designer will provide, the cost of those services, and the time period the work will take place in.

2.1.2.1 Deliverables

The deliverables specify exactly what the designer will accomplish in each phase of the project. They inform the client what will happen during each stage of the project, and provide an outline against which the designer's performance may be measured.

2.1.2.2 Cost

The cost of the design work is most often broken down in terms of the costs associated with each design phase. Each phase is given a monetary value, with the total cost of the project being the sum of all the phases. Proposals typically allow the client to "bow out" after the completion of each phase.

2.1.2.3 Time Line

The time line simply projects the specific time period during which the various deliverables will be completed within. A carefully constructed time line will allow the designer to monitor progress and provide the client with a reasonable expectation of when the project will be completed.

2.2 Criteria Formulation

Criteria formulation defines the goals of the design project for the designer as well as the client. The information for this section was derived from the Ballay model, interviews with other designers, and personal experience. Without a carefully developed set of criteria, solution of a design problem is difficult if not impossible.[2]

2.2.1 Information Gathering

The first step in developing criteria is the gathering of information considered relevant to the project. That information may include client goals, technical information, and market information. A thorough compilation and digestion of this information is necessary if the criteria formulation is to be reliable.

2.2.1.1 Client Goals

The first source of information that the designer will be presented with is likely to be the client goals.[3] They are also fundamental in the development of the criteria in that they are often the driving force behind the existence of the project itself.[4]

2.2.1.1.1 Cost

Cost of production, shipping, advertising, and retail costs are all important considerations in the design of most products.[5] These considerations have a great influence on material selection, production processes, and product features.

2.2.1.1.2 Manufacturing Resources

In the cases where the client is interested in producing the product in-house or locally, an understanding of available technologies will help to focus the design criteria..

2.2.1.1.3 Function

The client will come to the designer with expectations of the product function. An exact definition of that function will serve as a backbone for the design.

2.2.1.2 Technical Information

A solid grasp of the appropriate technical information is crucial for the designer by providing the designer with an understanding of the options available concerning technological issues. A broad technological information base aids the designer in exploring solutions which might otherwise be overlooked.[6]

2.2.1.2.1 Available Technologies

Technical information pertinent to the project is collected. It may be collected from a variety of sources--

texts, articles, databases, or experts. The restrictions placed on this list should be minimal, with the understanding a broad exploration of possibilities should be explored.

2.2.1.3 Market Information

Through an understanding of the user, the designer is able to resolve design issues more clearly. This information may be derived through a number of methods -- market survey, interviews, questionnaires, or task analysis. The information sought is selected dependent upon the design problem.[4]

2.2.1.3.1 Identifying the User

The client will most likely have identified a specific user group for the product and assembled a profile of their interests with respect to the design project. Knowledge of the user is critical if the product is to be a commercial and functional success.

2.2.1.3.2 Targeting Retail Cost

By identifying a market value for the product, the cost structure of the production process may be determined. Determination of the market value will give some guidelines as to what cost restrictions might exist for the product. In fact, the designer may discover that manufacture of the product within the confines of the market value is not viable. This information is vital in the creation of a realistic production budget.

2.2.1.3.3 Assessing Competitive Products

Competitive products provide a great deal of information to the designer. Strengths, weaknesses, and deficiencies in these products will aid in the improved design of the new product.

2.2.1.3.4 Examining Existing Work on the Project

In some cases, the client will come to the designer having already initiated some type of work on the project. This work may be examined in much the same way as competing products are examined, determining the direction for new design.

2.2.1.3.4.1 Images

Existing drawings and photographs are collected. Drawings may range from rough sketches by the client, to finished renderings by a previous designer. Gathering of these images provides the designer with a wealth of information and may be used as a starting point for further design.

2.2.1.3.4.2 Models

The opportunity to view previous model work improves the designer's understanding of the project. As with images, these models indicate certain advantages and disadvantages within the design which can be addressed in future work.

2.2.1.3.4.3 Design Site

In the case of architectural work and some industrial design work, an accurate recording of the design site is important. Images of the environment the design will exist in serve both as an inspiration to the designer and as practical information.

2.2.2 Information Distillation

The volume and variety of information involved in a design project can be immense. In order to establish clear criteria from this wealth of information, it should be organized and distilled into a manageable body. This organization will occur continually throughout the design process.

2.2.2.1 Defining Information Categories

In order that information may be distilled, categories for classification will be required. Definitions of these categories may be created at the outset of the project, evolving through the process as information is obtained. These categories should have relatively clear boundaries and definitions, and category selection is dependent upon the type of information available.[7] Standardized categories often exist in many design projects, but it is important to recognize categories which are unique to the each project. Examples of standard categories are materials and processes, and ergonomic principles associated with the problem. The selection of the appropriate categorization method is typically completed by the designer.

2.2.2.2 Classifying Information

The placement of information within a category will be based upon its compatibility with the category's definition; if a piece of information satisfies a category definition, it is included in that category. Placement of information is not to be exclusive, therefore if information satisfies more than one category it would be included in each.

2.2.2.3 Assigning Relative Values to Information

Within each category, values may be assigned to individual information packages in order that conclusions may be made about that category. The nature of the information determines whether such values are objective or subjective.

2.2.2.4 Organizing Information by Priority

Organizing the information according to its assigned relative values may be done to aid in the criteria selection process. If this is done, conclusions about each information category can more easily be reached.

2.2.3 Criteria Selection

With the information organized, the designer is able to make some decisions about criteria selection. The following three sections are not meant to indicate a rigid process, rather components which occur within the process of criteria selection. How and where this occurs for each designer will be different.[6]

2.2.3.1 Information Analysis

The condensed information may be analyzed, identifying common themes, technological restrictions, legal restrictions, and the other important factors. These elements are then organized as a single body of information. The manner in which this analysis takes place is largely dependent upon the designer's preference.

2.2.3.2 Criteria Selection

From this new body of information (the information analysis) criteria are established. Many of the criterion will be objective; issues regarding cost or legal constraints may be clearly defined. Others, such as aesthetic concerns, are subjective. These may be somewhat more difficult to define.

2.2.3.3 Prioritization of Criteria

The determination of the relative importance of the various criteria is integral to decision making during the design process. When concessions must be made during a design process, an understanding of the relative values of the criteria helps to clarify those decisions.

2.3 Information Translation

Much of the information assembled is formatted in a manner that is difficult for the designer to utilize. The designer is required to convert that information into a more appropriate format. The format utilized in the project is dependent upon the designer's preference and the application of the information.[8]

2.3.1 Written Briefs to Salient Points

Information within reports is often difficult to access. Making notations about the important elements within a report makes information easily accessible and more understandable to the designer.

2.3.2 Drawings and Specifications to Workable Format

Information regarding technical data, such as component specifications, are converted into formats that facilitate their clear understanding. For example, specifications are converted to drawings, drawings are converted to models, and so on.

2.3.3 Physical Models to Computer Models

For those designers who use Computer Aided Design and Drafting (CADD) in their work, there may be a need to convert existing physical models into computer models. For example, an industrial designer may find use in converting an appearance model into a three-dimensional CADD model, to explore the aesthetic implications of various surface treatments to the object.[9]

2.4 Concept Generation

This area within the design process involves the greatest degree of diversity in terms of the methods of work used by designers. Traditionally, designers have been known to utilize a substantial variety of methods, from roughing out thumbnail sketches on the back of napkins to creating full-scale models of projects out of materials such as clay, foam, and wood.

Work carried out within this phase, although performed with the criteria in mind, is meant to be creative and investigative. The designer typically chooses methods of working which are less structured and unrestrictive, allowing unfettered exploration to take place with a minimum of investment.[8]

Conceptual techniques vary, but knowing too soon that a concept will fail could potentially prevent further exploration of that concept and prevent it from being more fully developed. As Joseph Ballay states:

> ***"Systems which force a designer to make an early decision about the inclusion, coherence, or precision of information will be counterproductive. They will tend to close down a designer's inventiveness too early in the design process."***
>
> Balley (1987) [10]

2.4.1 Concept Development

2.4.1.1 Sketching

Historically a mainstay of designers, sketches utilized in the development of design concepts allow the designer to work through design ideas. The sketch is often the first external expression of a design concept, often drawn on paper with pencil. The immediate and non-precious nature of the sketch enables the designer to quickly work through ideas unencumbered by process or a sense of "investment" in the image.

When the process of design interferes with the design itself, the designer's ability to concentrate on the design is diminished. Further, if a sense of investment with regards to the creation of the image exists, there is a greater chance that the designer will terminate exploration at this stage before it may be appropriate.[11]

A further advantage of sketching is that it is portable. Designers are a creative breed, and this creativity can strike at any time in any situation. In fact, ideas are often generated as a result of the designer changing environments. Sketching is well-suited to the demand of portability, as the requirements of sketching are minimal. All that is required is a writing instrument and something to record the sketch on. The imprecision of sketching allows for work to be accomplished in less than ideal locations, without the need for a desk or other such devices that artificially tether other tasks to the work environment.

2.4.1.2 Rendering

Rendering of the sketches is carried out in order to "flesh out" some of the initial design concepts. This is accomplished in a relatively loose style, the intent being to clarify the sketches and explore them in somewhat greater detail. However, they are not intended to be used as a final image.

2.4.1.3 Sketch Modelling

Sketch modelling serves the same purpose as sketching, except that it is performed in three dimensions rather than two. Models are constructed so that the designer can work through and better understand the physical nature of a design concept, and to communicate these issues with the client. Architects use massing models to more clearly understand how the form of the project is working, and how it relates to the site. Industrial designers discover how components will fit, how the product feels when held, and how the aesthetic concerns associate with the functional aspect of the design. Typical materials used are foam, wood, and plastic.

2.4.1.4 Computer Model

The creation of computer models is a relatively recent addition to the design process. These models allow the designer to explore design form and layout, but do not allow for any physical feedback.

2.4.1.5 Procedural Mock-ups

A procedural mock-up involves enacting a brief "play" to determine how a user of a design might operate or react to that design. This aids the designer in determining methods in which a design can be approached and the ways in which the design can be interpreted. A procedural mock-up may be carried out through methods that vary in both style and scope. This can range from the designer creating an image of the scenario in their head as the design develops, to the observation of a sample group using a full-scale mock-up. Regardless of the method, this is a valuable tool in making design decisions.

2.4.2 Concept review

During conceptualization, designers often review concepts they have previously explored. This review may generate new factors to be addressed and clarify the progress of the design for the designer. The method through which this review occurs is largely dependent on the designer ranging from flipping through sketchbooks to placing all drawings on a wall.[4]

2.4.2.1 Interim Presentation

At the interim presentation, the designer presents the client with a selection of those concepts felt to be the most promising. This presentation is typically formal in nature and will indicate to the designer and client whether more conceptual work is needed, or if detail design may begin. Models, renderings, slides, and procedural demonstrations may all be part of this presentation.

2.4.3 Concept Selection

If the client is satisfied with the conceptual work a selection is made for detail refinement. The selection does not have to consist of one option alone but may be a combination of a number of concepts. Indeed, there may be a request to develop more than one concept. The selection of concept(s) to develop is usually made using the established criteria as guidelines for assessment.[4]

2.4.4 Detail Refinement

Upon approval at the conceptual phase, the design then moves into the detail refinement phase. One concept is normally selected for further exploration, although more than one may be selected in some instances. Any problems at the concept level are resolved here, the goal being to satisfy all criteria in a single solution. Satisfying all criteria is, of course, an ideal situation. Where conflicts in criteria arise, compromise will be required.

2.5 Detail Development

2.5.1 Information Conversion

The detail refinement stage is the next stage in the natural progression from the concept generation stage to the finished product. The concept generation stage provides most of the information used in the detail refinement.

The transition from the unrestrained concept generation stage to the tight, specific character of the detail refinement stage may require a regeneration of similar information. In some instances, though, the designer may use sketches and sketch models as "underlays" for detail drawings and models.[4]

2.5.2 Trade-offs

This is where concessions in the design of the product must be made. In an ideal situation, the aesthetic choices, the materials and processes selected, and functionality of the design are all optimised. In practice this is difficult to accomplish.

2.5.3 Testing

The issue of testing the design is an important one. How a product succeeds in terms of the design can be measured against its ability to satisfy the established criteria. The criteria are often of diverse variety and as such require several methods of testing through which the design can be evaluated.

2.5.3.1 Human Factors

This stage involves assessing the design-to-date in terms of human factors considerations. This would take into account all variables and criteria regarding the design and its interaction with the user.

The relative importance of this type of testing is determined by the nature of the product being designed. As product-user interaction becomes more fundamental to a design, the level of human factors testing becomes more important.

2.5.3.2 Function

2.5.3.2.1 Physical tests

Models and prototypes of the product can be tested for their ability to perform the goal functions adequately.

2.5.3.2.2 Finite Element Analysis

With the creation of a three-dimensional computer model, some judgement of engineering soundness can be made. Finite element analysis is the application of a theoretical force upon a computer model which tests the model's ability to withstand the expected forces which will occur in its use. These tests can vary from the examination of a building design to the suitability of a material selection for a power tool. Established criteria will be used as a measure of success.

2.5.3.2.3 Cost

Using information about the design, it will be possible to closely estimate the cost of production of a design. This would take into account all cost factors, from material cost through to fabrication and assembly. Again, success or failure will be judged against established criteria.

2.5.3.2.4 Visual

The physical appearance of a product may often determine its success or failure in the marketplace. Evaluation of the visual component of a product is required to ensure that all criteria involving appearance are met.

2.5.3.2.4.1 Human Factors Issues

Although truly a component of human factors testing, mention of the visual component of this issue is of value here. Clear understanding of a product's use is often as a result of its appearance. Whether through the use of icons, metaphors of form, or any other visual device, clear communication of a product's use is important, particularly in instances where misunderstanding may endanger the user. Testing of this nature would likely involve using a sample group of end users, examining the success with which the product prototype communicates its use, and determining where the product failed.

2.5.3.2.4.2 Aesthetics

The aesthetics of a product are somewhat difficult to evaluate. Except in cases where there is a set of aesthetic guidelines to follow, such as electronics firms maintaining a need for similarity of form in its product line, approval or disapproval of a product's aesthetic success is almost wholy subjective. In this case, the process is not so much that of testing, as it is a matter of obtaining feedback from others. The sources of feedback may vary, from the client directly to a sample group within the target market. Regardless of the method, any results will not be concrete.

2.5.3.2.5 Market

Evaluation of the product in terms of the market itself is closely tied to other values which may be examined at this point. Product function, cost, and visual concerns will each be components which determine a product's success in the marketplace. The product's potential success may be predicted through a sampling of the target market, obtaining feedback of the product's strengths and weaknesses, and where it may be positioned in the marketplace.

The testing of the design can take place at any point within the process, assuming that there is enough information for the particular test to make a reasonable judgement.

2.5.4 Design Refinement

If, after testing, problems with the detail design are discovered, efforts to remedy those problems will be made. The amount of work required at this point is dependent upon the nature of the problem. A minor change may be required or a fundamental flaw in the concept can be discovered requiring further conceptual work.

2.6 Release Package

The release package provides the final assembly of all of the pertinent information regarding the product and its design. The tasks within this phase of the design process fall into two groups; the organization and presentation of material previously created, and the creation and presentation of new material concerned with communicating the final design solution.[8]

2.6.1 Organization of Release Information

The release package contains many items; concept drawings, dimensioned drawings, technical information, final renderings, models, and written statements about the design solution. This information must be organized such that it can be easily accessed and used.

2.6.1.1 Creation of Release Package

There are two goals which are central to the release package; developing a package which enables the product to be created, and presenting the product in a manner that is convincing and easy to understand. At this point in the process, the design of the product has ceased. Of concern here is the communication of the design solution.

The designer has made all of the decisions that are to be made and is simply preparing the design information to effectively communicate the design, its function, and the methods through which the product can be realized.

2.6.2 Final Presentation

The final component of this phase is the presentation of the release package. This presentation is the conclusion of the design process and requires the designer to be able to present the design solution convincingly. Typical presentations involve product renderings, a slide presentation, the presentation of a model, and an accompanying oral presentation by the designer.[4]

The presentation of this information is similar to the concept generation stage. The principle difference between the work presented at this stage and that presented at the concept generation stage is a matter of refined detail. While the concept images were left loose and simple, the images presented in the release stage are tight and complete.

1) Discussions with faculty and students from The Faculty of Environmental Design, The University of Calgary, January 1991 to September 1991.

2) Christopher Alexander and Barry Poyner — "The Atoms of Environmental Structure", in Developments in Design Methodology, ed. Nigel Cross (Chichester: John Wiley and Sons, 1984)pp. 123-133.

3) Donald Norman, — The Design of Everyday Things, (New York: Doubleday, 1988) pp. 157-158.

4) This section was created as a result of interviews with other designers, and personal experience.

5) Norman, p. 157.

6) This section has been created as a result of information from the Ballay model, interviews with other designers, and personal experience.

7) J. Christopher Jones, — "A Method of Systematic Design", in Developments in Design Methodology, ed. Nigel Cross, (Chichester: John Wiley and Sons, 1984) pp. 12-13.

8) This section has been derived directly from the Ballay model.

9) Joseph M. Ballay, "An Experimental View of the Design Process", in System Design: Behavioral Perspectives on Designers, Tools, and Organizations, (Elsevier Science Publishing Co., Inc., 1987) p. 30-31.

10) Ballay, p. 42.

11) Ballay, p. 42.

Chapter 3
Conceptual Development

In the previous chapter, a series of tasks and sub-tasks associated with the design process were examined. By looking at the group of tasks and subtasks as a whole, common groupings of tasks were developed. From those groups, eight fundamental task requirements of this system have been identified. They are:

1) provision of a system screen,
2) provision for navigating the system,
3) provision for capture and storage of hard documents, images, and environments,
4) provision for notations,
5) provision for model-making,
6) provision for sketching,
7) provision for communication, and
8) provision for presentation.

The following section introduces the individual system requirements, and the reasons for their selection. Possible solutions to these requirements are also discussed.

3.1 System Screen

In order to work within the system, provision for some configuration of a work screen must be made. The system screen is the medium where much of the interaction between user and machine takes place. Without the screen, accomplishing tasks within the system would be virtually impossible.

The configuration of the system screen is restricted only by the available technologies. Flat screen technologies, tube technologies, or projected screens are each a possible solution to the screen requirement. The selection of the technology to use will be based primarily on decisions about the system as a whole.

3.2 System Navigation

The need for an ability to navigate around the system comes from the understanding that movement will occur from one task to the next. Navigation is the "steering" through a system, allowing the user to move from task to task in a controlled manner. Tools to execute tasks are of course necessary if any work is to be performed. Navigation and task execution are typically done through a series of commands, each including a series of arguments which specify the object(s) to be acted upon, the options available, and the definition of any parameters associated with them.

There are several ways in which users currently navigate computer systems and complete tasks, and in keeping with the goal of personalization of the system, it would be desirable to make available several methods of performing these. The following is a list of possible techniques.

3.2.1 Command Line Entry

Commands are typed from the keyboard and are restricted by structure. This technique places a great memory load on the user, and is relatively slow on input. Expertise can be achieved, and provides the frequent user with an ability to be explicit. This technique is unsatisfactory for novice or infrequent users.

3.2.2 Graphical User Interface

Using a pointing device and a graphical user interface, this technique invokes commands by pointing to and selecting the appropriate command icon. How selection is done is dependent upon the type of pointing device.

3.2.2.1 Pointing Devices

There is a considerable variety of pointing devices which are capable of assisting navigation through the system. The following is a list of those devices being considered for this system.

3.2.2.1.1 Mouse

This device is effective in its ability to point to specified locations on the screen. A device that sits on the desk surface, the mouse conveys movement in the X and Y coordinates through various technologies. The user's hand is placed over the device, with the movement of the mouse on the work surface being translated to movement of the cursor on the screen. Commands can be invoked from the mouse through the depression of a button or a combination of buttons, depending on the number of buttons provided.[1]

Mice have the advantages of being inexpensive, easily located by the user while looking at the screen, and having variable control-display gains. Although they do take up little space in their use, mice do require some space in addition to the keyboard, and thus may be inappropriate for portable or laptop use. A second disadvantage is that they are a relative input device, and may therefore be limited in their use as a drawing tool.[2]

3.2.2.1.2 Stylus

This device is also excellent in its ability to point. The primary benefit of this device is that it may be used directly on the screen, as opposed to another surface removed from the screen. This connection between the pointer and what is being pointed to is most natural for the designer. In discussing this benefit of the stylus, F M. Mims states:

> ***"Since this interface provides a direct relationship between output and input, it therefore allows natural pointing and/or drawing gestures to be used to input data."***
>
> Mims, 1984[3]

In the case of light pens, using such a device places great physiological demands on the user, requiring that the user to support his/her arm out to the screen in order to select an item or command. Over time, this work will cause fatigue, and reduce precision.[4]

3.2.2.1.3 Joy Stick

Although not often utilized in personal computer applications, the joystick does offer some advantages to a portable system. By nature of its design, the joystick has a very small footprint, requiring of the system very little surface area in which to work. The joystick can therefore be made integral to the keyboard. Unlike the mouse, there is no requirement of a second work-surface, and as such is appropriate in conditions of limited space.[5]

Joysticks are not particularly well-suited to drawing tasks, owing to their relatively low resolution. Joysticks are best-suited to targeting tasks, those involving pointing or tracking.[6]

3.2.2.1.4 Trackball

The trackball consists of a freely moving ball held within a fixed housing, moving the cursor by a like rotation of the ball. This device is similar in operation to the mouse, the two main types being optical and mechanical.

The trackball has several advantages. There is direct feedback from the ball's rotation, high resolution in the cursor movement, and may be used for extended periods of time when the forearm is supported. Because of these strengths, rapid cursor movement may be achieved. As with the joystick, the trackball requires very little in terms of space, and may be well-suited to portable or laptop configurations. Trackballs are not well-suited to drawing tasks.[8]

3.2.3 Speech Command

With speech-recognition technology, tasks may be executed with the aid of voice commands as input. Currently, this technology is restricted to small vocabularies with a limited application. In the near future, there may likely be an ability to use a much larger vocabulary, allowing for explicit selection of command. This technique could be used alone, or in conjunction with a pointing device. The primary concern with the use of speech for command initiation is that it places considerable memory demands on the user. With experience and personalization of the command language, this concern would be minimized.[9]

3.3 Image Capture

The requirement of image capture in this system is related to the many tasks which would require such a service. Information gathering, in particular the collection of hard documents, images, and environmental information, can all be performed using some form of image capture. Model images can also be stored this way.

Image scanning is the technology for this need. There are three methods of scanning -- paper feed, flat bed, and camera-based. The technology involved with these methods is essentiallythe same.[10] They each use light and a form of optics to focus an image of the object or document onto a cluster of light-sensitive electronic charge-coupled devices -- CCDs. Each light sensor on a CCD is called a pixel, which converts light into an electronic signal. The composition of the individual signals creates the digital image. Color images are created through the use of three color filters and one cluster of CCDs, each in turn extracting the red, green, and blue components of the image. This would require that the image-capturing device remain stationary during the process.

In the case where holding the image-capturing device is difficult (as with a camera-based system), the use of three different clusters of CCDs, each assigned to sense either red, green, or blue may be more reliable. The density and surface area of the CCD cluster defines the sharpness or resolution of the converted image.[11]

3.3.1 Paper Feed

The hard document passes over the CCD array at a known rate, recording the image in increments. The scanner creates scanned "slices" of the image one pixel in thickness. The digital image is created by a stacking of the slices. Creating an image in this manner has the advantage of having a greater resolution because the object is typically scanned at a one-to-one ratio.[12]

Paper Feed Concept

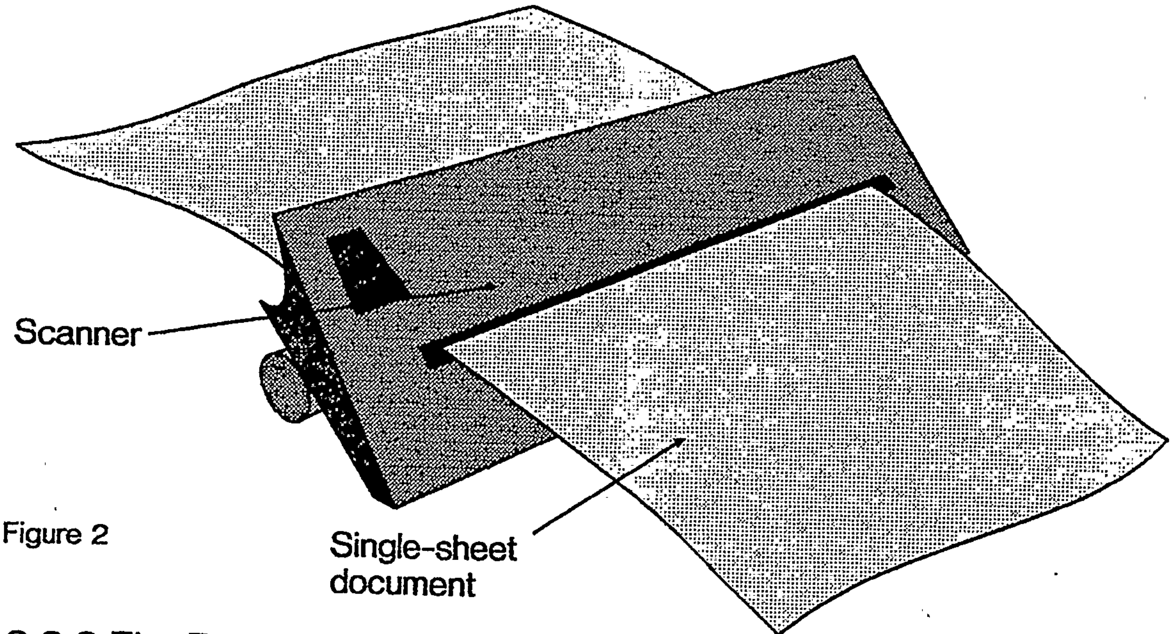


Figure 2

3.3.2 Flat Bed

This technique is much the same as in the paper feed method, except that the CCDs are moving past a stationary document. The result is the same as with the paper feed, except images from sources other than single sheets such as books may be scanned.

Flat Bed Concept

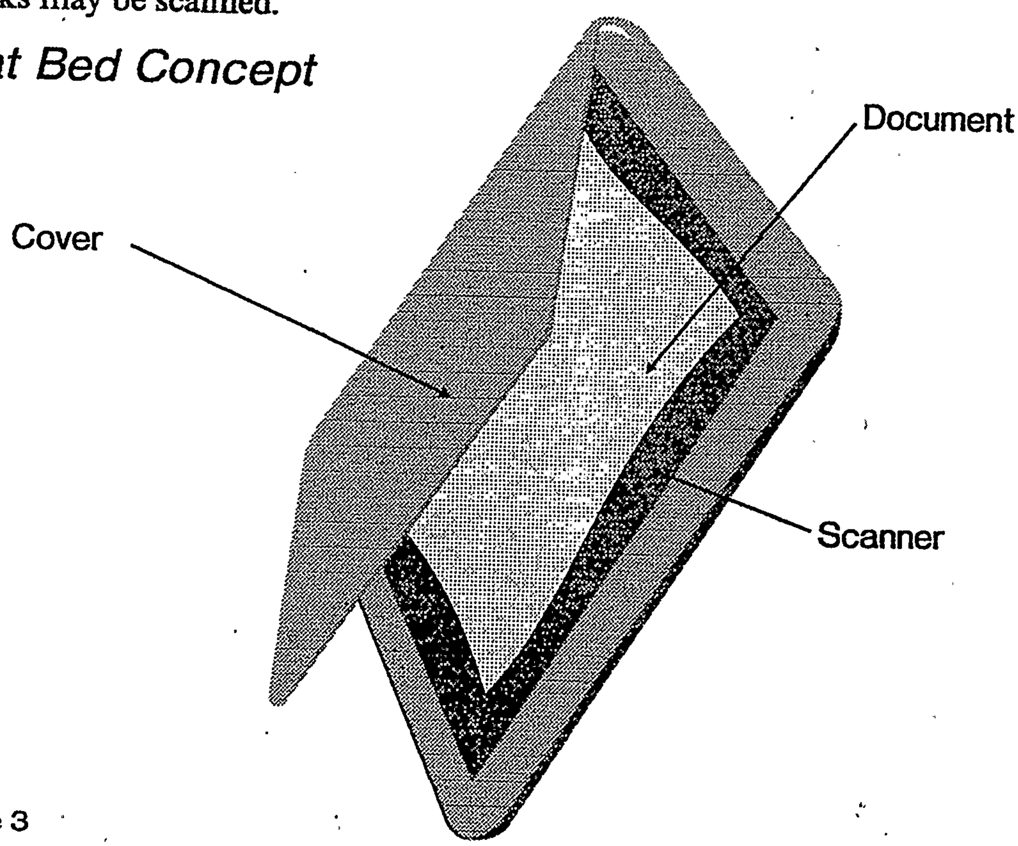


Figure 3

3.3.3 Camera-based

In contrast to paper feed and flat bed methods, camera-based methods use a cluster of CCDs in much the same manner as a standard camera uses film. The matrix of CCDs takes the place of the film, with separate clusters dedicated to red, green, and blue. This technique is more immediate than scanning, and also allows for recording images not possible with scanning -- large documents, models, or environments.[13]

The main drawback of using digitizing over scanning is that there will be a reduction in the resolution of the image captured. This is of special concern where great detail is required. For all techniques, optical character recognition software may be used to convert documents into text files, which may be used or manipulated as with any text file.[14]

Camera-based Concept

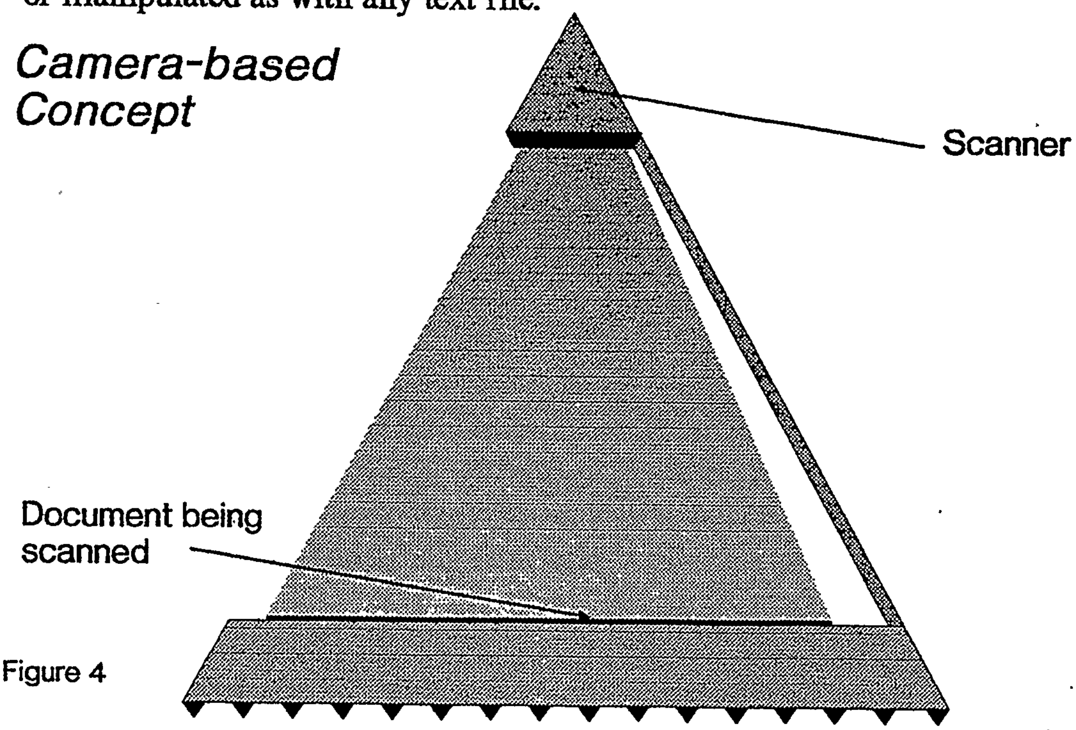


Figure 4

3.4 Notation

The need to provide for notational input is shared by several tasks. Report writing, drawing notations, and correspondence are a few of the tasks which require notational ability in varying degrees. Drawing notations are often short and concise, while reports may be of considerable length. An effort should be made to provide for both types of notation.

3.4.1 Keyboard Entry

A standard for notational entry, the keyboard remains a vital component in the creation of notation. Using a traditional QWERTY configuration or some other configuration such as the Dvorak layout, the keyboard is capable of quickly and accurately entering notations. There are, however, a number of drawbacks associated with the keyboard.

The first concern is the size of the keyboard. Although technology has allowed for the miniaturization of virtually everything material, it has yet to reduce the size of the human hand. The physical nature of the human hand places demands on the size of the keyboard that cannot be ignored. To perform best, the keyboard should remain full-size, and therefore places restrictions on portable or laptop computers.[15] Many laptops and now palmtops use keyboards that are far too small for extended use. In these cases, useability was sacrificed for portability.

A second concern is the nature of the typed notation itself. Typed statements, by virtue of both the way in which they appear and in the use of the keyboard, tend to be somewhat more formal than those which are hand-written. This formal nature conflicts with the need for an unstructured, natural method of making notations, as might be required during the concept generation stage.

In the case of report writing and other lengthy notational entry, the keyboard is well-suited to the task. This is supported clearly by Greenstein and Muto, when in a discussion on the benefits of keyboard use they state:

> ***"It is clearly the choice for applications involving significant amounts of textual input."***
>
> Greenstein and Muto, 1988 [16]

3.4.2 Stylus

The stylus is an excellent choice of input device for maintaining a natural and intuitive interaction between the user and the computer system.[17] The stylus is a direct replacement for a pen, both in the manner in which it is held and in the way it can be used. Notations can be placed anywhere on a page for recording drawings or they can be written out more structured, as if on a piece of lined paper.

One advantage that the use of a stylus for notations is that it could be the same device used when sketching. This allows for an immediate transition from sketching to making notes, unlike the transition which exists when using a keyboard. The stylus is inappropriate for protracted note writing. Using the stylus for report writing or any other lengthy text generation is uncomfortable and may result in fatigue.[18]

3.4.3 Speech

The use of speech for the creation of notation is an interesting idea. Perhaps the greatest benefit of using speech is that it frees the user to perform other tasks while making notes. Further, the physical demands placed on the user are minimal, except for the vocal chords and embouchure. The user should have few problems with fatigue or any other injuries.

One drawback to the use of speech in this application is that there is little privacy for the user. If used in a public space, any notations would be public. Whispering is possible, but does not wholly solve the problem. This technique is more appropriate for private environments.

Speech input may be interpreted in basically two ways. First, speech-recognition technologies could be used to convert the speech to a textual format. This technology is still in its infancy, but there is belief that the ability to recognize a large vocabulary efficiently is a realistic goal.[19] The use of speech with this approach would create notational entries which would be textual, similar to keyboard entry.

Another, simpler form of note-taking would be to simply attach a "voice-note" directly to the drawing or item, without conversion. Wang Computers have created a product known as "Freestyle', which uses such an idea for the transmission of communications between users within a network. Images, documents, or notes alone can be sent via electronic mail which have a voice-note attached. This use of speech is by far a simpler approach than the speech-to-text conversion. Voice-notes would be used to either augment or replace more conventional textual notations.

3.5 Modelling

Traditionally, models have been made in order that the designer can better understand the physical nature of a design concept, work through problems, and communicate these issues with the client. Architects use massing models to more clearly understand how the form of the project is working, industrial designers discover how components will fit, how the product feels if it is to be held, or how the aesthetic concerns are associating with the functional aspect of the design.[20]

As computer programs improve, there is a movement among designers to use three-dimensional computer modelling packages in order to create models. These models allow the designer to realize their design concepts in strikingly real form. The models can be explored extensively, manipulated, and altered on the fly to examine design solutions. Questions about color, materials, and composition can be answered through the ability to alter and manipulate the object.[21]

The traditional method of model-making is immediate, the space of the object is real, and the object can be held. The technological approach of creating computer models affords accuracy if required, an ability to make changes relatively easily, and can also enable the object to be viewed in a manner not normally possible in physical models.

Generally, the advantages of one are the disadvantages of the other. The traditional method of model-making is somewhat imprecise, unless the designer is willing to invest the time to do otherwise (which would negate the immediate nature of the exercise). Changes to a physical model are difficult, often requiring that a new model be made.

Computer models, on the other hand, are typically more difficult to construct, unless the forms of the design are simple. Computer models also lack reality in the physical sense. They do not occupy a volume, nor can they be held such that the designer/viewer can feel the object.

Consistent with the basic belief that the user should be able to work in a manner that is preferred, rather than the manner which is available, there should be provision for both methods of work within this system. The disparity between the two basic techniques suggests that there would be an advantage in finding some method for combining them, while allowing them to exist as separate entities. The goal is to find a system which allows for both methods to be used. Joseph Ballay states:

> ***"Solid Models assist cognitive aspects of spatial problem solving; computer-aided design systems need a surrogate for solid models."***
>
> Ballay, 1987[22]

For the system to make use of physical models, there must be a method in place to allow for conversion of those models into a usable format -- computer models. Several techniques of creating a three-dimensional computer model from a physical model exist, each of which has advantages over the others. The following discussion indicates those qualities.

3.5.1 Photogrammetry

Through the use of two optical inputs, spaced a known distance apart, information can be obtained about the physical characteristics of an object. Three-dimensional computer models are generated through a comparison of the two images, using triangulation to determine surface distances. Unfortunately, this only allows for information from one view to be used, unless there is some method by which the object can be rotated and viewed from several angles, maintaining a consistent coordinate space.

The benefits of this technique are that objects of considerably large size may be digitized, and that most of the work is being performed by the machine. An architect would (theoretically) be able to digitize a building site, for example, with little workload placed on the user.[23]

Photogrammetry Concept

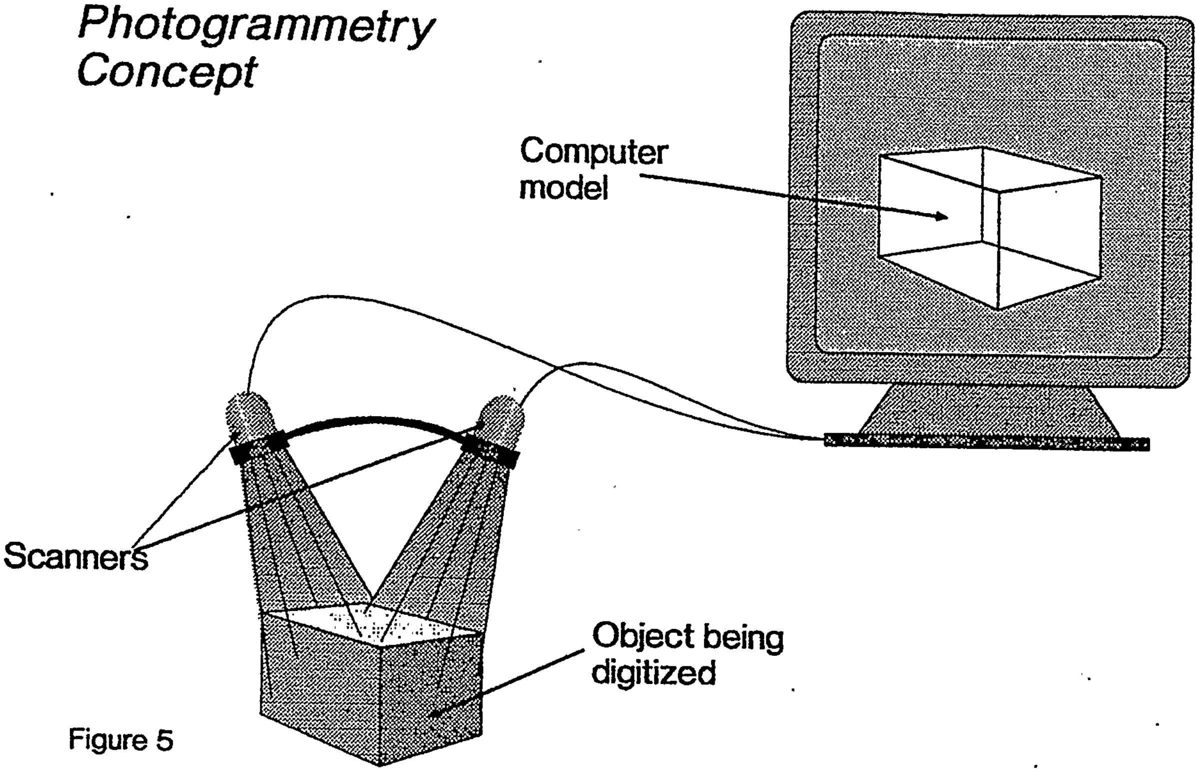


Figure 5

3.5.2 Laser Digitizers

Available in a variety of configurations, these systems bounce a laser beam off the object being digitized, which is interpreted by a receiving unit. With a known distance between the laser and the receiver, the distance from them to the object being digitized is determined by the length of time for the laser beam to travel from the laser to the receiver, having been "bounced" off

Laser Digitizing Concept

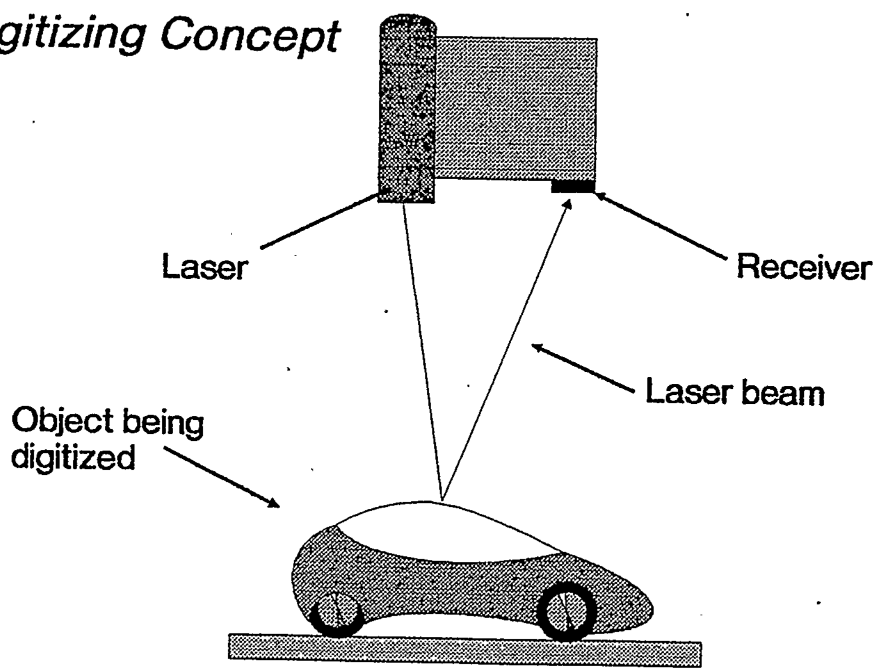


Figure 6

the object. Since the laser beam travels at a constant velocity, the distance from the object may then be determined. The object is then moved a known distance from the laser/receiver unit, where another point in space is determined until the whole of the object's surface has been digitized.

As with photogrammetry, information about the area of the object not visible to the laser is not available without rotating the object. Secondly, this technology is extremely dependant upon the accuracy of the laser and receiver positions, and as such is fragile. A benefit of this technology is that the workload is placed on the machine rather than the user.[24]

3.5.3 Pen Digitizers

This technique employs a pen device which "traces" over the surface of the object being digitized. This is achieved through the use of a pen that emits a low frequency magnetic field, it's position in space being detected by a sensor placed near the object.[25] The object can be traced in its entirety. Points along the surface are selected by the user with the pen, the level of detail in the conversion being wholly controlled by the user. This technique captures not only X, Y, and Z coordinates, but the directional attitude of the pen as well. This information can indicate to the system the attitude of the surface being touched, assuming that the user is capable of accurately placing the pen in the correct attitude.

As with photogrammetry and laser digitizing, the vast amount of information associated with this method places great demands on the system in terms of memory requirements and processor speed. Software may be used to compress the data. Another drawback of this approach is that the object must be held firmly in place so the digitizing pen does not accidentally move the object during digitizing (which would destroy the coordinate integrity of the space).

Pen Digitizer Concept

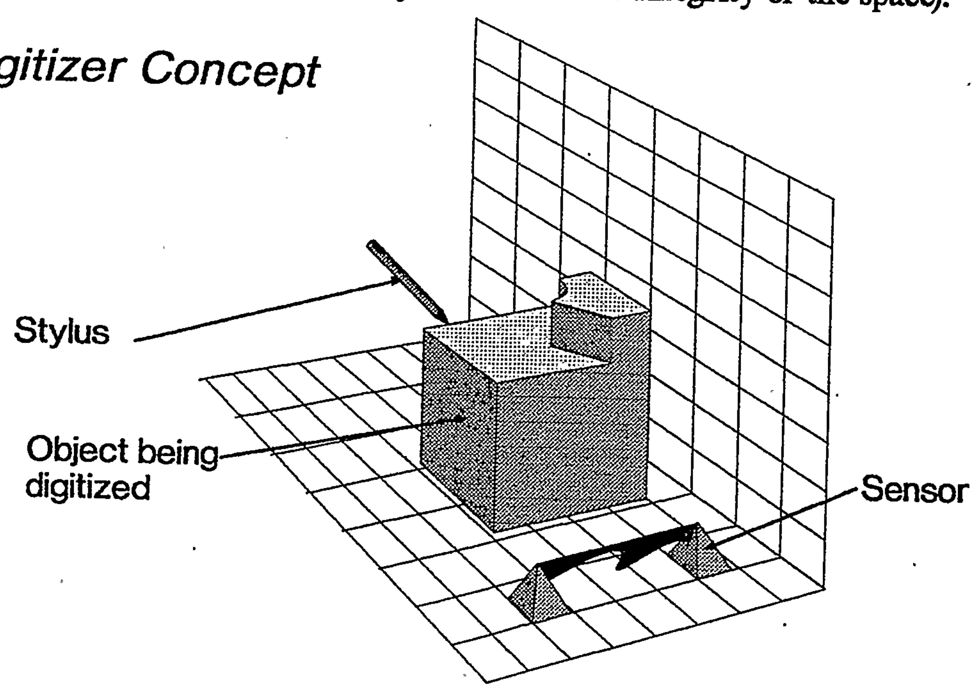


Figure 7

A final concern is the task demand placed on the user. While the other technologies perform the task of digitizing automatically, using the pen-based system requires substantial effort on the part of the user. Accurate representation of the model requires that a considerable number of points are used in the creation of the CADD object, particularly if there is a requirement for higher resolution in the model.[26]

The conversion from computer models to physical models is of a similar complexity to the conversion in the other direction. However, the processes are somewhat more time-consuming, more expensive, and require the use of machines that exist separately from the computer system. As these machines would be external to the system, they do not fall within the scope of this paper and will not be discussed.

3.6 Sketching

Sketching has long been a mainstay for designers. Without an ability to sketch, the designer would be considerably restricted. Particularly in the conceptual phase, sketching is a provision that cannot be overlooked.

The computer can adapt to the notion of sketching in a number of ways. What is required is a substitute for the paper, and a drawing instrument. The drawing instrument could be replaced by pointing devices such as mice, trackballs, or styli, each with a varying degree of success. In this case, the stylus is the appropriate choice, being the device that is most directly associated with a drawing instrument.[27] This creates consistent mapping between the traditional method of sketching and the computer-aided version. The same concern exists for the issue of "paper".

As with the drawing device, the substitute drawing surface should be natural and appropriate to the task. Many computer systems now use a stylus/tablet device to input drawings and hand-written text. The tablet sits on the horizontal surface of the desk, while the output of the drawing exists on a computer monitor that sits vertically some distance away.

The principal problem with this setup is that there is a disruption of normal control/display relations between the movement of the pen and the "surface" that is being drawn upon. What many system designers have done to alleviate this problem is to install a ball-point on the end of the stylus and have a sheet of paper placed over the tablet. This then provides direct feedback to the user as to the mark the pen is making on the screen by making a duplicate mark on the tablet. This is fine as long as there will not be any manipulation of the image after it is initiated. Once there has been a change to the image, any reference to the image on the tablet is useless. The stylus from that point onward is left to operate as if there were no ball-point at all. In fact, the remaining ink image may well prove disruptive to the process.

The same problem will exist if there is a desire to rework old sketches, or any other type of input requiring a pen on a previously created image. The solution to this would instinctively be to write directly on the screen, thereby eliminating any distance between the pen and the mark it makes. This is particularly important if there is to be a consistency between traditional horizontal methods of sketching and a computer-aided method. The mapping in this case would be complete.

Beyond the simple concept of pencil and paper, consideration of other media in which designers sketch is important. Media such as watercolors, felt markers, chalk pastels, and others should be considered when making a decision about the construction of the "pen" device. Fortunately, much of the work in creating alternative types of marks is software-dependent.

Markers, chalk pastels, pen-and-ink, and the pencil all are similar in terms of the physical nature of the marking device. Methods which use a brush, such as watercolors, might require an adaptation of the stylus so that it will physically behave like a brush. Although it would be possible to use a conventional stylus to create "brushed" images through the application of software, such a device would ignore the physical feedback so important in brush-work. This problem might be solved by the addition of a special tip to the stylus, or through the use of a separate brush-type stylus.

Steve Strassman, while a graduate student at MIT's Media Lab, developed a similar program called Hairy Brushes. Hairy Brushes allows the user to "dip" a virtual paintbrush into different types of ink, us fast or slow drawing, apply spatter effects, and even simulate a drybrush style. [28]

3.7 Communication

The need for a communication link is driven primarily by the designer's need for information during the design process, and the assumption that conceptual work is sometimes done in arbitrary locations. By including an ability to communicate with external sources, the designer has access to information far beyond that which would otherwise be available. In addition, there would be an ability to communicate with others, such as the client or other members of the design team.

Access to information is one of the more powerful tools the computer has given us. Exclusion of that capability would be a detriment to this product. The decision is then to select the technology to be used.

Using a cellular link would appear, for the time being, to be the best choice for telecommunications. Although promising, satellite links are not yet feasible on this scale. Conventional modems, although they are effective, would restrict significantly the system's ability to access information from any location, as they require a direct telephone hookup. Using a cellular modem will provide the user access to information from any location.[29]

3.8 Presentation

Portfolio presentation, interim presentation, review, and final presentation each require some method for displaying work. By virtue of the many instances in which designers may need to give presentations, the inclusion of a tool for that task is desirable. There are two approaches being considered; use of the system screen and/or a projected image.

3.8.1 System Screen

Use of the system screen for presentation is consistent with the use of a portfolio case. Images to be viewed would be brought up on the screen, either through selection or as part of a programmed presentation. This method would be used only in instances where the viewing group is small -- two to three people.

3.8.2 Image Projection

This technique would allow the designer to present to a large group of people. The images presented could vary greatly in size, depending upon the distance of projection and the area being projected upon. Unlike the use of the system screen, this method would require the use of a component dedicated to presentation. There are four techniques being considered.

3.8.2.1 External LCD Projection Screen W/Overhead Projector

This technique is currently available for most computer systems. The technique uses an external LCD screen placed over a standard overhead projector, the image on the screen being projected like a standard transparency. Currently, three devices are needed; the computer, the LCD screen, and an overhead projector.

LCD Projector Concept

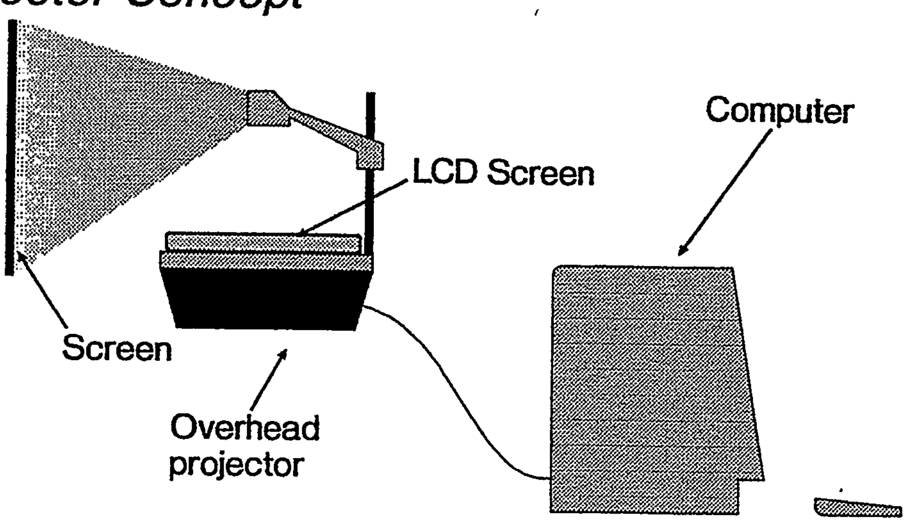


Figure 8

3.8.2.2 LCD Projector

Very similar to the above technique and also currently available, this method uses a small LCD screen through which light passes to project the image on the wall. This technique is more akin to a slide projector than an overhead, and exists as one unit. In this setup there would be two devices; the computer and the projector. The main drawback with this technique is that the small size of the LCD screen causes a reduced resolution of the projected image.

LCD Projector Concept

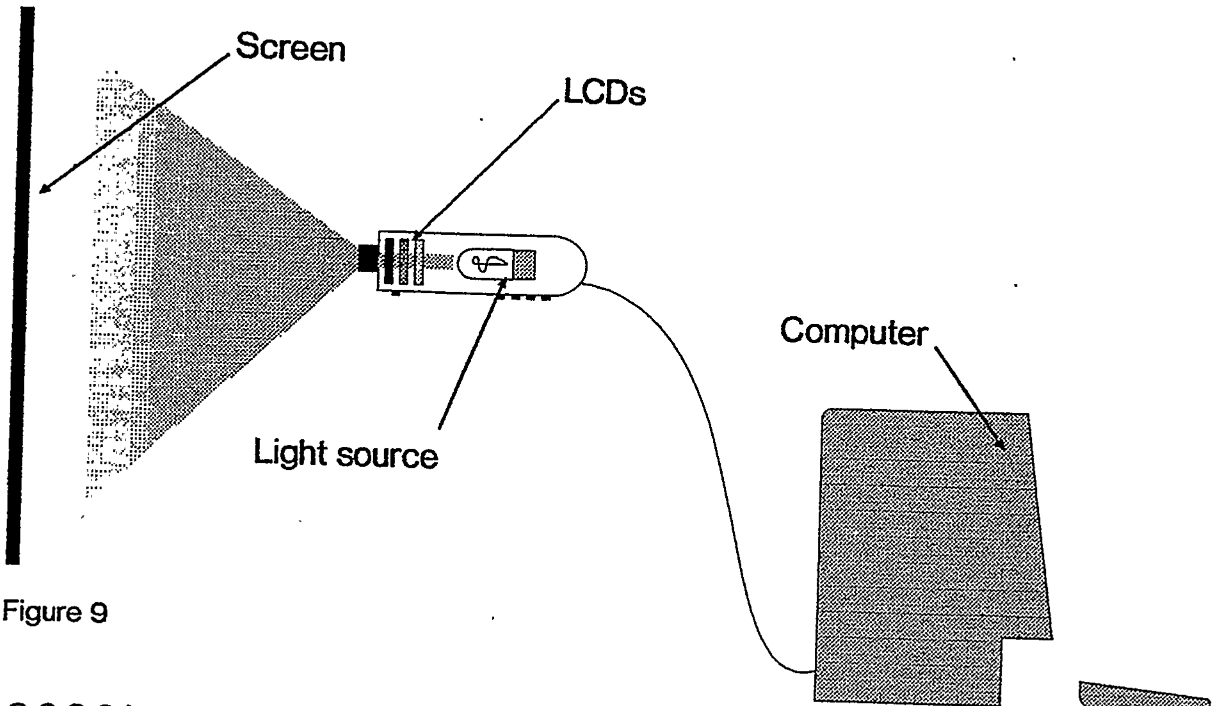


Figure 9

3.8.2.3 Integral Overhead Projection

This technique is an adaptation of the existing LCD screen/overhead configuration, and is of my own invention. The screen used in the system would perform two functions: it would serve as a standard LCD screen as well as a transparency. This technique would use the system screen in the projection of the image, by passing light through that screen to optics which would direct the image to the projected surface. The light could either originate from below and pass through the screen as in the existing method, or it could originate from above passing through the screen, onto a reflective plate and back out through similar optics. This technique utilizes the existing screen, but would require that a light source and optics be provided. I believe this to be a feasible alternative.

Integral Overhead Projector

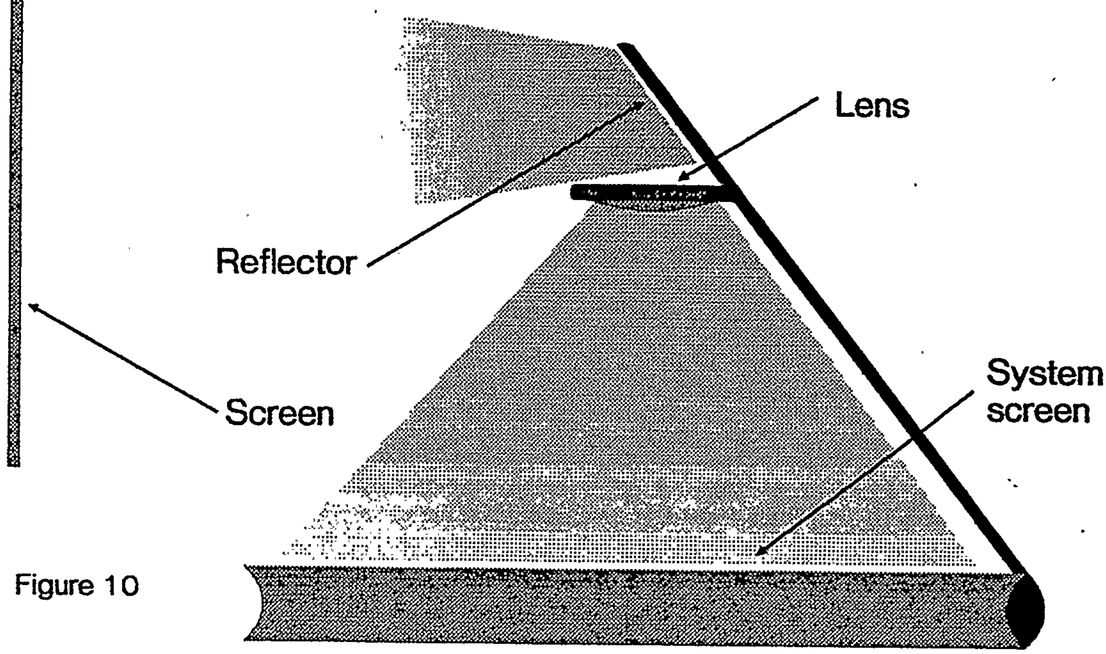


Figure 10

3.8.2.4 Integral Projector

This technique simply includes the projector device within the body of the computer. Unlike the integral overhead approach, this device would require that a second screen be used for projection. However, there would likely be a reduction in resolution with this technique. This reduction is because the projection screen would be relatively small, reducing the total number of pixels which translates to a much rougher image after projection.

Integral Projection Concept

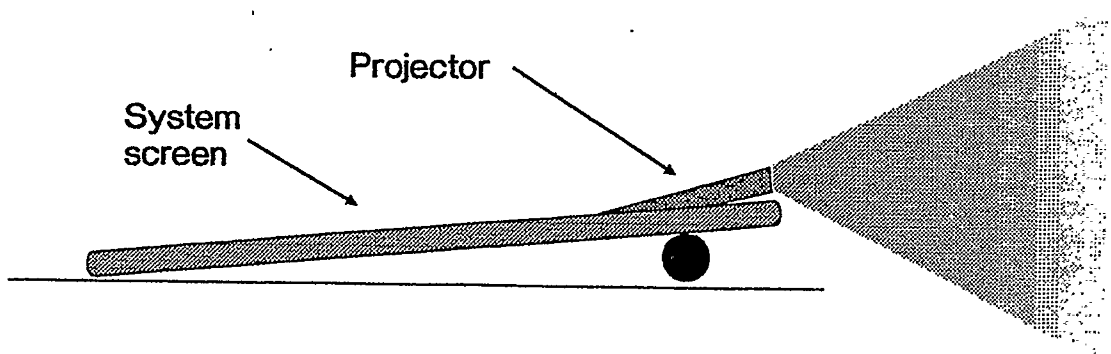


Figure 11

3.9 Concept Solution

With the conceptual alternatives explored, resolution of the system as a whole becomes possible. In order that all eight of the functional requirements may be satisfied, efficient selection and organization of technologies is critical. Technologies selected should be able to be applied to as many different tasks as possible.

3.9.1 Stylus

The inclusion of a stylus within the system appears necessary, owing to its potential involvement in a great number of design tasks. In fact, the stylus is likely to be a principal tool in the use of this system. Sketching, system navigation, text entry, creation of CADD drawings, and three-dimensional-digitizing are each tasks which will profit from the inclusion of a stylus. The technology selected for the stylus allows the stylus to work without the need for any physical connection to the system.

The Stylus - Concept Sketches

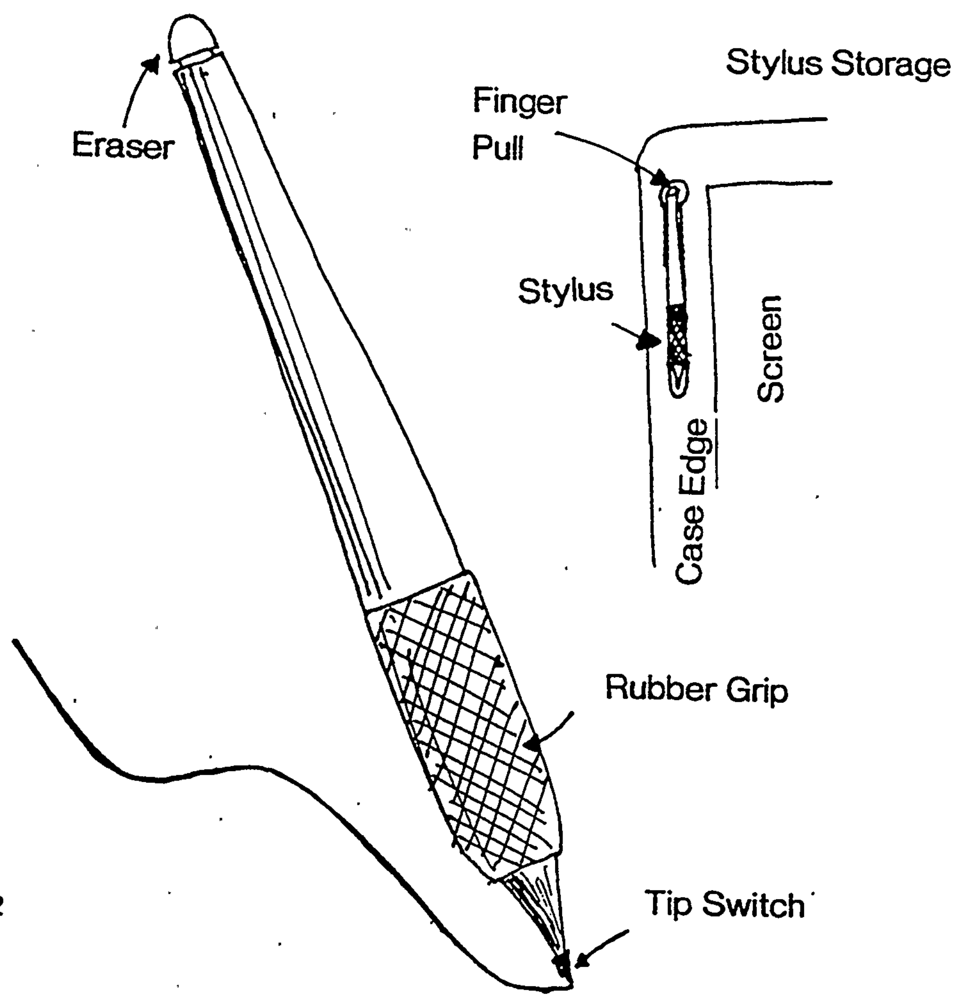


Figure 12

3.9.2 Keyboard

Although capable of entering text, the stylus is not particularly well-suited for protracted writing sessions. As there are likely to be cases where documents of extended length will require creation, a keyboard is felt to be necessary. For the keyboard to be of real use, it should be full-size, as any reduction would likely inhibit its functional ability. Although this will place some size restrictions on the system, they are not felt to be insurmountable. Storage of the keyboard is to be in the back of the system, either folding out or removed completely for use.

The Keyboard - Concept Sketches

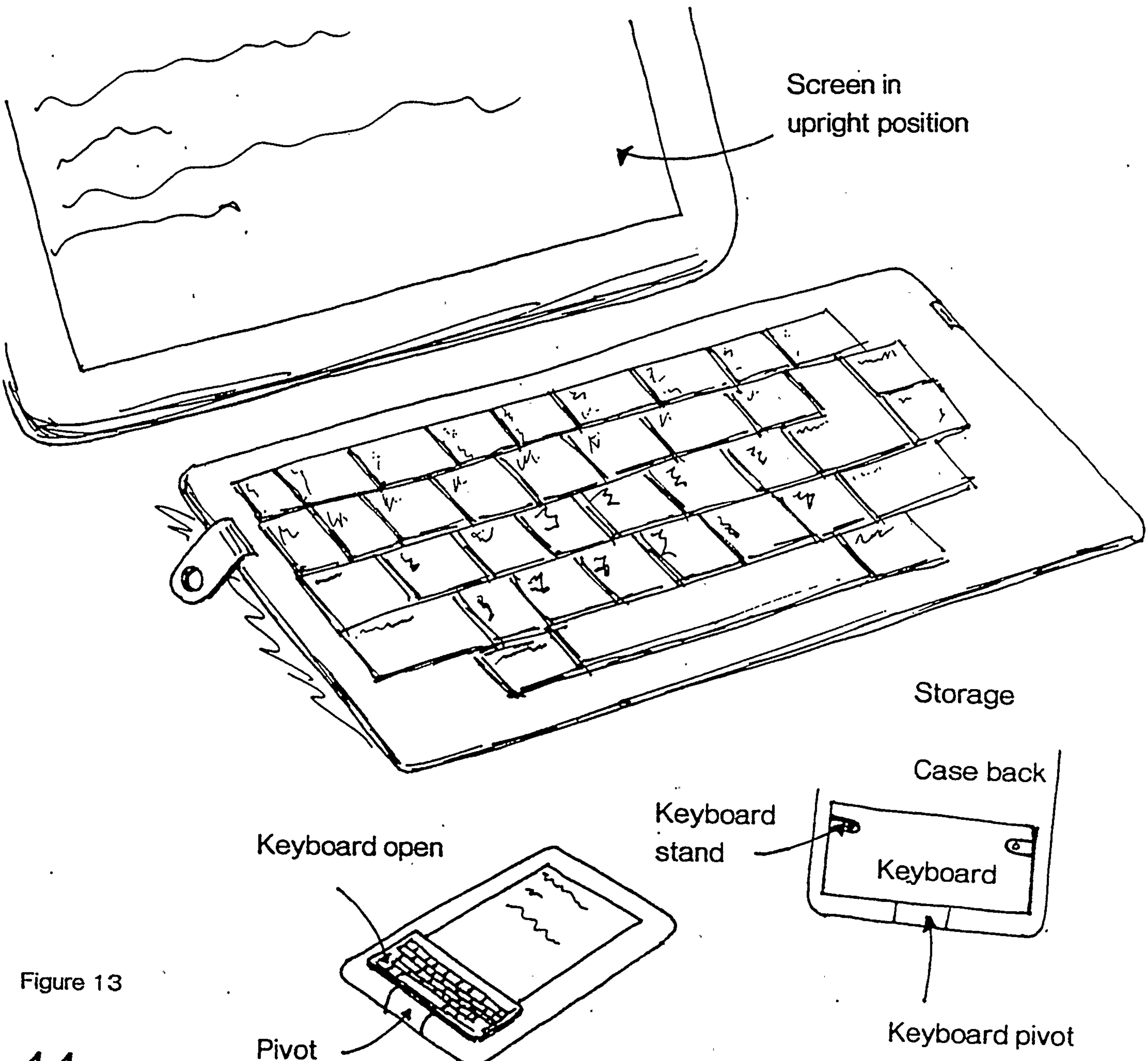


Figure 13

3.9.3 Digital Camera

There are basically two types of "objects" that will be scanned by the system -- two dimensional documents/images and three-dimensional environments/objects. The model that will be used in this design is that of the copy-stand and camera, which uses a camera mounted in a stand situated over the document/image to be photographed. This arrangement is typically for the capture of two-dimensional images. The camera can be easily removed, and is then used for more conventional photography of environments and objects.

The flexibility of that configuration is felt to be ideal for this system's use. The solution will mimic the layout of the copy-stand, with the system case acting as a support and stand for a removable camera. As with the copy-stand, two-dimensional documents/images may be scanned, or the camera may be removed from the system for capturing environmental images.

The form of the digital camera, although not identical, is reminiscent of existing cameras, in particular those of the 110 mm format. This is done to provide the user with a connection with past technologies, to aid in the use of the new technology.

The Camera - Concept Sketches

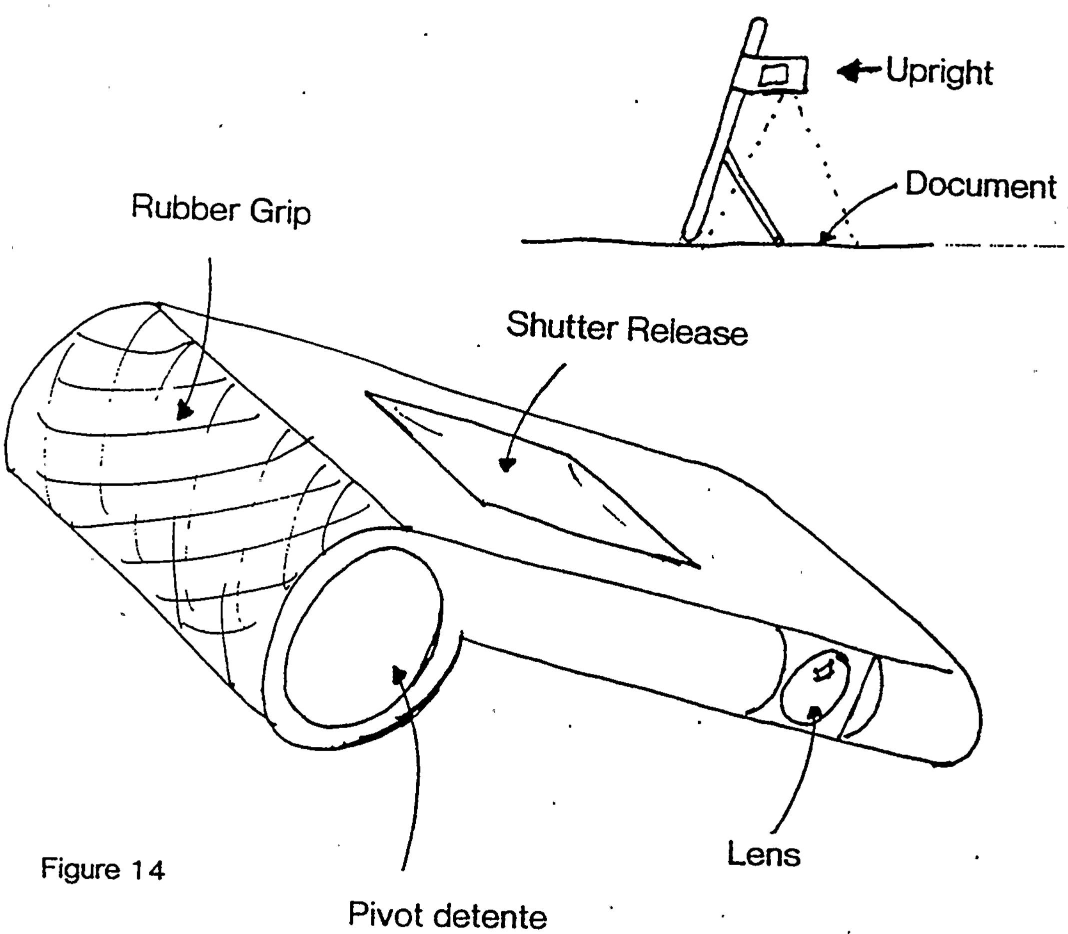


Figure 14

3.9.4 Projector

After evaluating the potential of the various technologies, selection of an LCD-based unit was made. LCD-based projection was selected for its portability, and its relative flexibility in terms of the kind of "case" it can function in. The concept selected is a blending of the two LCD concepts previously put forth, in that it can be integral to the system, and it can be removed and used as an external unit.

The form of the projector is such that it conforms with that of the digital camera, and uses the same method of fastening and support. This configuration allows for several varied arrangements for projection.

The Projector - Concept Sketches

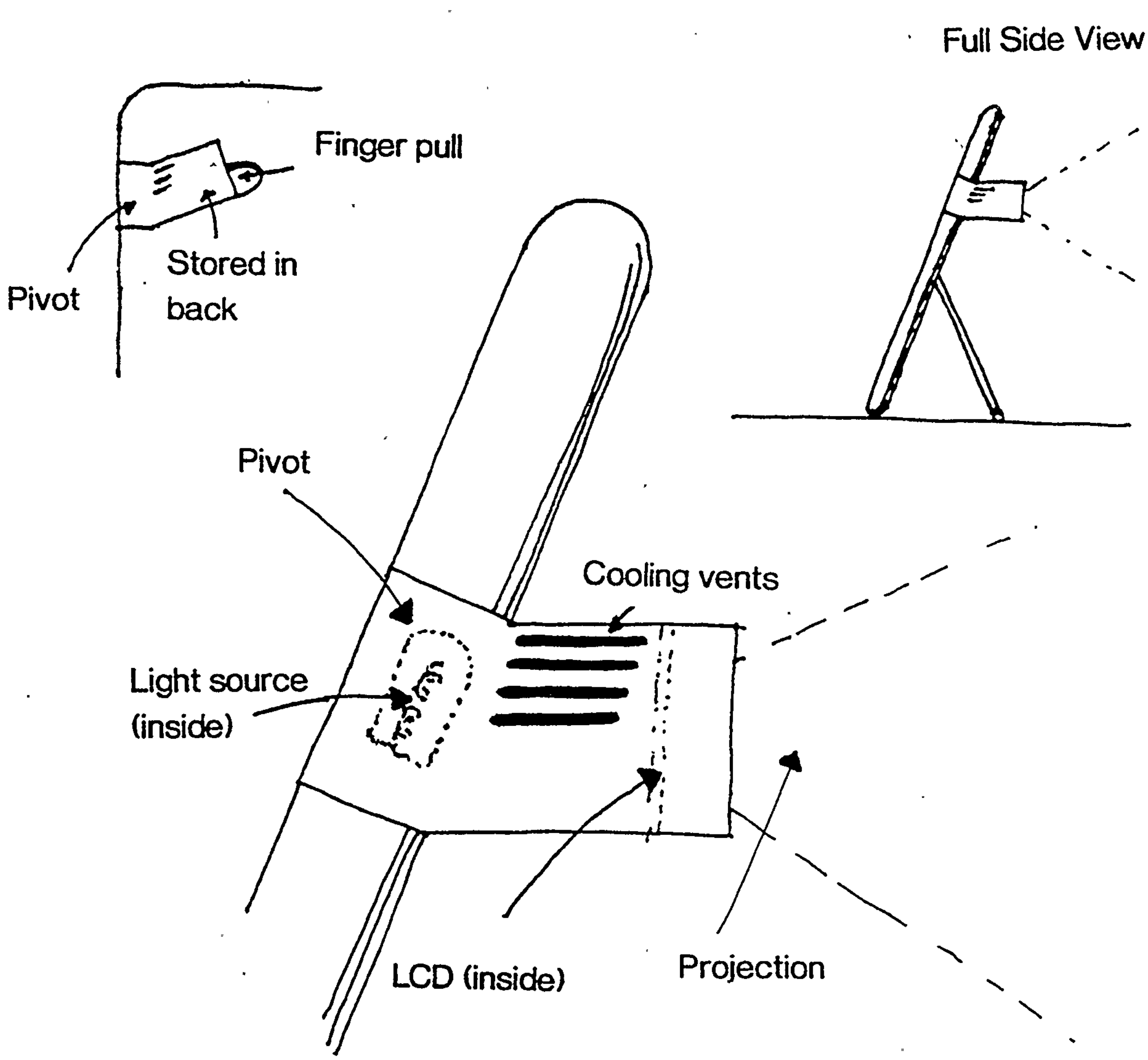


Figure 15

3.9.5 The Case

The model for this product is the designer's sketchbook, a rectilinear object. Most media for writing, drawing, painting, or sketching has in the past been rectilinear in form. It is felt that the use of a rectilinear form in the design would therefore be appropriate.

The size of the case will be restricted by the volumetric requirements of the components, but will remain as a rectilinear object.

The System Case - Concept Sketches

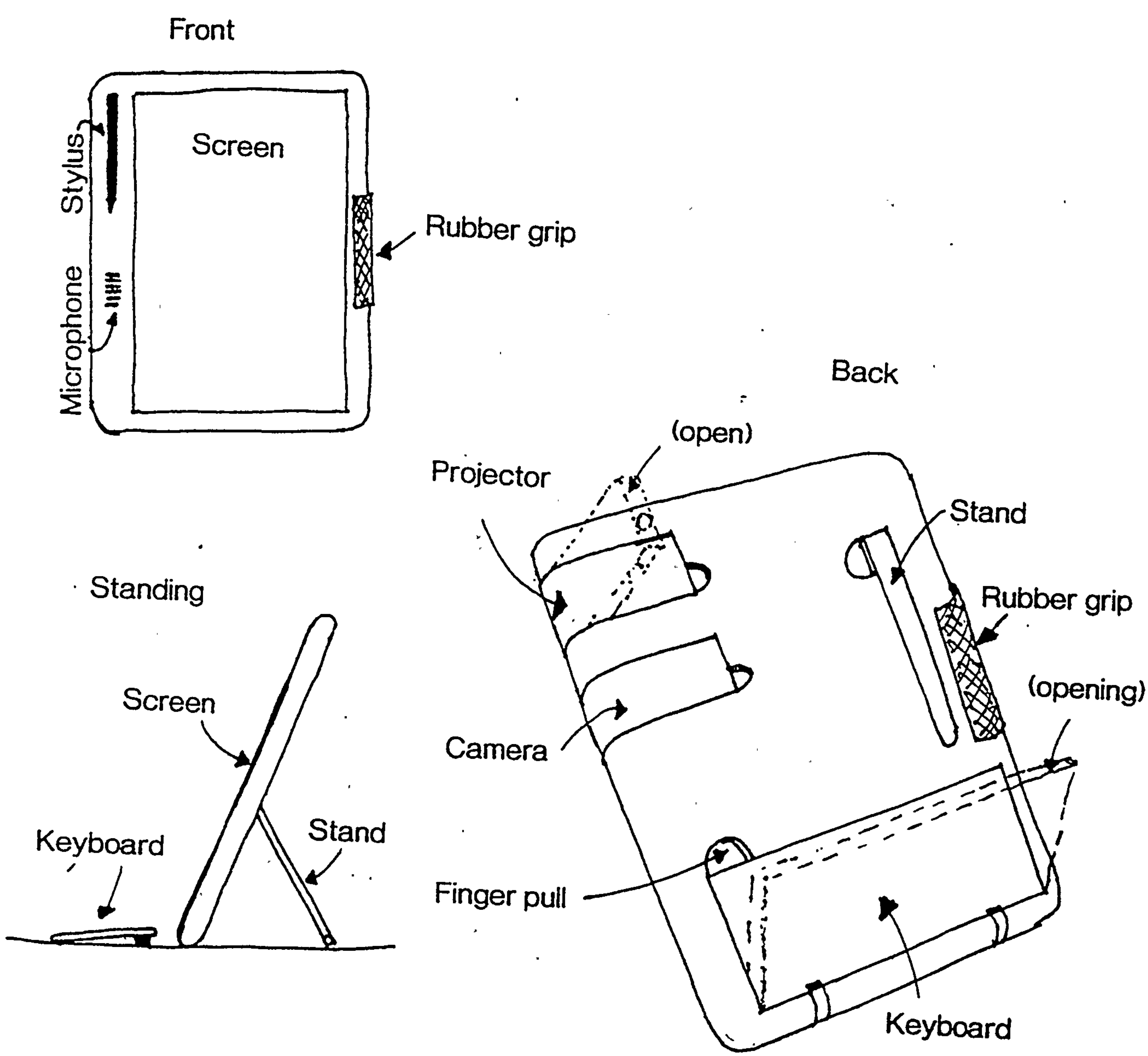


Figure 16

3.9.6 Other Components

Other issues, such as the inclusion of a cellular link or voice input have little effect on the concept, other than the need to provide space for the associated hardware. Although important, they have little impact on the physical nature of the product, and will not be discussed in great detail here. These issues will be addressed at some length in the following chapter discussing the design solution.

1) Lynn Y. Arnaut and Joel S. Greenstein — "Human Factors Considerations", in Input Devices, ed. Sol Sherr, (New York: Academic Press, Inc., 1988), p. 94.

2) Arnaut, pp. 95-96.

3) F.M. Mims, — "A few quick pointers", in Computers and Electronics, May, pp. 64-117, quoted in Arnaut, p. 104.

4) Arnaut, p. 104.

5) Arnaut, p. 101.

6) Arnaut, p. 101.

7) R.N. Parrish, et. al., — Development of design guidelines and criteria for user/operator transactions with battlefield automated systems. (Synectics Corp., U.S. Army Research Institute for the Behavioral and Social Sciences), quoted in Arnaut, p. 101.

8) Arnaut, p.98.

9) Richard D. Peacocke et. al., — "An Introduction to Speech and Speaker Recognition", in COMPUTER, September 1990, pp. 26-33.

10) Thomas E. Davies et. al., — "Digitizers and Input Tablets", in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), p. 209.

11) D.V. McCaughan et. al., — "Applications of CCDs to Imaging", in Charge-Coupled Device Systems, ed. M.J. Howes and D.V. Morgan, (Chichester: John Wiley and Sons, 1979), pp. 241-295.

12) McCaughan, pp.247-251.

13) McCaughan, pp. 251-252.

14) Davies, p. 210.

15) Joel S. Greenstein and William H. Muto — "Keyboards", from Input Devices, pp.166-169.

16) Input Devices, p. 123

17) Thomas E. Davies et. al. Digitizers and Input Tablets", from Input Devices, p. 191.

18) Arnaut, p. 92.

19) Peacocke, p. 32.

20) Joseph M. Ballay, "An Experimental View of the Design Process", in System Design: Behavioral Perspectives on Designers, Tools, and Organizations, ed. W.B. Rouse and K.R. Boff, (Elsevier Science Publishing Co., Inc., 1987), pp. 28-29.

21) Philip Robinson "The Emergence of Smart CAD Software", in Computer Graphics World, July 1990, pp.55-58.

22) Ballay, p. 43.

23) Tom McMillan, "3D Digitizing", in Computer Graphics World, January 1989, p.47.

24) McMillan, . 47-49.

25) Davies, p. 211.

26) McMillan, pp. 47-50.

27) Davies et. al., p. 191

28) Ernest R. Tello, "Between Man and Machine", in Byte Magazine, September 1988, pp. 288-293.

29) Tom Kiely, "Data Superhighways", in Computer Graphics World, December 1989, pp. 40-48.

Chapter 4

Design Solution

After exploration of a number of technological and conceptual alternatives, a solution to this design problem was reached. This solution was selected because it satisfied the design criteria and, I believe, appropriate to the task of design. Technologies were selected because they were able to satisfy the task requirements, and were compatable with the other technological demands.

4.1 System Configuration

The configuration of the system was resolved using an existing tool as an example. The notebook, a companion to many designers, is a tool for the storage of information, written down or sketched, and as a media for doing conceptual explorations upon. The immediacy, the portability, the suitability of the form, and the ease of use of the notebook are all charateristics to be admired. The system is configured to reflect the qualities of a notebook, with the value-added benefits of the computer.

The concept of the computer as a form of notebook is not new. In the late 1960s, Alan Kay developed the concept of the "Dynabook", a notebook computer created around his vision of the computer as a form of "super-medium". The Dynabook was to be a notebook computer with a million-pixel screen, eight processors, and both wireless and cabled networking. [1] The system I envision is quite similar to the "Dynabook", as a tool capable of aiding great variety of tasks.

The system is organized so that each component is separate and distinct, while remaining within the confines of the case. The components are tied together formally by the perimeter of the case, where most connect with the system. Further, the form of the perimeter (the arc) was used to guide aesthetic treatments of the components. Figures 17, 18, and 19 demonstrate the system's organization.

4.2 Case Dimensions

The specifications of the case are somewhat difficult to determine. As much of what typically determines case size (cpu size, memory requirements, battery size, and so on) are future technologies, estimating the volumes they will require is not a simple task. Rather than guess these values, the parameters which can be identified are used, with provision for the other technologies by estimation.

There are three dimensions which are of importance in the determination of the case size -- screen size, keyboard size, and suitable thickness of the system.

4.2.1 Screen Size

The determination of the size of the screen is not a simple issue, especially when discussing it in terms of a drawing surface. The ways in which designers prefer to sketch and draw are as varied as the number of designers. Some prefer to do small thumbnail sketches on the back of napkins, while others prefer to work on wall-sized sheets of kraft paper, producing images several meters in dimension. In order to resolve this issue, a rationale must be developed to select an appropriate size. In this case, there are three factors that will aid in this process.

4.2.1.1 Portability

Portability is to be considered a given condition, therefore the size of the screen must be small enough that it can be included in a system that would be defined as being portable. It should be said that portability is not simply an ability to carry the system with you; if that were the definition, a Sun SparcStation would be considered portable. Portable in this case refers to the object's being easily carried, such that the decision to bring the system along is not a difficult one.

4.2.1.2 Functional Ability

While portability argues for having a screen of the smallest possible dimension, functionality argues for the largest possible dimension. As the size of the screen increases, so do the possibilities for use. The tradeoff in screen size is primarily between portability and functionality.

4.2.1.3 Precedence

Precedence is the argument used to settle the conflict between portability and functionality. A rational approach, precedence was sought for both issues, the goal being to find two precedence sources that were compatible. There were found two sources; existing paper sizes and the size of a standard briefcase. The paper size addresses the functional issue by providing a format in a familiar dimension to designers, while the briefcase dimensions give precedence to the portability issue.

Fortunately, there is a correlation between a standard paper size (A3) and briefcase dimensions. The briefcase dimensions are referring to overall dimensions of the case, while the paper dimensions refer specifically to the screen size. If the decision is to maintain screen size as the full size of A3 paper, then the overall dimensions of the computer will be greater, with the need for some amount of material around the perimeter of the screen.

If the overall dimension is to refer to the size of the case, then the screen itself must be somewhat smaller than A3 paper. Since portability is a key issue, the case should not exceed the A3 size, and so the screen will exist within those dimensions. The final dimension of the screen will then be dependant upon the function of the perimeter of the case.

4.2.2 Keyboard Size

Maintaining a full-size keyboard within the system is important in the need to provide for extended textual input. Keyboard dimensions, if to remain full-size, require a dimension of 287.5 mm in its width.[2] This provides enough room for full size keys to be placed 19 mm apart in the standard QWERTY configuration. As the keyboard is placed along the shorter of the two dimensions, the width of the case must be increased to 312.5 mm to house the keyboard comfortably.

4.2.3 System Thickness

The thickness of the system depended primarily on three factors: a comfortable thickness for carrying the case; a reasonable thickness such that the screen may be comfortably sketched upon; and provision for enough volume to allow for the inclusion of the various known hardware requirements (keyboard, digitizer, projector), and those unknown (memory, etc.). This thickness was determined to be 25mm, based on guidelines for cylindrical grip sizes.[3]

4.2.4 Form

The form of the case was taken from the convention of paper, a rectilinear form, and technological constraints placed upon the system screen. The continuity of form between paper and the system provides a connection between the old and new technologies, and allows the user to approach the new technology in a more familiar manner.

System Front

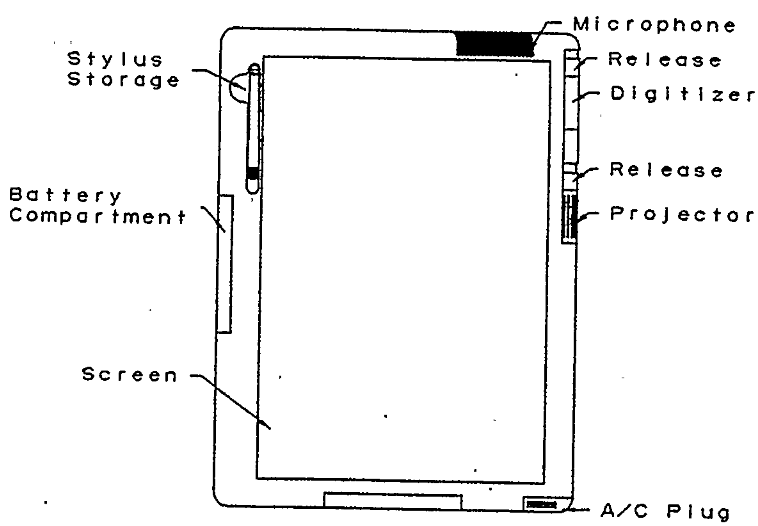


Figure 17

System Front with Keyboard

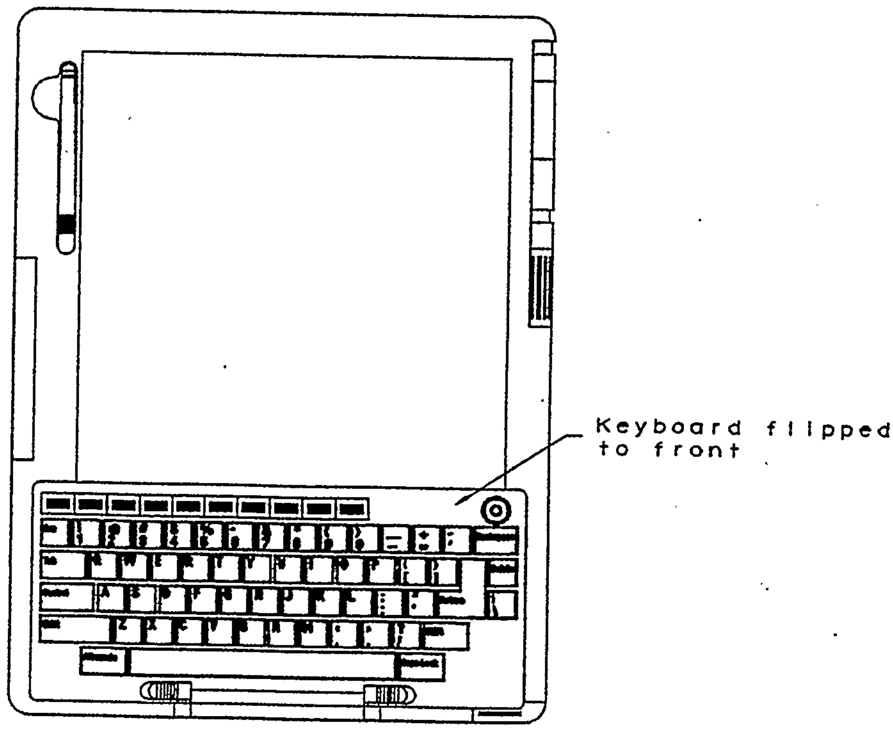


Figure 18

System Back

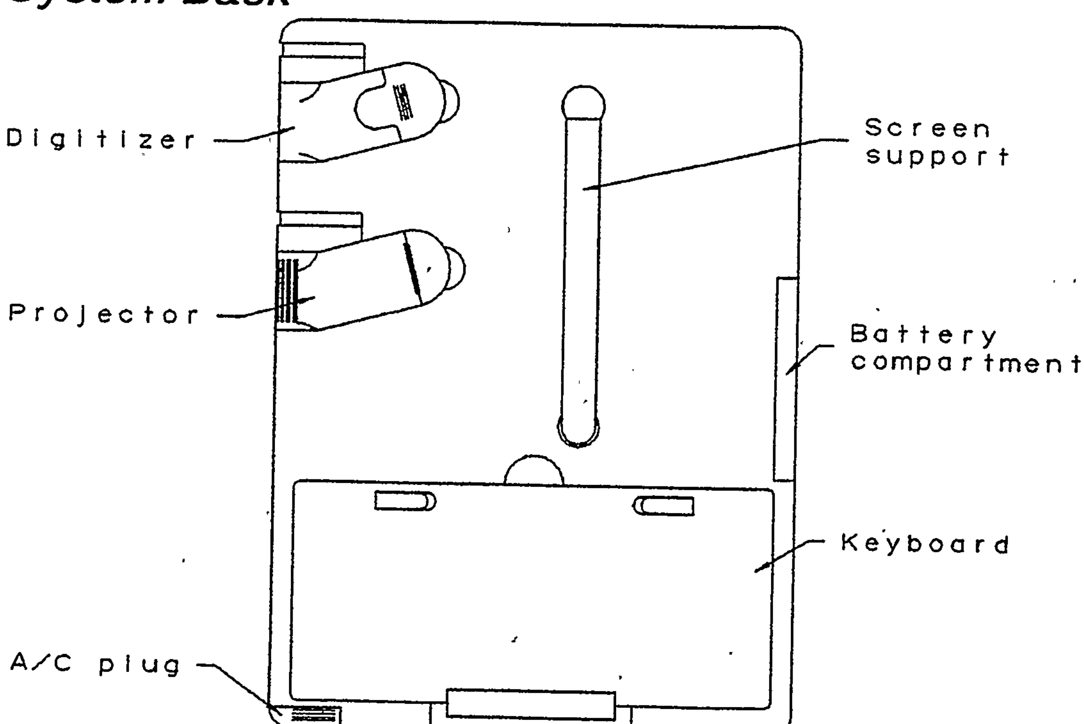


Figure 19

4.3 The Screen

The four key concerns are that the screen be relatively large, that it be flat with a very narrow profile, a low consumer of power, and that it be in colour. The technology that is felt to best suit these criteria is that of Field Emission Displays, or FEDs. This technology is capable of creating a screen of virtually any size, is only 2.3 mm in thickness, is a low power consumer, and is capable of displaying approximately 16 million colours at three times the brightness of LCDs.[4]

4.4 The Stylus

The stylus is fairly straightforward; being configured as an erasable pen, with the writing tip at one end and an eraser at the other, and is not physically connected to the system. The form is that of a typical pen, and of similar dimensions. The stylus is stored along one edge of the system, within a recess accessible from the system face.

The stylus is retained within the recess by detentes, and may be removed by grasping it at the access hollow. The stylus is in full view of the user, rather than being hidden within the system. Storage of the stylus involves the inverse of this operation.

Stylus Profile

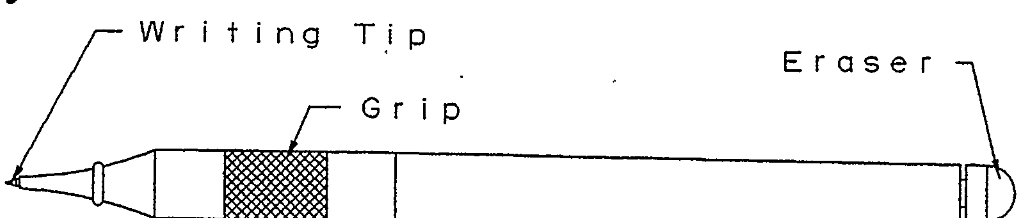


Figure 20

Stylus Storage

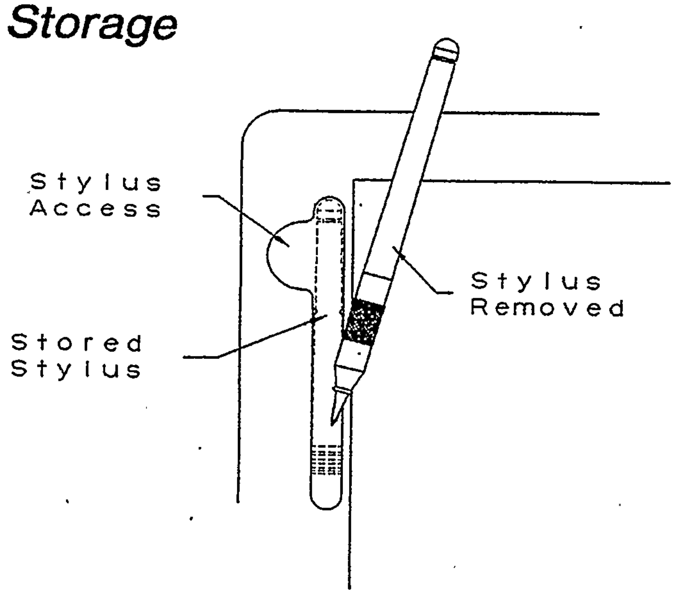


Figure 21

4.5 The Digitizer

The first concern was that the digitizer needed to be reasonably high above the work surface in order that a minimum of distortion could be achieved. This brought forth the concept of using the system itself as the stand. The desire to have the screen inclined at 15 degrees from the vertical while performing this task necessitated a bend at the digitizer handle of the same 15 degrees. This situates the digitizer parallel to the work surface.

Digitizer

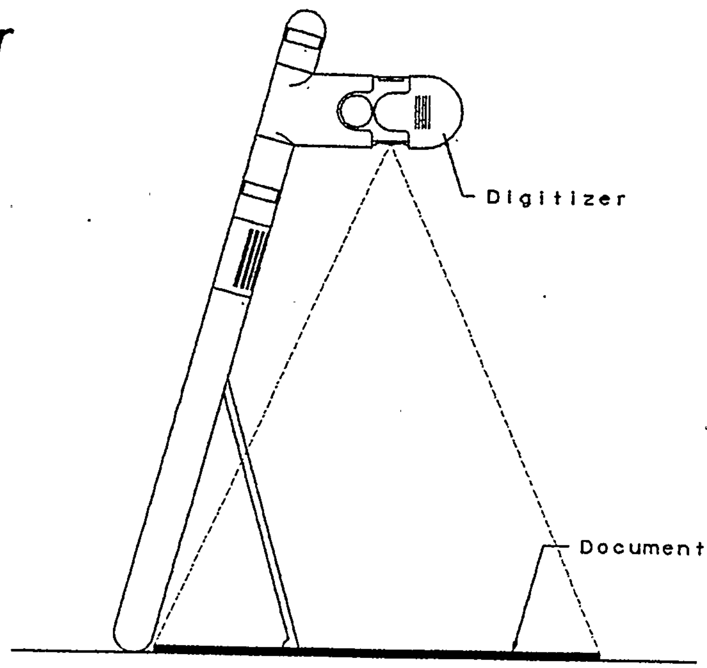


Figure 22

The digitizer is normally stored in the system, and may be swung out for scanning, grasping the end of the digitizer at the access hollow. The digitizer then locks in place via a detente in the pivot, which again is concentric with the system edge. The digitizer may be removed completely by pressing the pivot release. This mechanism is shown in figure 23.

Digitizer Storage

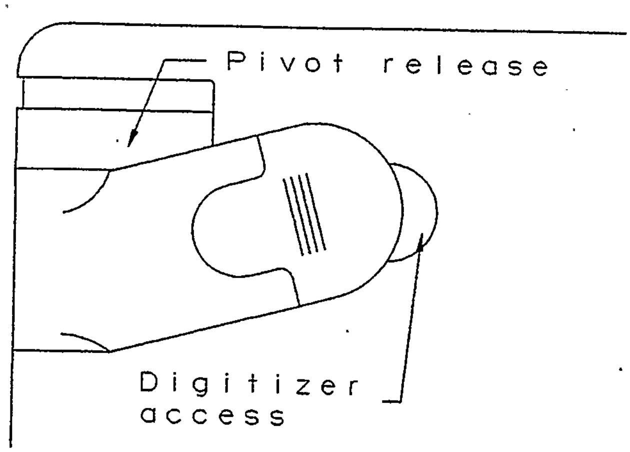


Figure 23

Digitizer - Open

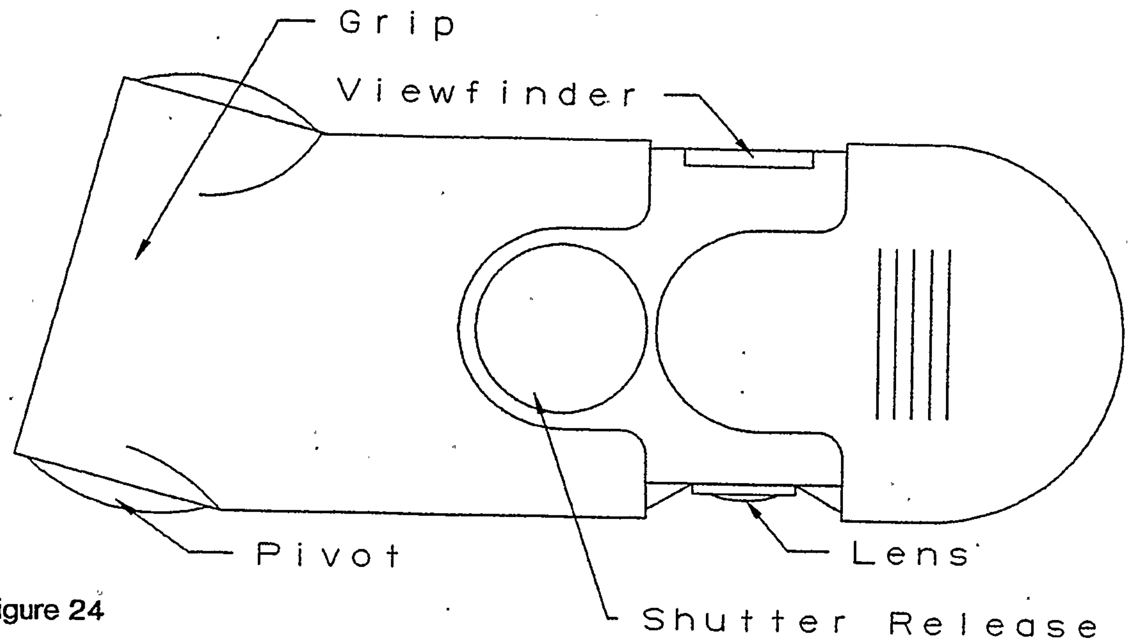


Figure 24

Digitizer - Closed

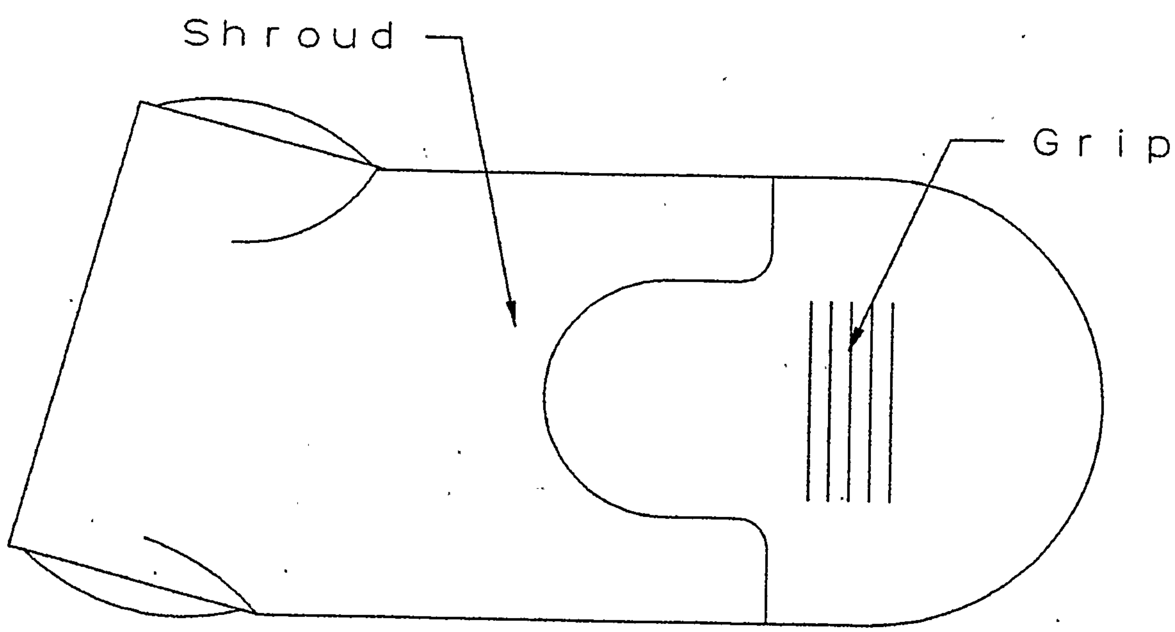


Figure 25

4.6 The Projector

As in the case of the digitizer, it was desirable to have the projector elevated with the system screen remaining at 15 degrees from vertical. The difference is that the projector is oriented horizontally, rather than vertically as in the digitizer. An external power supply is required to power the light source, and so a removable wall plug is supplied to plug the system in. Power to the projector is supplied through the system.

System Front

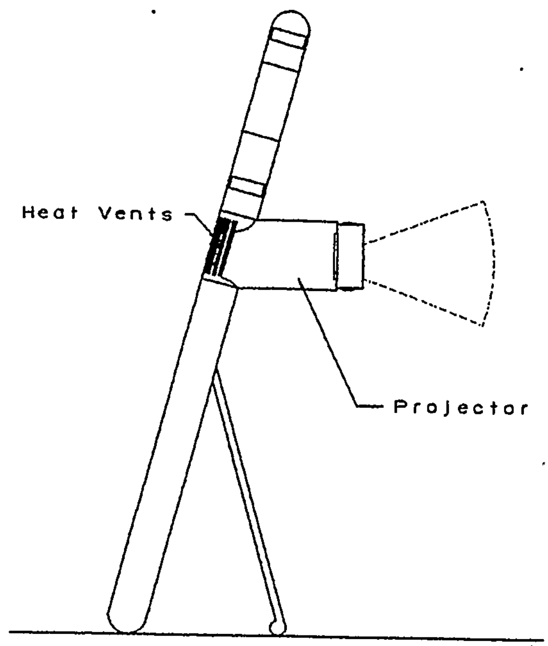


Figure 26

As figure 27 demonstrates, the projector may be configured in two alternative setups; inverted to project over the presenter's shoulder, and independent of the system. The mechanism for bringing the projector into the operating position is identical to that of the digitizer, except that the power supply is plugged directly into the projector when removed, rather than into the system.

Alternative Projector Arrangements

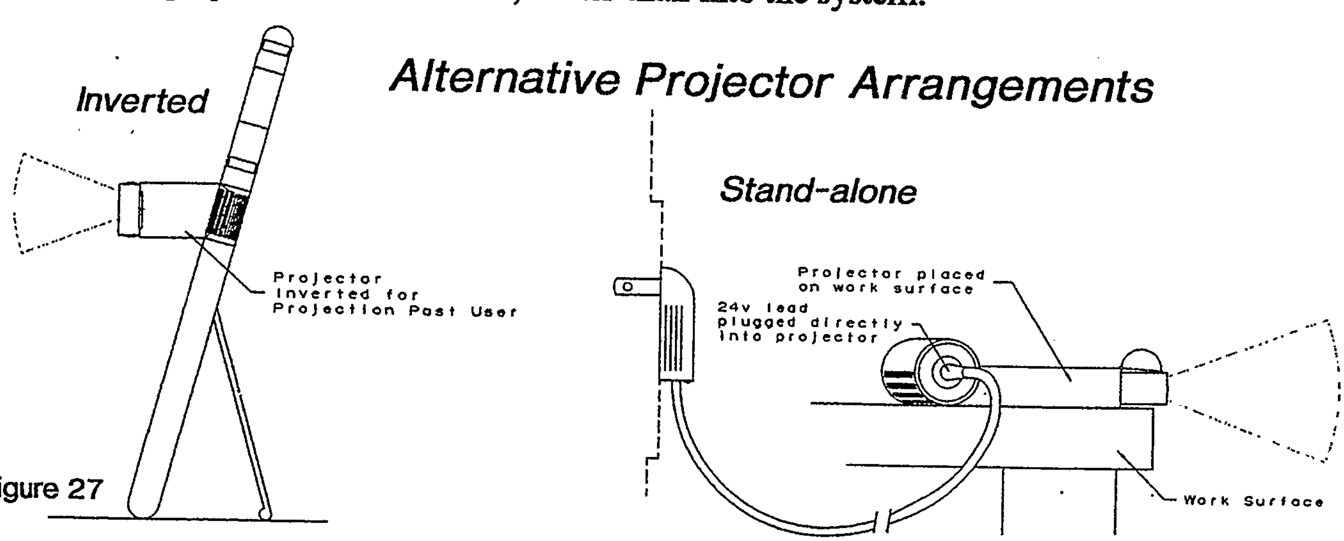


Figure 27

4.7 Keyboard

The keyboard itself stores in the back of the system, being able to swing around and position itself on the screen surface. The keyboard is held in place at the system front by magnets installed in both the keyboard and the case. The keyboard partially obscures the screen, which will, through software, adjust its visual dimensions to that which is not covered. The keyboard may be removed, set on its stands, with the screen set up on a stand as well.

Keyboard Pivot Action

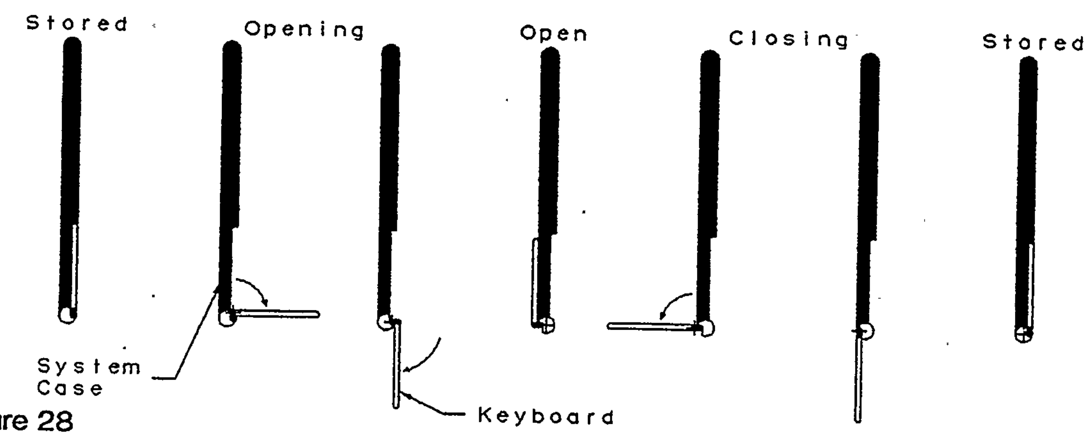


Figure 28

In the upper right hand corner of the keyboard is a joystick base, into which the stylus may be inserted. This provides the user with a pointing device (joystick) while using the keyboard, in place of the stylus alone.

4.8 Voice

In order to make provision for voice input, the system requires some form of microphone within it. This device is located at the side of the work surface. The way in which the voice input is dealt with will be the responsibility of voice-recognition software, and as such is not within the scope of this project. This system will provide the necessary hardware for this technology.

Microphone

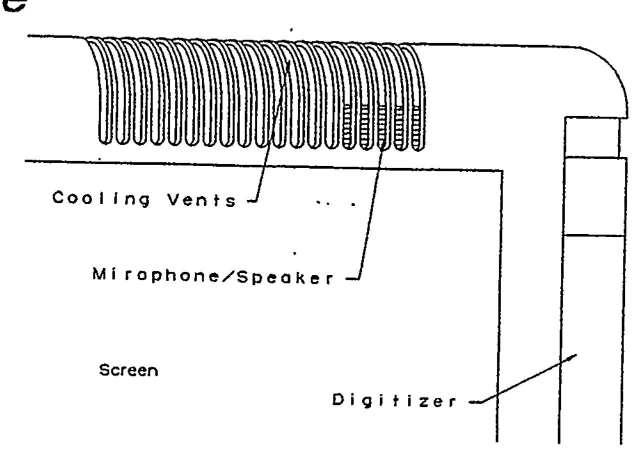


Figure 29

4.9 The Stand

It was first necessary that the screen be able to stand in order that the digitizer and projector may be used; secondly that the system be set up with the keyboard independent of the screen. Finally, it was felt that it would be desirable to allow the screen to be set up in either landscape or portrait configurations, to allow for different image formats. The solution which follows is capable of fulfilling these criteria.

The stand is first released from the back, then swung around to the appropriate position for either the portrait or landscape position. The stand is held in place firmly by detentes, and is adjustable such that the screen will stand from 10 to 35 degrees to the vertical.

Stand - Stored

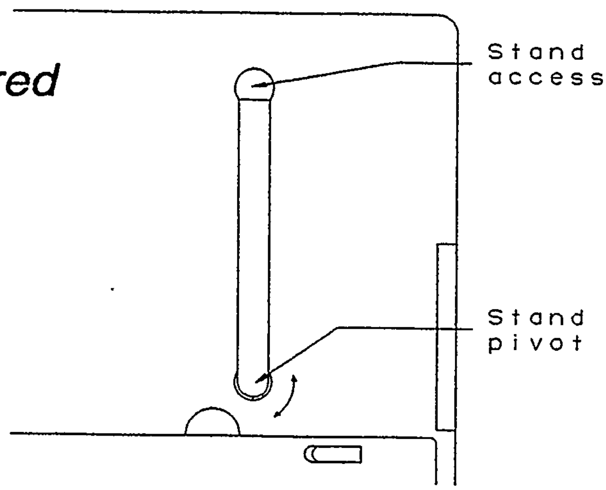


Figure 30

Stand - Profiles

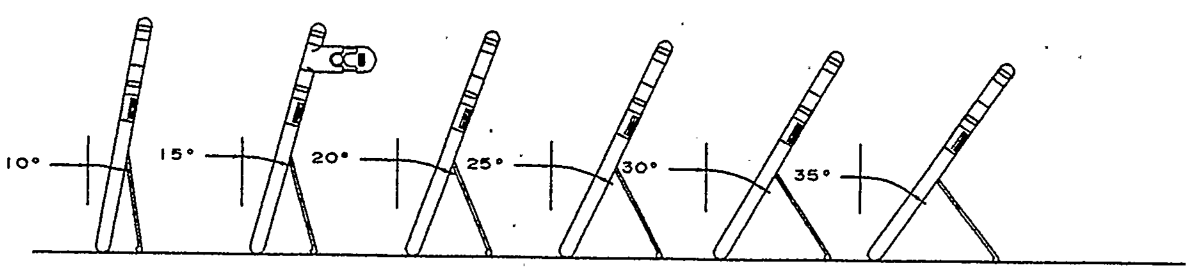


Figure 31

4.10 Power

As stated earlier, power to the projector is supplied via a wall plug. This power source is also used for the recharging of the system. The system will operate on battery power much of the time. The selection of the battery technology will not be made here, as the power requirements and future technologies are unknown.

The battery will be removable, to allow for exchange. This takes into account the possibility that the battery may fail, needing replacement, or the user's carrying more than one charged battery.

Power Input

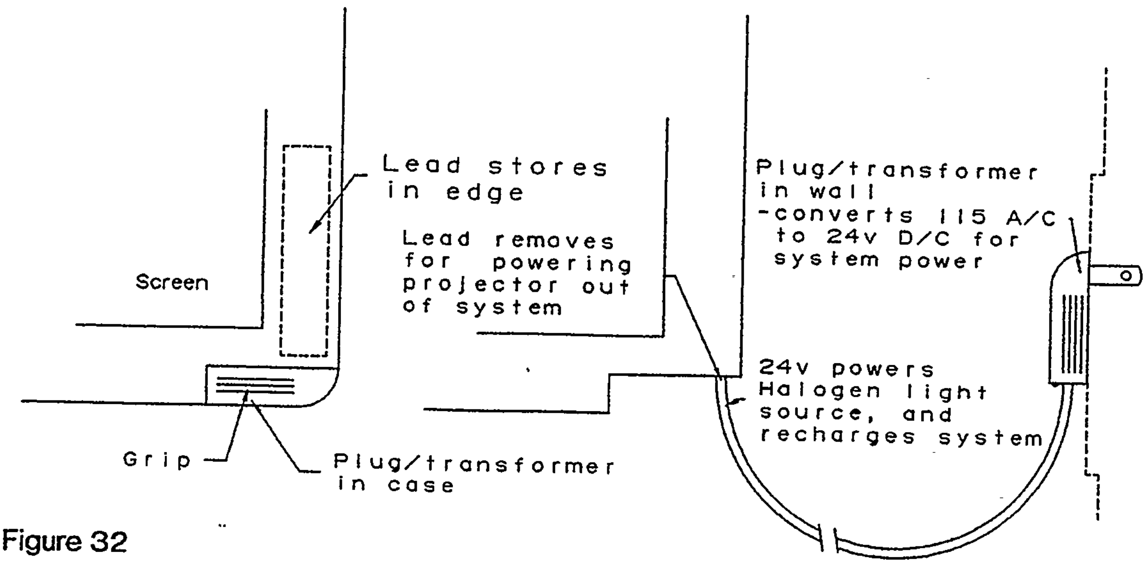


Figure 32

4.11 Memory

Memory technology is moving forward by leaps and bounds, and so estimating what capabilities will be available in the near future is difficult. However, this system will likely be a significant consumer of memory, given the nature and volume of the information being stored. Memory will be required in the system proper, the projector, and the digitizer.

A requirement of some form of physical media by which data may be stored should also be addressed. Floppy disks, or the developing technology of solid state memory cards may be used for this need. The use of floppy disks is a greater power consumer than the cards, but the current state of the card technology does not allow for as great storage capacity. The selection of which technology will depend on the card technology's development.

4.12 Telecommunications

Installed within the confines of the system will be a cellular link, which will be used for connecting the system to the outside world. There will be no external antennae, rather an internal one. This link, in conjunction with the microphone used in voice input, could serve as a cellular phone for voice communication. Because of the overlapping nature of conversation, there would need to be provided a speaker to handle voice being transmitted and received simultaneously. This configuration is not ideally suited for this task, but it would be available.

4.13 Handle

There is no integral handle; rather, a handle will be provided in the system carrying case. The logic behind this is that it would only be while in transit that the system would require a handle, which would also be the only time the system needed to be protected.

4.14 System Configurations

The system may be used in a number of configurations, the principle ones which are as follows:

4.14.1 - As a note-pad, with all but the stylus stored away. The stylus would be the sole method of input.

Notepad Configuration

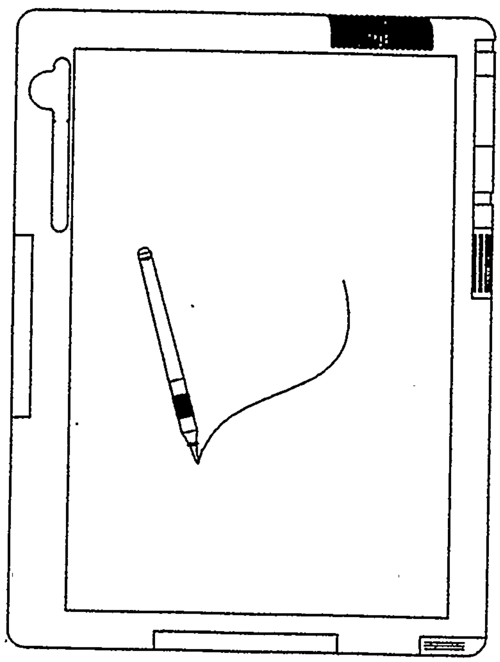


Figure 33

4.14.2 - As a note-pad with keyboard, with all but the stylus and keyboard stored away. In this configuration, the keyboard has been flipped around from the back to the front, partially covering the screen. The stylus may still be used for sketching, or it may be placed in the joystick base. This configuration most closely mimics a laptop.

Notepad/Keyboard Configuration

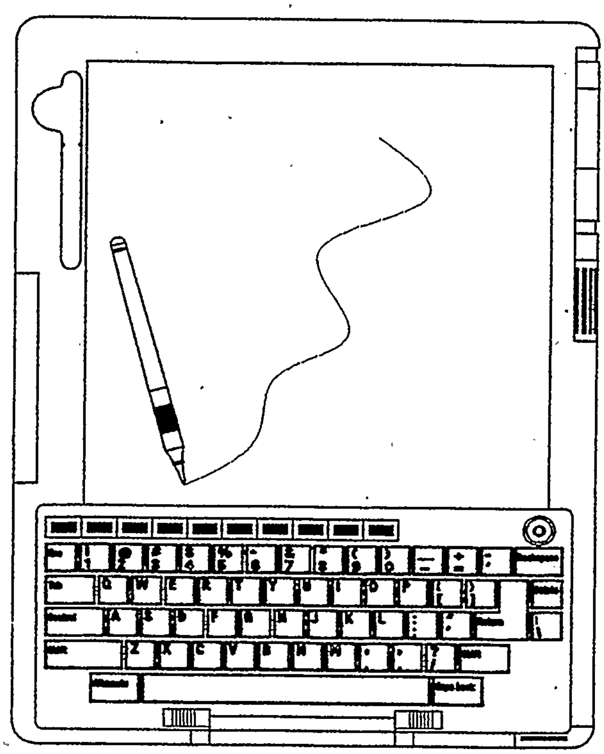


Figure 34

4.14.3 - As a conventional PC, with the keyboard set up separately from the system, the screen standing in either landscape or portrait position, and the stylus placed in the joystick base. This configuration is like that of conventional systems, placed on a desktop.

Desktop Configuration

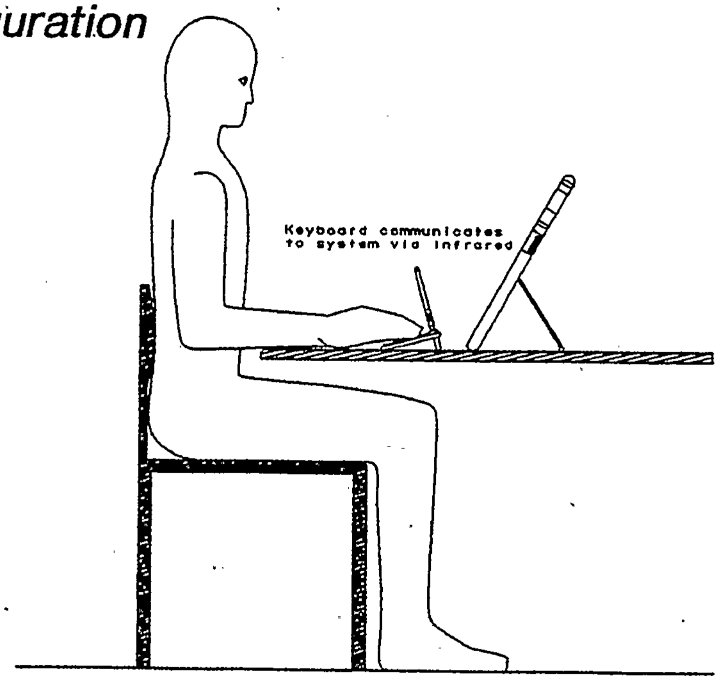


Figure 35

4.14.4 - As an image digitizer, in one of two ways:

4.14.4.1 - As a scanner, with the digitizer folded out from the system, which is standing in the portrait position. The keyboard may or may not be set out from the system, dependent upon the nature of the work being performed. Scanning of documents is completed directly below the digitizer, in the manner of a copy-stand. Please refer to figure 22.

4.14.4.2 - As a digital camera, the digitizer being completely removed from the system, and used as a camera. The digitizer would operate independently from the system, and would transfer the captured images once reinstalled. Please refer to figure 24.

4.14.5 - As a three-dimensional digitizer, with the stylus being used to trace the object of interest. The object would be placed on the screen, in close proximity to the sensor. The keyboard may or may not be used, dependant upon the complexity of the task.

4.14.6 - As a projector, in one of three ways:

4.14.6.1 - With the projector folded out from the system, which is standing in the portrait position. Again, the keyboard may or may not be set out from the system, dependant upon the nature of the work being performed. The projector is facing forward, such that the screen image and the projected image both face the same direction. Please refer to figure 26.

4.14.6.2 - As above, except that the projector is placed inverted on the system, such that it projects opposite to the direction of the screen. In this case, the viewer of the screen would have the image projected over his/her shoulder. Please refer to figure 27.

4.14.6.3 - With the projector completely removed from the system, set at a location away from the system. The system would act as a remote control for the projector, using infrared signals. Please refer to figure 27.

1) Bob Ryan, "Dynabook Revisited with Alan Kay", in Byte Magazine, February 1991, pp. 203-208.

2) This value is empirical, determined from the measurement of various full-size keyboards.

3) Suzanne Rodgers et. al., Ergonomic Design for People at Work, (New York: Van Nostrand Reinhold Co., 1986), p. 255.

4) Nick Baron, "LCDs and Beyond", in Byte Magazine, February 1991, p. 234.

Chapter 5

Scenario of Use

In order that the use of this product may be demonstrated clearly, a scenario of its use will be used. For this exercise, the industrial design of a product will be demonstrated, although a similar scenario could be applied to architecture as well. The intent here is not to demonstrate how the product is used by one designer, but the ways in which it can be used to achieve the particular task goals. To that end, at each task sequence there will be a brief description of possible alternatives.

5.1 Getting the Job

To be involved in the designer process, the designer is first required to obtain work. This is done through the presentation of a portfolio, interviews, and the supplying of references. The system's responsibility is the presentation of the portfolio. The portfolio consists of drawings, CADD models, or digital images stored in the system from past work.

There are two ways in which the portfolio can be presented; on the screen itself or projected on the wall. The choice of presentation method will be dependant upon the number of viewers, the environment within which the presentation is taking place, and the preference of the designer and/or the prospective client.

For reviewing the work on the small screen, the designer could present the work as a pre-programmed show, with an ability to modify the process through simple manipulations. In order that the designer be able to select images from the portfolio easily, all of the images pertinent to the presentation would be shown at once on the screen in reduced size. The designer would then select from the displayed images the desired image, and that image would then occupy all of the screen. The designer could move from any one image to any other by moving back and forth between full and reduced images.

The process for viewing projected images would be virtually identical, except that it would not be necessary to move back-and-forth between full-size and reduced images. The projected and the screen images do not have to be the same, and so manipulation between images may be done on the system screen, allowing the projected image to remain full-size.

Manipulation of the images may be done in a number of ways. They may be selected through the use of the stylus, the joystick, or by voice. Both the stylus and the joystick would select images by pointing and selecting, while voice could select an image by name.

The projector could be left attached to the system, or it could be free-standing, using the system as a remote control. Communication between the system and the projector would be through infrared transmission. A benefit of using the projector as a free-standing item is that the designer would then be free to move, presenting from a location separate from the projector.

5.2 Information Gathering

Once the job has been acquired, the designer will collect information pertinent to the project. The first source ofinformation would be the client. The designer will likely be supplied with a variety of information, each with a number of methods by which it can be gathered and stored.

5.2.1 Documents, Databanks, and Drawings

Documents will come in two formats; as hard-copies or as computer files. The hard copies will be digitized using the digitizer camera, in either the copy-stand configuration or as a camera. The image could then either be converted to a text file using Optical Character Recognition (OCR) software, or it could be left as an image. These files can also be retrieved from facsimile transmissions.

Computer text files can be transferred from the source system to the designer's system via cellular modem. The variety of sources could be vast. Through the use of telecommunications, the designer will have access to information pools worldwide. The system would be able to search the appropriate data sources for all pertinent information.

5.2.2 Models

As with documents, models can be "photographed" or they can be transferred as computer files. Of course, file transfers are only possible if the model exists as a CADD object. In order that a physical model may be converted to a CADD model, it would be digitized using the pen-based digitizing system. The precision of the CADD model is up to the user; the precision being dependant upon the number of points on the object that the user inputs.

5.2.3 Information Distillation and Prioritization

As information is being collected, the user would place flags alongside the file which indicate the nature of the information. This allows the designer to organize and present the information easily, and in a manner which best suits the particular project. With this ability to access information, the designer is better able to organize it in terms of its impact on the criteria development.

5.3 Criteria Selection

As in the distillation and prioritization of information, the ease of manipulation of that information increases the likelihood of informed criteria selection. Information would be obtained in a number of ways. The designer could ask the system to present all of the information pertinent to a particular issue; for example, all information dealing with materials and processes could be brought up to be reviewed at once. Using that information, the designer along with the client could develop criteria concerning the way in which the product is to be manufactured. Depending on the type of information available, an expert system could be used to make recommendations about the criteria selection.

Another purpose the system could serve in this process would be in the role of "checker". The computer would be performing query tasks, such as asking if the designer had considered other related issues, and if not, would he/she like to see information concerning those issues. The designer is ultimately in control, with the system acting as a questioning helper.

Once the criteria are determined, they would then be stored along with any associated quantifiable values (e.g. - the product must fit within a pocket - 60mm x 80mm x 10mm). Also to be included within this body of information will be the individual criterion's relative importance in terms of the other established criteria. This is important when trade-offs begin to be necessary.

The designer will be able to determine the nature in which the criteria information are presented and accessed. Some designers might like to see that information presented as text, stored away to be looked at only when called upon. Others might prefer to see that information presented in more graphical ways, with perhaps a pie-chart showing the criteria and their relative importance, and to keep that information in a corner of the screen as a constant reminder of the situation.

5.4 Concept Generation

With the design criteria firmly in place, the designer is now in a position to begin conceptualizing. The ways in which designers perform such work is greatly varied, the system being designed to accommodate as many different techniques as reasonably possible. Owing to the variety of techniques, they will be discussed individually rather than as elements within a sequence.

5.4.1 Sketching

Sketching is provided for by the inclusion of a stylus and the system's ability to take its input. The designer draws directly on the screen, using the stylus in the place of a conventional drawing instrument. The designer will be able to select the type of line being drawn, the colour and media. For example, a drawing could begin as a pen and ink, and then colored and shaded using watercolors.

The designer will be able to select the drawing style in the same manner as in other manipulations; there will be an opportunity to select from a menu on screen using the stylus to select, a function key on the system can be selected which is dedicated to a particular function within the software, or the designer may use a voice command to initiate a selection. This selection can be done by any method at any time, without the designer being constrained by any one method.

5.4.2 Sketch Modelling

The ways that designers model are of great variety. Provision has been made to allow the designer to model in as many ways as is practically possible, including an ability to continue to work in traditional ways. There will be opportunity to enter the modelling process by several techniques.

The designer will be able to begin this process using traditional methods, such as using foam, wood, or clay in the creation of the models. The designer will then be able to take that model and digitize it using the stylus to trace around the model, creating a three-dimensional computer model of the form. This allows the designer to continue working in a traditional manner, while still being able to exploit the power of the computer for later development.

The designer will be able to control the level of detail produced in the computer model, simply by controlling the number of trace points on the surface of the physical model. The greater the number of points selected, the greater the level of detailing in the computer model. This benefit is balanced with the increased workload placed upon the user.

Once digitized, the computer model can be manipulated in order to increase the level of detail, or make changes to the model. The designer would also be able to make multiple copies of the model, allowing the generation of a variety of design alternatives based upon the same initial form.

The manipulations of the model are consistent with most other manipulations within the system. Manipulations can be made through keyboard, joystick, stylus, voice, or a combination of these inputs. The way in which the designer chooses to manipulate will be personal, dependant upon preference and the suitability of the device selected to the task.

The keyboard will likely not see much use in this phase, although it would be applicable where notations or specific numeric input is required. The joystick will be appropriate in conditions where the system is configured in a traditional manner, with the keyboard sitting in front of an upright screen on top of a work surface. In this instance, the joystick will replace the use of stylus as pointing device, as using a stylus in such a configuration would prove uncomfortable.

Voice as input would likely only be applicable to general requests, such as file selection, or in conjunction with a pointing device. For example, the user would point to an entity to be acted upon, using a voice command to indicate what action to take upon that entity. This enables the user to define specifically what is requested, without keyboard input or the need to select an item from a menu.

The stylus, in addition to being used in a mouse-like manner for the selection and invocation of commands and so forth, would be able to perform manipulations unlike the other devices. As both the position and attitude of the stylus are potential components of stylus input, the stylus could perform a number of tasks with respect to these three-dimensional models. These could all use the stylus as a form of proxy for the selected entities or objects. For example, a 3D CADD object could be moved and rotated in virtual space, by moving and rotating the stylus in real space. The movement of the CADD object would directly mimick the movement of the stylus.

The designer would be able to manipulate the modelling by assigning the stylus as the source of movement information, with the model mimicking the movement of the stylus. As the stylus is rotated, tilted, or moved, so too will the selected entity. This is applicable not only to models as a whole, but to the component entities as well. The designer would then be able to make changes simply by motioning the stylus in space.

The designer would also be able to generate a computer model without beginning with a physical model. For creation of a computer model from scratch, CADD software will be used to generate the form. There would be available a variety of methods with which the CADD models can be constructed, depending on the software selected. The use of primitives within a system, for example, would allow the designer to quickly build rough models, providing a set of basic "building blocks" for model construction.

One opportunity that the stylus provides would be the ability to "draw in space", using the stylus to trace the outline of an imaginary object. This would not allow for any amount of detail, but would provide a simple method of creating the basic form. The designer would be given feedback as to the point in space being digitized through the system screen. Envisioned is a three-dimensional cursor moving within a space, with x, y, and z positioning shown on the "walls" of the space.

The designer would be supplied with a variety of tools with which to manipulate the objects. There would also be provided the ability to view the objects with different textures, as different materials, and in any variety of colours.

5.4.3 Background Activity

As the concept generation phase evolves, a number of processes will be going on in the background. As the design develops, an expert system will be monitoring the information being created. This expert system will handle a variety of concerns, such as material selection, component specifications, and the suitability of the design within the criteria outline. An example might be the system's recommending a material for the design to date, or possible changes that could be made to the design in order to better satisfy the design criteria.

The system will also act as a helpful assistant, providing information to the designer as requested, or volunteering information which may be important. For example, if the designer defines a component within a product as a keyboard, the system would ask the designer if he/she would care to review information pertaining to keyboards. If the designer said yes to that question, the system would search all pertinent sources, and present the designer with a list of documents. The designer would then select the article(s) to be reviewed.

5.4.4 Review

As concepts evolve, the designer would be free to review the development of the design. This would be accomplished in one of two ways; by viewing the images one at a time on the system screen, or by projecting any number of images onto a vertical surface, using the projector described in the portfolio phase of the project. By using the projector for review, the designer will be able to view several images at once. This will provide a clear view of the concept development of the project. As in the presentation of portfolio, this information could also be presented to the client as an interim report. The techniques of moving through the presentation would be the same as well.

5.5 Detail Design

Once the concept to be developed had been decided upon, the design would then move into the detail development stage. As in the concept generation stage, the designer will have a number of tools available for the execution of this phase.

The designer would continue to have available any and all information collected to this point in the process. The availability of this information is important in the detailing of the design. The information generated during the concept generation stage; the drawings, the computer models, and design specifications will all be used in the creation of the detail drawings and models.

The ability to use previously generated information is invaluable for an efficient process. The designer will be able to convert sketches, sketch models, notes, and speech to forms which are more appropriate for detail work. Sketches and sketch models may be used as underlays, over which new drawings are created. They may also be used as the initial form which would then be edited to final form.

The designer would call up the selected file, and request that it be prepared for detailing. The system would make the appropriate conversion. Sketches could become the basis for a rendering, or a rough model could be developed into the final model.

Unlike the concept generation stage, detail refinement requires all criteria established at the outset be satisfied within the design solution. The system would aid the designer in this task, by monitoring the design detail and notifying the designer of possible breaches of design criteria.

An example of this would be the tallying of product cost based on material and components used in the design, using the current costs attained from external databases. This value would be compared with the costing criterion, and if beyond the allowed limit, the designer would be notified of the problem. If so desired, the designer could query the system for alternative design solutions to better satisfy that criterion. This technique would be applicable to all criteria.

Consistent with other areas within the design process, the designer will be free to select any input device or combination thereof which is considered to be most appropriate for the particular task.

5.6 Release Package

In creating the release package, the designer is providing the client with information which clearly communicates the product's construction, use, and physical appearance. The designer will use a number of techniques in the creation of this package. These are the same basic techniques used in other areas of the design process.

The designer will be creating rendered images, dimensioned drawings, appearance models (or prototypes), finished and rendered CADD models, and a variety of accompanying documentation.

The manner in which these items are produced is virtually identical to that of previous phases. Also, some entities previously created will likely be included in the release package.

The designer will often supply the client with a hard copy of the design package, which would require the use of an external print device. In the case of appearance models or prototypes, the designer would again be required to use an external device for their creation. Such technologies as previously mentioned would be used to create three-dimensional models from the CADD objects. These models would then be finished by hand. If so equipped, the client would also have access to the computer files themselves, importing the information into their own system.

Once the final images, models, and documentation have been assembled, the designer is now ready to prepare the final presentation. As stated earlier, the presentation can be predetermined, with the designer establishing the presentation sequence, or it can be left loose, allowing the designer to present in a less formal, improvisational manner.

Upon completion of the presentation, the designer would then field questions from the audience, using the system again to move to various images in aid of the response. Using the system as a remote, the designer would have immediate access to all images within the presentation. The designer would also be free to use the system for demonstrative work, perhaps sketching in order to get across a point.

5.7 Conclusion

As with all scenarios, complete demonstration of the ways in which a product may be used is difficult. This scenario was used to demonstrate the nature of the system's use, rather than as an inventory of all possible methods. Also, as software would be developed, the ways and available means by which a task could be executed would change over time. The way this system is to be used is not cast in stone; this system is intended as a dynamic entity, its purpose being to enable of design work, and to provide a truly portable system.

Conclusion

The goal of this project was to create a computer system which would assist the designer in the task of design. The system was to provide an environment that enabled the designer to work in a natural and intuitive manner, providing support for the various sub-tasks within the process.

Concepts were generated, from which the design solution was determined. The concepts developed were of considerable variety, each with its strengths and weaknesses. These concepts then formed the foundation for the final design solution.

This project has been successful, although there may be shortcomings. The design developed provides most of the tools required in the Ballay design process model, but may be lacking for some alternative design models[1]. By restricting the exploration to the Ballay model, task boundaries could be set. Without that restriction, the options would be endless and the project goals possibly unobtainable.

The relatively large number of component requirements placed considerable organizational demands on the system. With such a large and varied group of task needs, it was difficult to prevent the design solution from becoming a cumbersome contraption, both physically and psychologically. In reaching the solution to this project, a consequential goal became the minimizing of the contraption effect. The extent to which this goal was fully achieved is open to evaluation. However, it was a key consideration during design.

Because of the organizational requirements and human factors concerns associated with this project, funtionality was a primary concern in the design of this product. The trade-off between form and function had to side with function, an approach that I felt was the appropriate one.

The success of this design solution can only be measured by constructing a prototype and testing it with critical users. This would be the next step in the product's evolution. A suitable user interface would have to be developed, and the selected technologies refined. Through usability testing, the true success of the design could then be measured.

The future of computers is unknown and most likely it lays a long way from what has been proposed here. This product reflects my vision of how the computer may serve as a design tool, and is centered around the design process paradigm which I have come to understand. As the ways we work change and technology develops over time, that paradigm may likely cease to apply. Systems of the future will likely be created using different rules and different models, and so may not be anything like what we currently expect a computer to be.

In time, the computer as an object may dissappear completely, becoming truly a servant to the demanding master. I believe that as time has passed, the computer has been receding from our consciousness. Ultimately, I believe that the computer as tool will become invisible. As Seymour Papert states:

> ***"What I hope is that sometime, maybe 15 or 20 years - maybe 10 or 15 years is too soon - sometime we won't even talk about the computer. It will dissolve away into the environment or the world we live in."***
>
> Seymour Papert [2]

1) J. Christopher Jones, "A Method of Systematic Design", in Developments in Design Methodology, ed. Nigel Cross, (Chichester: John Wiley and Sons, 1984), pp. 9-33.

Omar Akin, "An Exploration of the Design Process", in Developments in Design Methodology, ed. Nigel Cross, (Chichester: John Wiley and Sons, 1984), pp. 189-208.

Christopher Alexander, "The State of the Art in Design Methods", in Developments in Design Methodology, ed. Nigel Cross, (Chichester: John Wiley and Sons, 1984), pp. 309-316.

Horst Rittel, "Second-generation Design Methods", in Developments in Design Methodology, ed. Nigel Cross, (Chichester: John Wiley and Sons, 1984), pp. 317-328.

2) Seymour Papert "The Byte Summit", Byte Magazine, September 1990, pp. 235-236

Appendix A
Human Factors Considerations

The human factors considerations which apply to the design of this product are both diverse and numerous. Most are physical in nature, while some apply more to the cognitive aspect of product use. In order that these considerations may be demonstrated, the system will be assessed component by component. The population subject group will include from the 2.5 percentile Japanese female to the 97.5 American male. This group was selected in order to address as broad a range of the world population as possible.

A.1 Keyboard Issues

A.1.1 Dimensions

There are four concerns when considering the design of a computer keyboard: key spacing, the nature of the keys themselves, the layout of the keyboard, and the angle at which the keyboard is placed.[1]

A.1.1.1 Key Spacing

> ***"The size and spacing of keys on general purpose alpha-numeric keyboards are largely based on design conventions rather than on empirical data."***
>
> Greenstein and Muto, 1988[2]

Typical key dimensions are 13 mm square with centre-to-centre spacings of 19 mm (Alden et al., 1972).[3] Owing to a slight restriction in available spacing, the horizontal centre-to-centre spacing was reduced to 18 mm on this keyboard. This is within reasonable limits considering the relative lack of specific dimensional requirements. A slight increase in key size to 15 mm is being used in order to offset the decrease in spacing.

A.1.1.2 Key Characteristics

The key pad used in this design is constructed of an elastomeric material. In a study by Brunner and Richardson (1984), elastomeric keyboards with and without auditory feedback were tested for user preference, along with a snap spring keyboard and linear spring keyboard. The study indicated that the elastomeric keypads performed well, and that the inclusion of a crisp auditory feedback will, in some circumstances, improve the performance and preference rating of the user.[4]

"We believe that clear and unambiguous, tactile and auditory performance feedback were primary determinants of the preference and performance data. The double-peaked force/travel function of Keyboards B and D (elastomeric keyboards) provides tactile feedback concerning multiple points, rather than just the endpoint, of each keystroke. This coupled with precise auditory feedback, was of primary importance in both final performance and ease of adjustment to each new keyboard."

Brunner et al., 1984[5]

Elastomeric keyboards are therefore an appropriate technology for this application.

A.1.2 Keyboard Layout

The keyboard layout of this product will follow the QWERTY standard. Although there are problems with this layout, the pressures of convention are so great that changing the design becomes undesirable.[6]

The QWERTY Layout

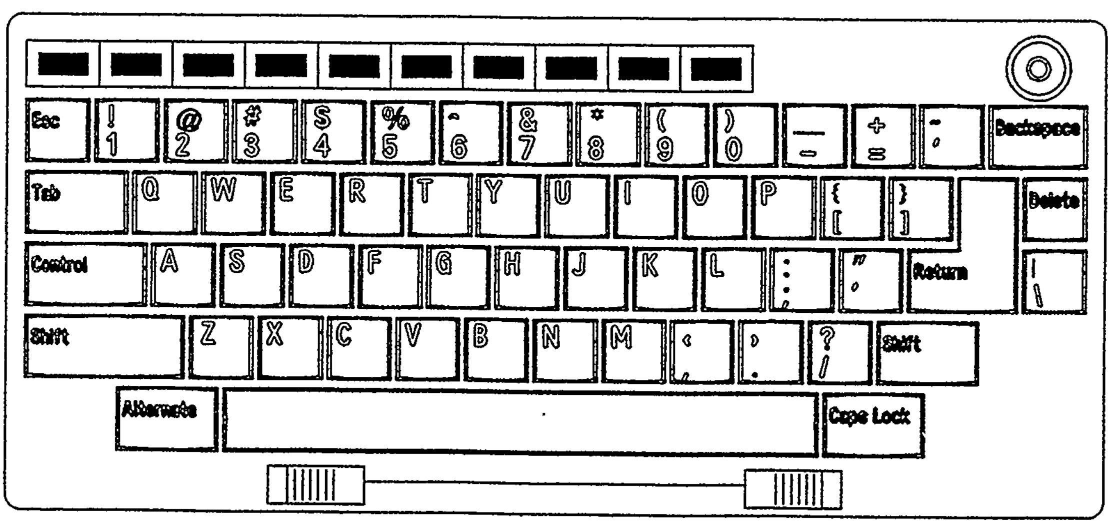


Figure 36

The QWERTY layout is not without endorsement. In a study by Kinkead (1975)[7], a series of recommendations were developed for efficient keyboard design. They state:

- the keyboard use the frequency of letter pairs to ensure that most keystrokes alternate from hand-to-hand;
- the least frequently used characters be assigned to the bottom row and to the ring and little finger;
- and that there should be a minimal occurrence of successive keystrokes from the same finger. Kinkead's analysis indicates that the QWERTY layout conforms to these constraints quite well.

There are problems with the QWERTY layout, which have provided some of the impetus for the development of alternative designs. Noyes (1983)[8] lists a series of key concerns:

- "It overloads the left hand-57% of typing is carried out by the non-preferred hand for the majority of the population.
- It overloads certain fingers. (The differential strength of fingers, however, is perhaps less an issue with today's electronic keyboards than it was with earlier manual typewriters.)
- Too little typing is carried out in the home row of keys (32%). Too much typing is (52%) is carried out on the top row. (Most critics of the QWERTY layout have assumed that home-row keying is the fastest. Kinkead (1975) noted, however, that while this may have been so on manual typewriters, top-row keying appears to be fastest for skilled typists on electric typewriters.)
- Excessive row hopping is required in frequently used sequences, often from the bottom row to the top row and down to the bottom again.
- Many common words are typed by the left hand alone.
- Forty-eight percent of all motions to reposition the fingers laterally between consecutive strokes are one-handed rather than easier two-handed motions."

As previously stated, the decision to use the QWERTY configuration is based largely on convention. Established as the standard by the American National Standards Institute in 1982, it would be difficult to move users of the QWERTY layout to convert. For that reason, the QWERTY layout will again be used.

> ***"The widespread acceptance of the QWERTY keyboard is reason enough to caution against deviation from this layout."***
>
> Greenstein et al., 1984[9]

A.1.2.1 Alternative Keypad Configurations

In order that an alternative to the QWERTY layout be provided, it will be possible to replace the elastomeric pad with another pad in the configuration of the Dvorak layout. The Dvorak layout is considered as an alternative only, and will not be discussed in this report.

A.1.3 Keyboard Height and Slope

When configured in the typical manner, the height and the slope of the keyboard becomes an important factor. Unfortunately, information regarding keyboard height and slope is inconsistent. Burke et al. (1984) determined there are not specific values for height and slope, rather there are ranges of acceptability. These ranges again are unclear, although from his data a home row height range would include values from 64 mm to 84 mm.[10] Emmons and Hirsh determined that home row heights as low as 38 mm would be acceptable.[11]

A critical problem with much of this data is the confounding interference between height and slope. In order to reduce the key height there must also be an accompanying reduction in slope. The difference from keyboard to keyboard in terms of the height-to-slope ratio is the thickness of the keyboard. Greenstein et al. (1984) recommend that the keyboard be adjustable between the angles of 5 and 15 degrees.[12]

Keyboard Height and Slope

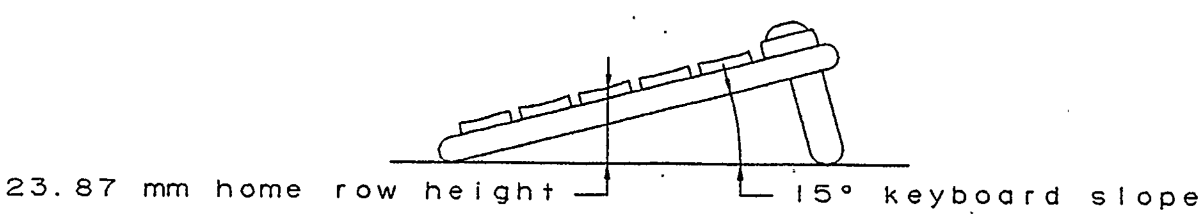


Figure 37

In 1979, the West Germany Deutsche Institut fur Normung (DIN) established specifications for keyboard height, while developing other specifications for office computer work-stations. Those specifications indicate that home row height cannot exceed 30 mm, with a slope of no greater than 15 degrees.[13] There is no clear justification for the selection of 30 mm as the height requirement. Cakir et al. (1980) state this as following:

"...every millimetre that can be spared in keeping the thickness of the keyboard to a minimum helps to reduce the postural loading on the user by ensuring the correct working level...it is desirable that the thickness of the keyboard, i.e., the distance from the base of the keyboard to the home row of keys, should not exceed about 30 mm".

Cakir et. al.[14]

Evidently, assessment of the keyboard in terms of height and slope is difficult. Owing to the restriction in terms of available space within the system, the notion of angle adjustment is not considered a reasonable possibility. Instead, an optimum slope/height was selected, using all data sources as input. The keyboard uses two fold-out supports to create a situation of a 15 degree slope and a 23.87 mm high home row. This configuration falls within acceptable dimensions.

A.2 Joystick/Stylus Combination

There are two specific human factors concerns surrounding the joystick. Placement and removal of the stylus from the joystick base must be simple, and the action of the joystick be appropriate for its intended tasks.

The receptacle for the stylus is cone-shaped, allowing the user some amount of imprecision in placing the tip of the stylus in the receptacle. The user is not required to find the specific point of contact with the joystick base, only the area which leads down to it. The need for fine motor control is lessened through this approach.

The joystick is of a constant displacement design, with a consistent ratio between the displacement of the joystick and the cursor on the screen. It is also non-centering, with the joystick being able to rest at any position in the X-Y plane. This allows the user to leave the cursor at a specific point on the screen. Because of the consistent ratio between joystick movement and the cursor movement, the mapping from one to the other is natural.[14]

Joystick Layout

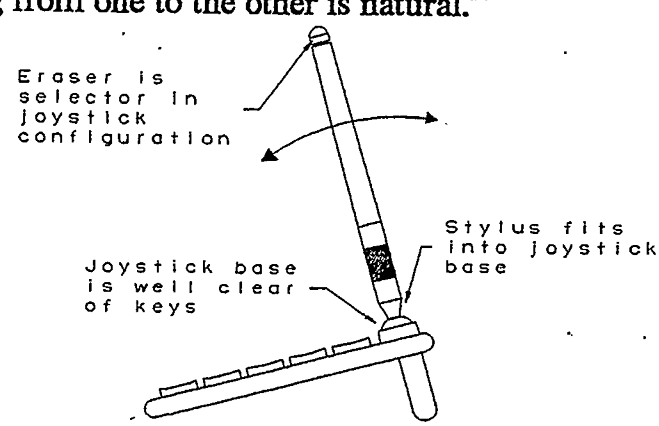


Figure 38

A.3 Product Dimensions

A.3.1 Surface Dimensions

The overall product dimensions were selected such that it would enable sketching on a reasonably large surface, it would provide enough space to contain a full-size keyboard, and would remain portable and comfortable to carry.

Issues such as a "reasonably large" work surface, or portability are difficult to quantify, and as such were difficult to determine in the course of the design of this product. For sketching, it is almost always the case that bigger is better. Unfortunately, an increase in size is offset by a decrease in portability.

As demonstrated in the discussion of the design solution, the final size of this product was determined as a function of keyboard size, and a desire that the product would remain both functional and portable. As keyboard size is a given, and what constitutes a reasonable size for a work surface is subjective, it is the issue of portability that can be addressed in terms of human factors.

Fortunately, as the system is intended to be carried under the arm in the manner a book would be carried, there is ample room for virtually any member of the adult population to carry this product. Using the sum of the lengths of the upper arm, the forearm, and the distance from the wrist to the hand grip, it is possible to determine the size of the object which can be carried in the prescribed fashion.

Using the sample 2.5 percentile japanese female as the limiting value, the defining dimension would be 239 mm (upper arm, measured from the clavicular link to the elbow) plus 208 mm (forearm, measured from the elbow to the wrist) plus 64 mm (hand grip to wrist).[15] This then adds to an overall dimension of 511 mm, well in excess of the 305 mm width of the case. This is demonstrated in figure 39.

A.3.1.1 Carrying the System

The thickness and profile radius are perhaps the primary determining factors in determining how comfortable the system will be to carry and hold. The case will be carried in one of two ways; by using a hook grip around the case edge when it is out of its carrying case (as in figure 39), or by using the same hook grip through a handle provided in the carrying case.

The physiological effects on the hand are similar in both carrying situations. Given an estimated weight of 1.8 kg of the system, and using the 2.5 percentile japanese female as the lower limit, the pressure on the carrying hand will be approximately 6.3 kPa, well within the maximum recommended skin pressure of 150 kPa.[16]

The principle difference between the two methods of carrying the device is the placement of the mass relative to the grip. In the method where the case is gripped, all of the mass is situated above the grip. This creates a situation where the load must be kept in balance continually, or the device will fall to the ground. As the device also remains uncovered in this grip, it is likely that it

Carrying Clearance

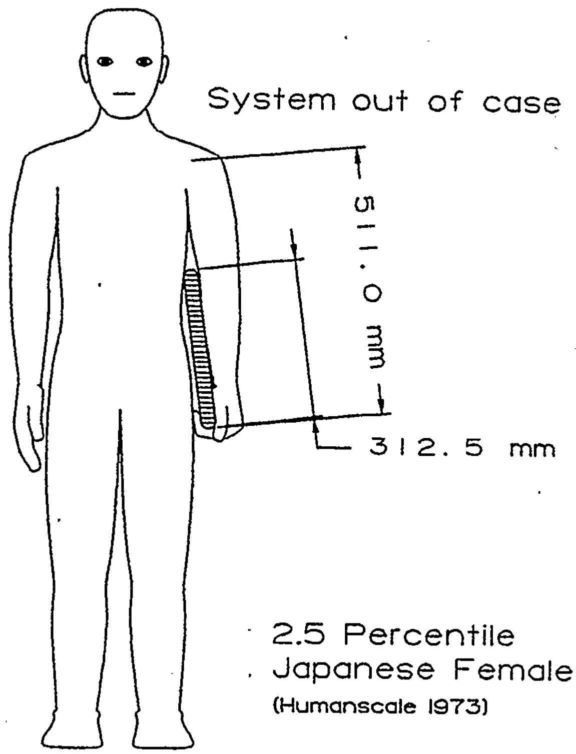


Figure 39

would only be used in situations of intermittent use.

The use of a handle moves the mass below the grip point, and as such removes any balance concerns. This enables the user to carry the device without being concerned of it dropping to the ground accidentally. Further, the placement of the handle ensures that the user will grab the case in a balanced position.

Carrying Comparison

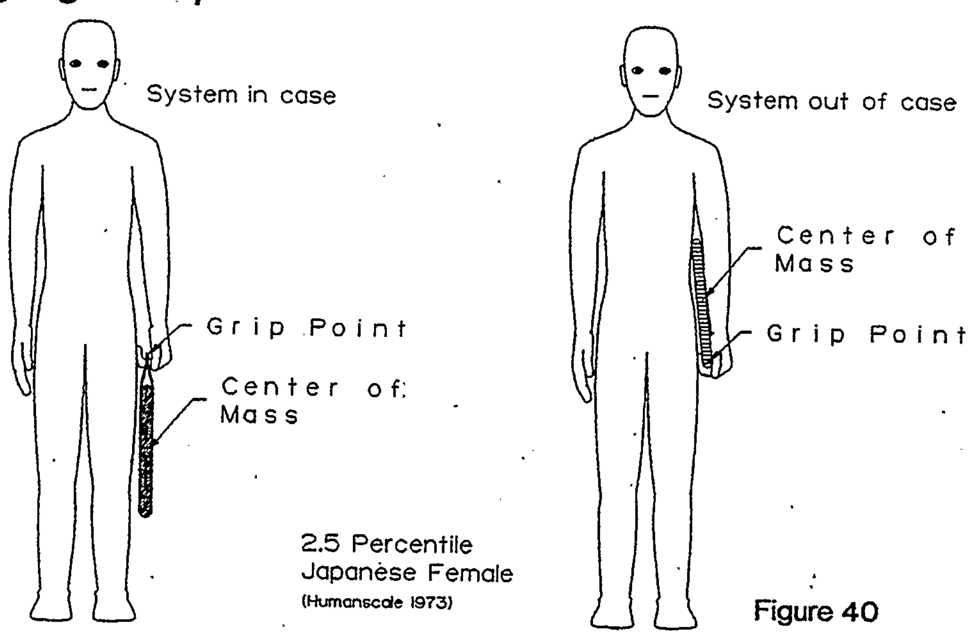


Figure 40

A.4 Layout

It is important that the user not be required to hunt for the required component, rather that the component be placed such that they are readily visible, rather than being hidden within the form of the system. As Donald Norman states:

> ***"Make things visible on the execution side of an action so that people know what is possible and how actions should be done..."***
>
> Norman 1988[17]

The general layout of the product is such that it makes evident all of the components within the system. The camera/digitizer, the projector, the keyboard, the stand, and the stylus are all readily accessible and openly presented in the case.

System Layout - Back

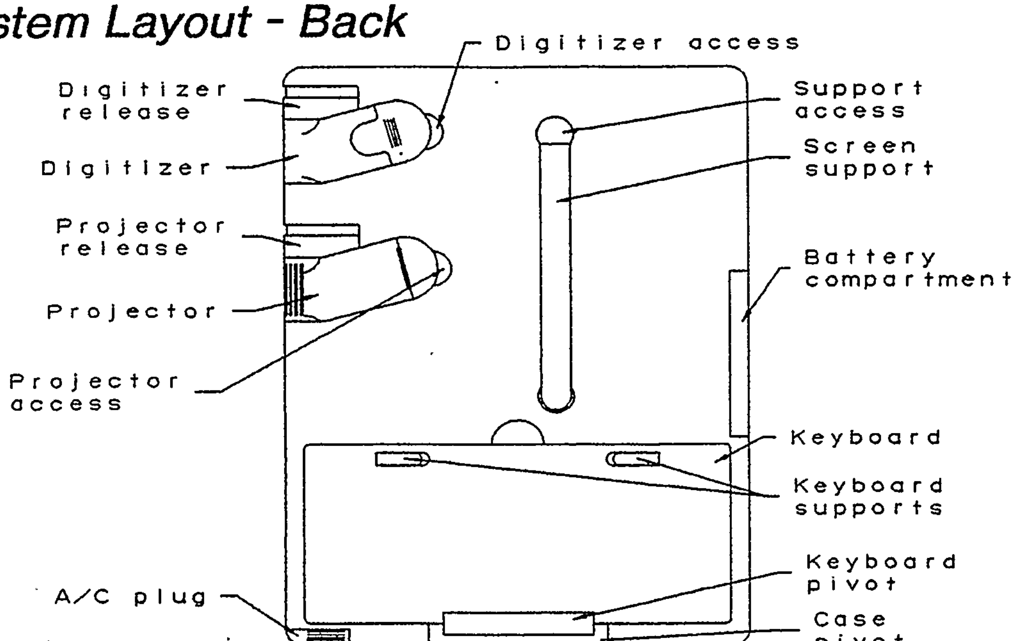


Figure 41

A.5 Component Releases

The three key issues concerning the component release mechanisms are that they be easily identified, that their operation be clear and straightforward, and that there be a consistency in the operation of all release mechanisms.

Identification of component releases is accomplished by colour coding. The use of colour greatly improves the user's ability to identify and locate the release mechanisms. In discussing this issue, R.E. Christ states:

> ***"When tasks which involved searching were reviewed, colour was superior in all cases."***
>
> Christ, 1975[18]

All releases have been identified through the application of a bright green colour. This colour was selected for three reasons;that it is becoming a standard colour used to identify such devices[19], it is visible, and a sense of safety is conveyed.[20]

Operation of the release mechanisms is indicated through the use of "grip bars". The grip bars indicate the direction in which the mechanisms are to be moved through their form -- at ninety degrees from their lengthwise direction. The grip bars, in addition to their communicative quality, also provide the user with a textured surface against which to push.

This technique is used for all releases found on the system. By doing this, the user is required to learn only one technique for accessing components. Further, all of the releases are spring-loaded, and so the action for both retrieving and replacing a component are the same.

A.6 Camera

A.6.1 Consistency with the Conceptual Model

Norman (1988), in discussing how users approach novel objects, states:

> ***"When we encounter a novel object, how can we tell what to do with it? Either we have dealt with something similar in the past and transfer old knowledge to the new object, or we obtain instruction."***
>
> Norman, 1988[21]

Since instruction will not always be available, it was felt preferable that the form and operation remain consistent with a familiar object, in this case a 110 mm camera. The consistency in operation and form between this new object and that of the familiar 110 will go a long way in aiding the user's understanding of its operation.

A.6.2 Left and Right Handedness

The issue of left and right handedness in cameras has been largely ignored. Although the left-handed component of the population lies somewhere only between 8 to 10 per cent[22], it is still important that this component of the population be considered. To that end, the camera has been designed such that it is symmetrical through its body, with the handle sitting slightly off centre.

The symmetry of the camera body allows the camera to be used equally well in either of the left or right hand. The asymmetry of the handle, although it does alter slightly the grip from left to right, remains comfortable in both hands.

A.6.3 Handle

The handle is at 15 degrees to the camera body, which approximates the angle of the grip through the hand. Diffrient et. al. defines that angle as being 12 degrees, within a reasonable measure from the handle value.[23] Figure 42 demonstrates how the camera is to be held, viewed from the bottom. This is a version of the precision grip.[24]

The handle diameter is obtained from the perimeter of the system, that being 25 mm. This diameter is not particularly critical, as it is not so much a handle as it is simply the terminus of the camera in the hand. The diameter of the handle reduces the potential of placing pressure on the fleshy area of the palm.

Digitizer Hand Grip

50th Percentile U.S. Adult
-digitizer held in right hand

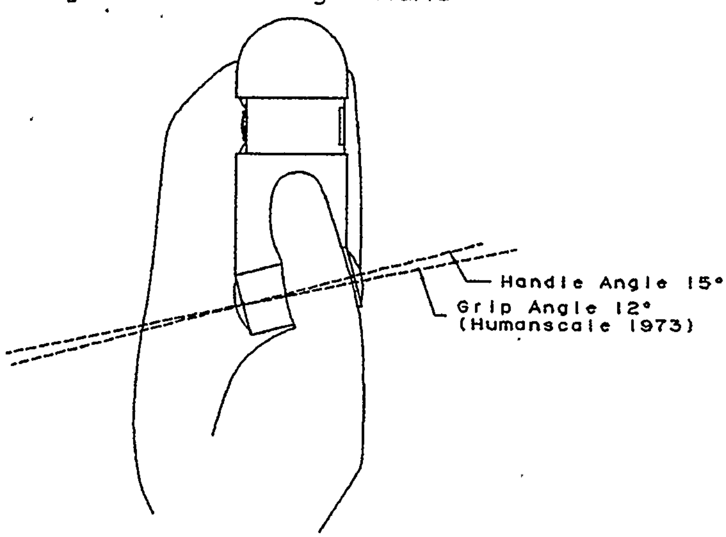


Figure 42

A.6.4 Shutter Release

The shutter release is designed such that it is available only when the camera has been opened up for taking images. This eliminates the possibility of accidental triggering of the camera mechanism when in transit, or otherwise not being used for taking images.

With the camera opened, the shutter release is located approximately 60 mm from the outer grip edge, and is 20 mm in diameter. These dimensions allow a variety of users to activate the release easily, using either the thumb or index finger for activation (depending upon left or right-handedness). Further, the relatively large size of the shutter release will enable a large segment of the population to activate the camera.[25]

A.7 Projector

The projector itself has very few considerations in terms of human factors concerns. The issues which are important deal with the communication of how the projector is opened, and of its potential hazard. The front of the projector has a protective cover, which opens to expose the lens and to allow it to focus. As with other release mechanisms, coloring, grip bars, and arrows are used to indicate its movement.

One side effect of using the projector is that there will be production of a considerable amount of heat. Although there is an effort to reduce the heat contained by the unit, it is likely that this device will produce enough heat as to become a hazard. In order that the risk of burns be reduced, a warning icon is placed on the projector at the area of heat.

A.8 Stylus

As the prime task of the stylus is to perform as a sketching tool, it is important that the form of the stylus be consistent with that type of operation. Also considered important was that the stylus designed be consistent with other writing instruments, in order that there be a continuity between the new device and traditional tools.

Stylus Dimensions

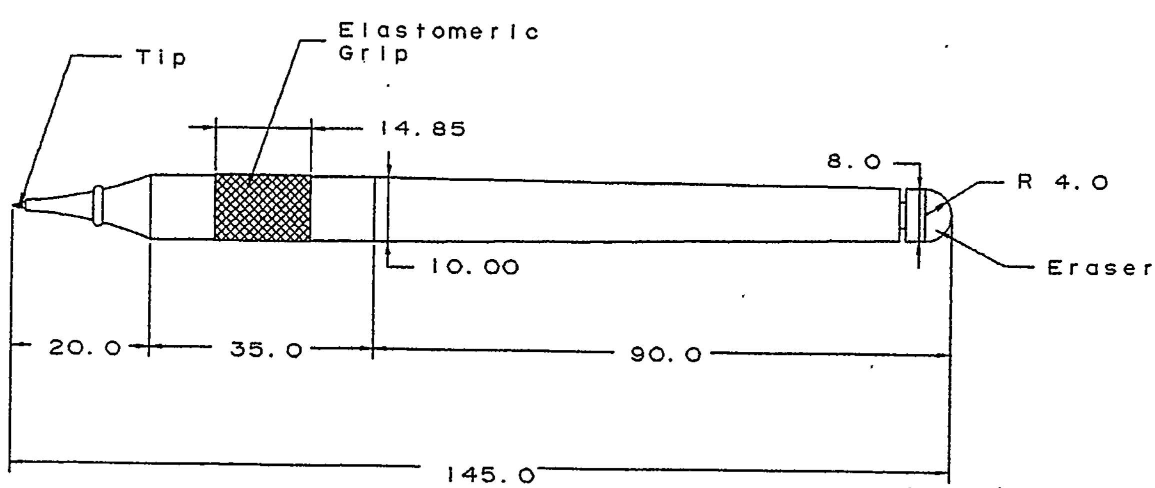


Figure 43

The form of the stylus is similar to that of a standard writing pen. It is slightly tapered from the eraser end to a maximum width of 10 mm, at a distance of 50 mm from the writing end. The stylus then retains that diameter of 10 mm, until it again tapers sharply 15 mm from the writing end down to the writing tip. The overall length of the stylus is 140 mm.

There is strong continuity with the stylus's form and method of operation, and traditional drawing instruments. Mapping between the stylus and its output is consistent with the expected outcome, using traditional methods as a guide. For both the creation ofimages and their erasure, the application of the stylus appears well-suited to the task.[26]

The stylus is intended to be held in a precision grip, held through the palm and controlled by the thumb, index finger and middle finger. The diameter of 10 mm is appropriate for such a grip configuration.[27]

The important consideration in the length of the stylus is that it must be long enough that it not terminate in the hand, rather that it extend past the edge of the hand. This requires that, given the size of the 97.5 percentile male hand, the length would need to be a minimum of 110 mm.[28] In order to allow for differences in holding techniques and the inclusion of an "eraser", it is felt that the length of 145 mm is appropriate.

A.8.1 Tip Switch

The tip switch of this stylus uses depression activation for invocation.

> ***"The tip switch provides positive tactile feedback; its pressure characteristic is contoured through pre-activation and post-activation travel. This actuation characteristic allows a user to generate very positively a tip switch signal as desired while moving the stylus around the digitizer surface."***
>
> Davies et al. 1988[29]

Both the writing tip and the eraser use this type of switch.

Stylus Switch Mechanisms

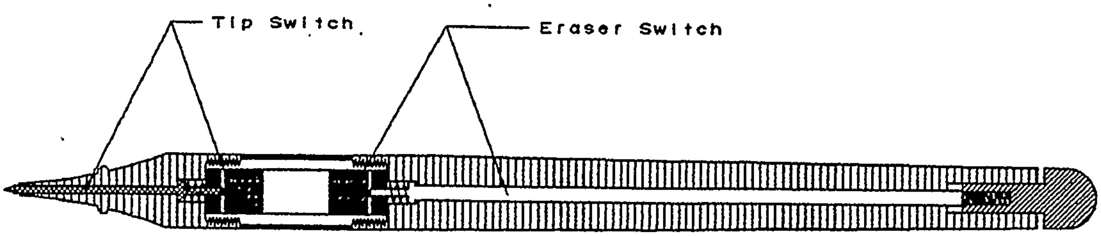


Figure 44

A.8.2 Storage

The method of storage and retrieval are readily apparent to the user. The storage recess, along with the access hollow, clearly indicate how the stylus is to be maintained. By storing the stylus in this manner, it is readily found and retrieved.

The stylus may also be stored in the joystick receptacle when the keyboard is brought to the front. This provides the user a place to set aside the stylus while typing, a joystick, and presents the stylus to the user for easy retrieval.

A.9 Screen Stand

The stand is a relatively straightforward device. The important issue here is that the user must be given clear feedback as to the positioning of the stand. This is achieved by the inclusion of distinct detente positions, which indicate clearly through tactile feedback to the user that the stand is solidly in place.

The screen is adjustable between 10 and 35 degrees, in 5 degree increments. Adjustment of the stand allows the user to set up the screen such that its plane is at 90 degrees to the user's normal sight line, and to minimize the effects of glare from the work environment.[30] These issues are potentially at odds with one-another; it may not be possible to adjust the screen such that it is at 90 degrees to the normal sight line and without any glare from external light sources.

Of the available angle settings, there is one of particular importance; that being the 15 degree setting for scanning and projecting. It is important that the user be able to easily determine that angle when setting up the system for these two operations. This has been achieved through the use of a colored triangular area along the side of the stand at the pivot point of the stand. This form indicates to the user the 15 degree mark by setting up the proximal edge of the form parallel to the case back.

Stand Settings

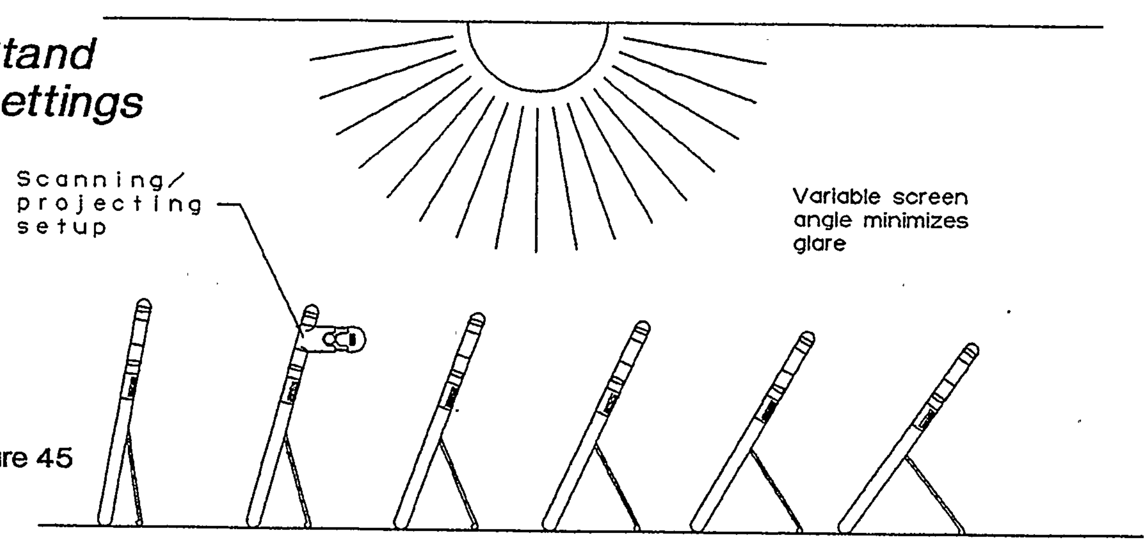


Figure 45

A.10 Screen

There are three human factors issues regarding the screen; the screen angle when supported by the stand, the reflective nature of the screen, and the use of colour or monochrome images.

As stated above, the screen is adjustable from 10 to 35 degrees. Glare from the screen in all conditions is minimized by the use of a nonreflective glass for the screen. This further reduces the fatiguing effects of glare from environmental light sources, and increases the opportunity to eliminate glare while maintaining a screen angle at 90 degrees to the user's line of sight.

Population vs Configurations

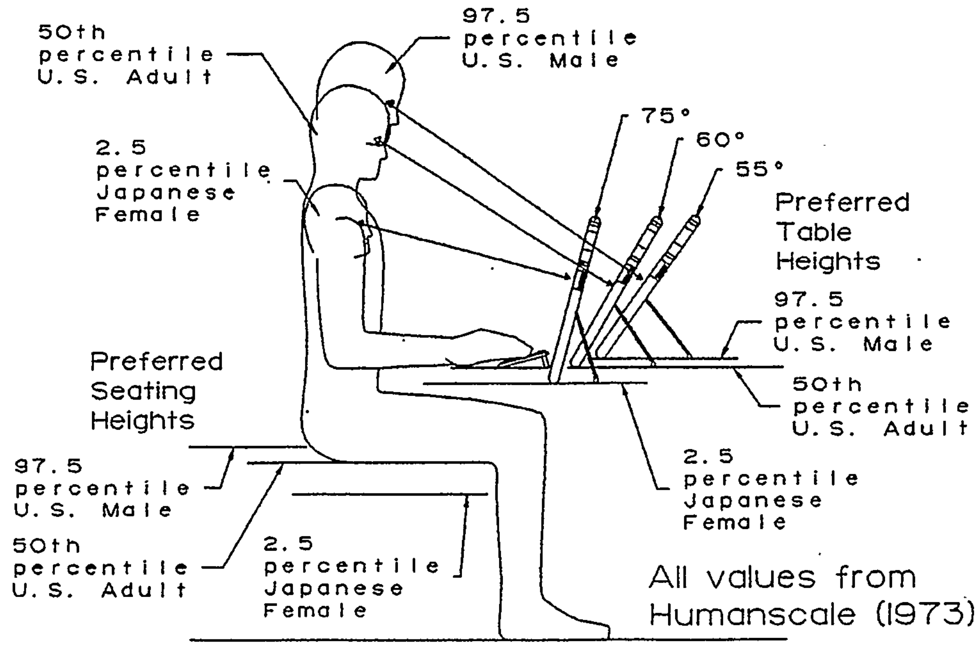


Figure 46

A.10.1 Colour

The selection of a colour screen, beyond the provision of producing colour images, aids in the user's ability to navigate the system. The use of colour provides an additional method by which the user may retain, organize, and mentally store information, reducing the memory load placed on the user by the system.

Benbaset et al.(1986) examined the joint and individual effects of colour and graphics within the context of different user characteristics and task settings.[31] Their findings were that:

-colour improves performance in a recall task

-colour improves performance in a search-and-locate task

-colour improves performance in a retention task

-colour improves comprehension of instructional materials

-colour improves performance in a decision judgement task

These results were largely endorsed by the study by Hoadley (1990).[32] The selection of a colour monitor is appropriate, given the findings of these studies.

A.11 Vision

A.11.1 Typing

As figure 47 demonstrates, the configuration of the system when typing is appropriate in terms of the user's field of view. In elevation, the user can easily view the whole of the screen within the limits of easy eye and head movements. The normal sight line, 15 degrees below the perpendicular, ends near the centre with the head tilted forward 16.75 degrees.[33] In this case, the screen is tilted back at 30 degrees, within 1.75 degrees of perpendicular to the normal sight line.

Vision - Typing

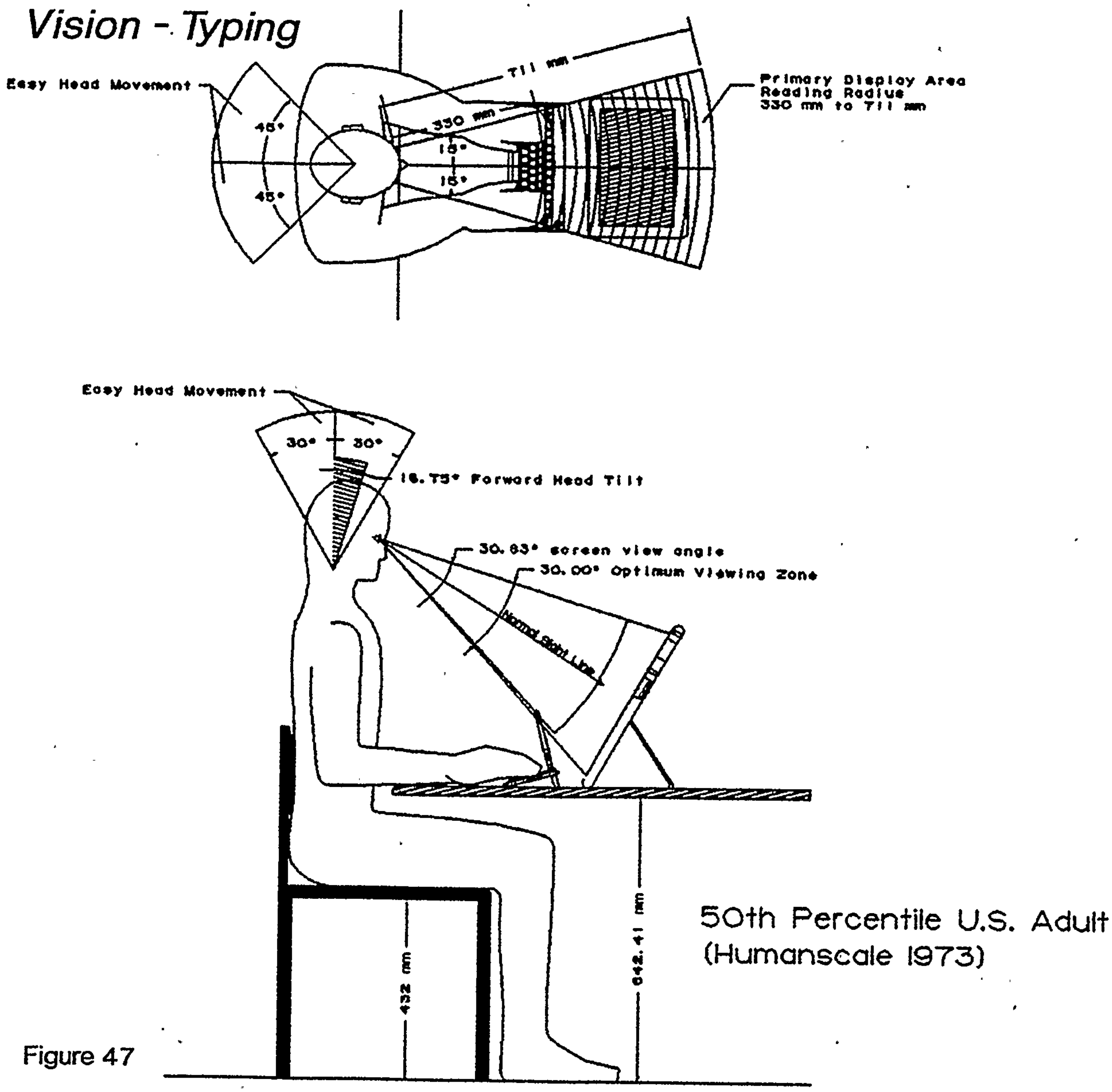


Figure 47

The need for tilting the head forward unfortunately cannot be avoided, except through the elevation of the screen above the typing work surface. This may be a problem over time, requiring the user to hold his/her head in an unsupported position, which has potential for causing fatigue. As stated, this problem could be alleviated through the elevation of the screen such that the head may be held vertically while viewing the screen.

Horizontally, the viewing of the screen, the keyboard, and the document being scanned falls within the limits of comfortable head and eye movement. The keyboard and screen both fall within the limits for primary display, while the document falls within the boundary for secondary displays. These are both in keeping with their relative importance to the system.

Finally, with the configuration demonstrated (50th percentile U.S. adult), the screen falls in the middle of the allowable reading radius for primary displays. This will change from user to user, but it is felt that any change would likely still fall within the allowable limits.[34]

A.11.2 Scanning

Although similar in basic configuration, the set up of the scanning configuration does cause some visual problems. Owing to the requirement that the screen be set up at 15 degrees from the vertical, it is unlikely that all but the smallest of users would view the screen at an appropriate angle. As figure 48 demonstrates, the 50th percentile U.S. adult views the screen at 16.75 degrees from the normal sight line.

Although not ideal, this configuration is felt to be optimal given the other system constraints. As in the typing configuration, this visual problem can be alleviated through the elevation of the screen above the typing surface. In this case, there would be the creation of a new problem, that being the requirement of the user to raise his/her arm in order to manipulate the original document being scanned, which would cause further fatigue.

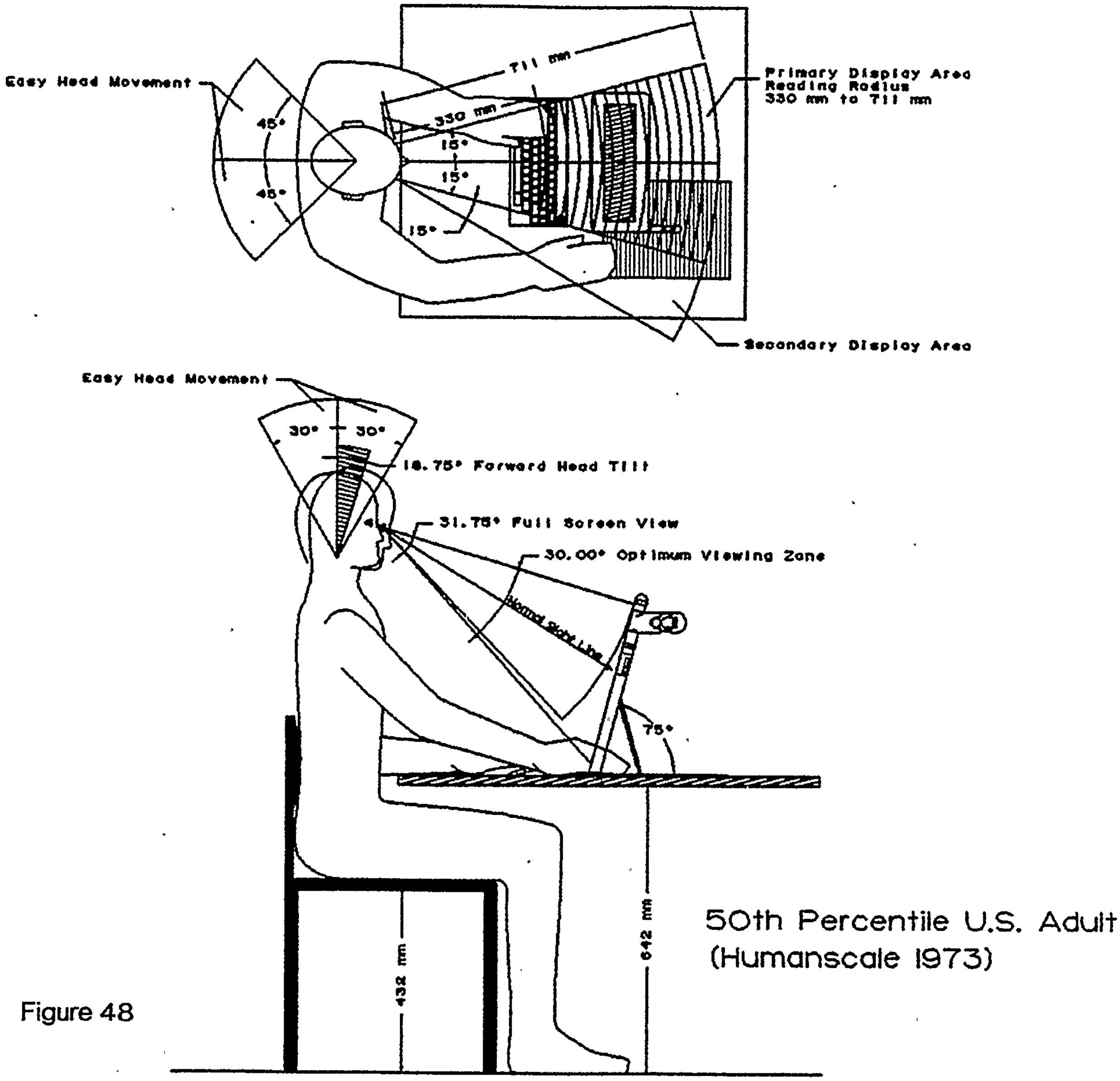


Figure 48

A.1 1.3 Laptop

Determination of the success of this configuration is difficult. There will be a great many ways in which a user may choose to position the screen, providing a like variety of human factors. Figure 49 shows a particularly bad configuration, where the user is required to go to the edge of the comfort limit in forward head movement, and go slightly beyond the limit of the optimum viewing zone for primary displays. This condition places a load on the neck as the head is moved further out from a position of support. Other configurations, such as that demonstrated in figure 50, are likely to be superior to this example.

Vision - Laptop

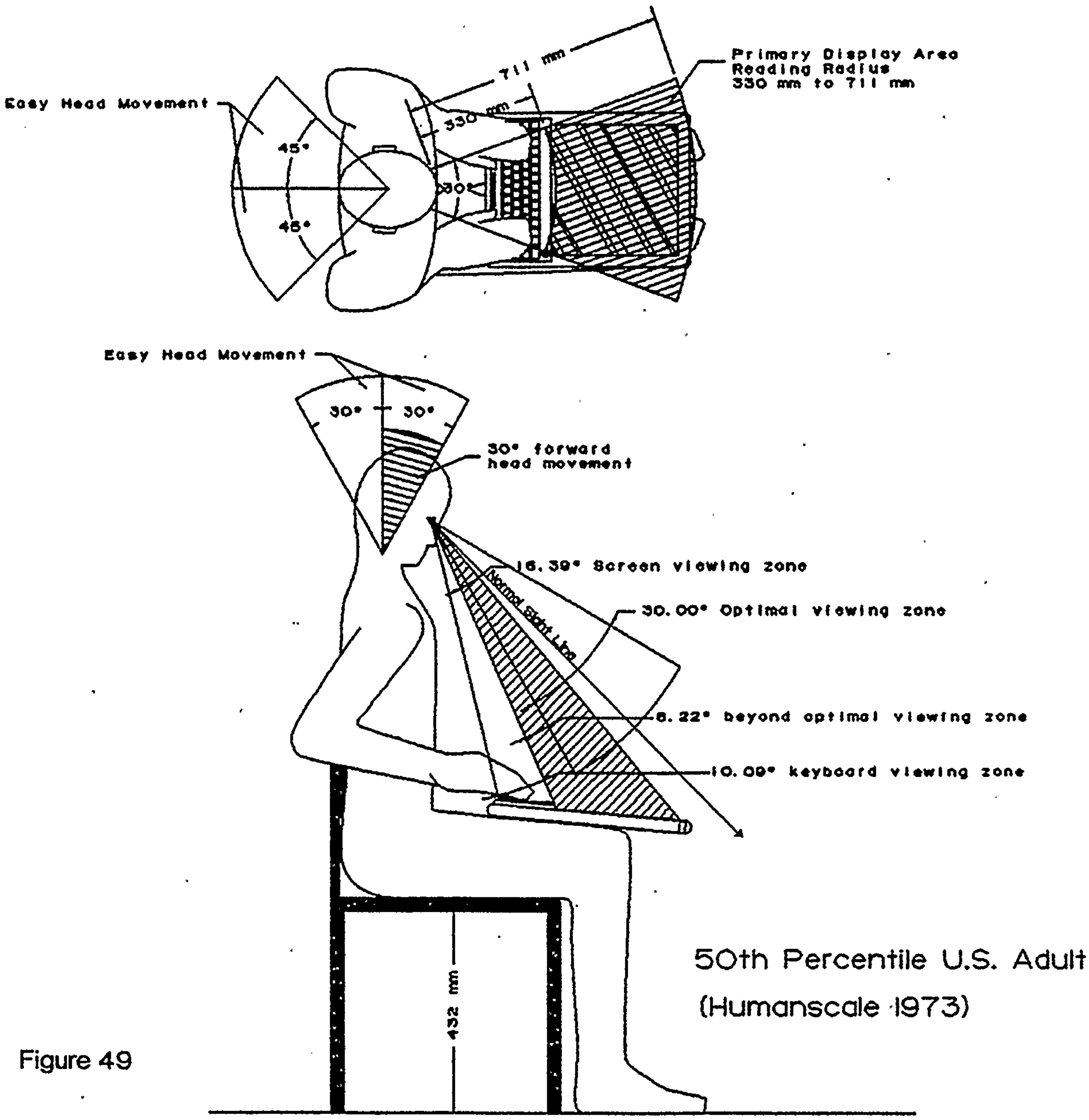


Figure 49

Vision - Alternative Laptop Configuration

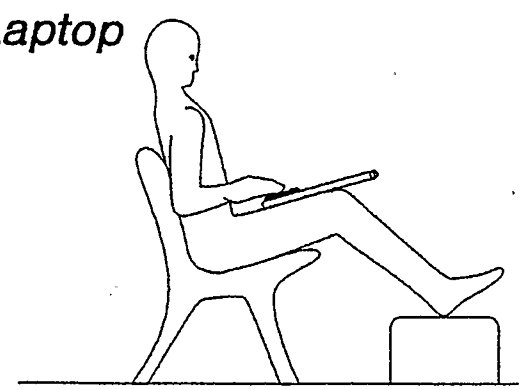


Figure 50

A.12 Graphical User Interface

The Graphical User Interface (GUI) is beyond the scope of this project. I would be remiss, however, in ignoring its importance in the design of this product. The ability of the user to move through the system is due in a very large part in the quality of the GUI. In many ways, the industrial design of this product is an extension of the GUI, enabling the execution of those tasks requested through the GUI.

A.13 Configuration Assessments

A.13.1 Typing

As stated in the discussion on keyboard slope and height, there is disagreement about how a correct typing posture is defined. I have selected the convention of an upright operator, with hands and forearms in a horizontal position. This requires that the seat and table height be adjustable, which is not within the scope of the design.

Typing Configuration

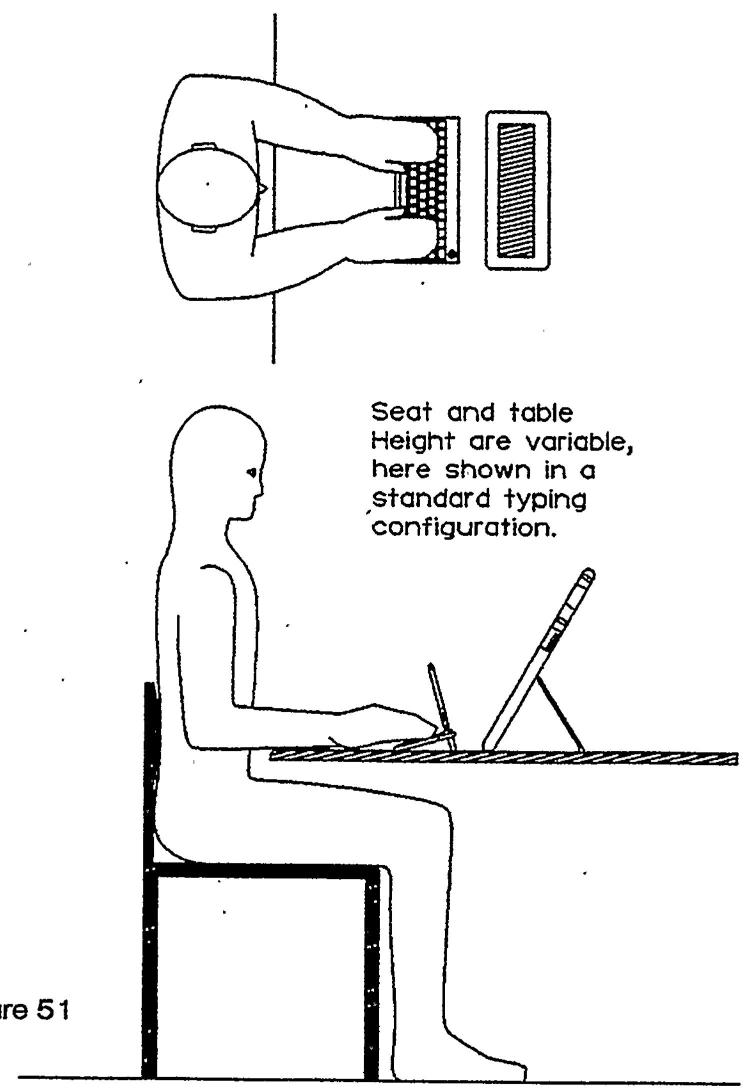


Figure 51

Assuming that the seat and table are adjustable, the design of this product allows for proper posture when typing. As figure 51 demonstrates, the user may type in the defined manner. Admittedly, this is primarily a function of the ability to adjust the seat and the table.

The components affecting this system in this configuration are the keyboard, its characteristics, and the user's ability to view the screen. As these have already been discussed in this paper, they will not be reviewed here.

A.13.2 Scanner Layout

As the scanner is viewed as a device that could potentially be used in prolonged sessions, it is felt that the human factors considerations regarding its layout be a high priority. The comfort of this configuration is critical; an ineffective solution potentially limiting the likelihood of the device's use, or adversely affecting the user.

A key concern in the layout of the scanner is that the user should remain comfortable throughout the process. Owing to the great potential for protracted sessions at this task, the first decision was to allow the operator to be seated during its execution. David Oborne (1982) states that:

> ***"Allowing the operator to sit relieves him of the need to maintain an upright posture, which reduces the overall static muscular workload required to 'lock' the joints of the foot, knee, hip, and spine, and reduces his energy consumption."***
>
> Oborne, 1982[35]

Scanning Layout

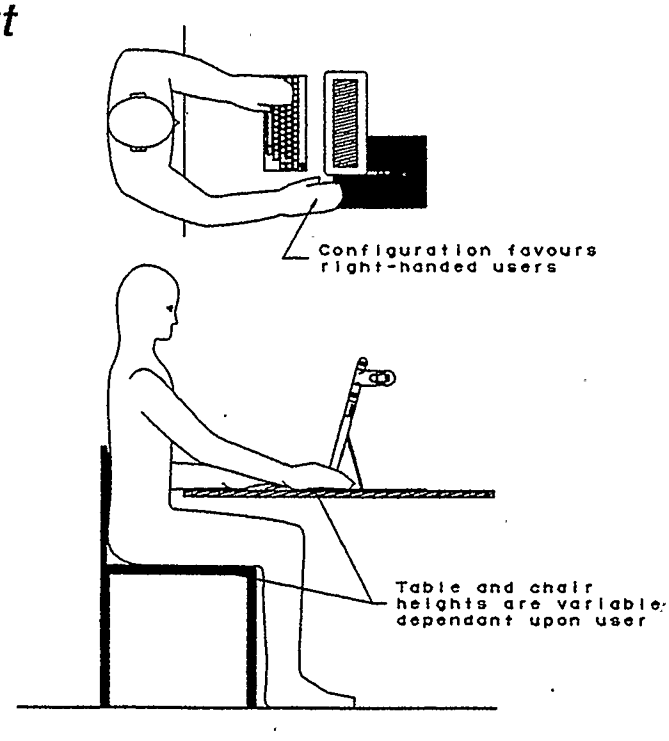


Figure 52

There is also a further improvement in circulation when sitting. Seating allows the musculature to relax, and the resulting lowering of the hydrostatic pressure in the veins reduces the resistance of the blood returning to the heart.[36]

Seating offers yet another advantage; the seated position provides the operator with a more stable posture than that of a standing operator. This stability allows the operator to more precisely control upper body movements, in this case the movement of the document/image to be scanned.[37]

As important as the supporting of the operator through sitting is the supporting of the operator's arms during the task execution. This is achieved by placing the work area on the desk and right of centre of the system. By placing the work area in this location, the operator's arm is supported by the desk, rather than remaining unsupported as in a standing posture.

By placing the work area right of centre of the system, the user has a clear reach to the documents being scanned. Not only does this allow the user to manipulate the documents without changing his/her seating posture, it also provides the user with a clear view of the document for retrieval from the scanning area.

The last key issue with respect to the configuration is the question of feedback. Accurate feedback is critical if the user is to understand the current state of the system, and what should be done to move that state to another. In terms of scanning, it is important that the user have a clear understanding of what image is truly being scanned, as opposed to what he/she thinks is being scanned.[38]

By providing a real-time image of the document being scanned on the system screen, the user is given clear feedback as to the image being scanned, its position relative to the scanner, and through natural mapping between the screen image and the document, an ability to make appropriate adjustments in order that the desired alignment is achieved. For this to be effective, the screen must be in a position that is readily available to the user. As figure 52 indicates, this criteria is met by this configuration.

As stated, alignment of the document will be done primarily through visual feedback. In addition to that, the system stand acts as a reference point, against which the user may place the document. By supplying this reference, the user's need for precision is initially reduced.

A.13.3 Sketching

The task of sketching is a rather unstructured activity, never being quite the same for any two individuals. Sketching may take place on a desk top, a drafting table, on the user's lap, or any number of places. This makes an assessment of the human factors of the task difficult, as they are largely dependant upon the sketch environment. Refer to figure 53 for an example of a sketch posture.

There are, however, some issues which may be addressed. The principle concern is the comfort of the arm as it rests against the edge of the system. Owing to the thickness of the system (25 mm), there is potential for the edge of the case to place too great a pressure on the arm tissue. This concern is alleviated by the radius of the edge, being the maximum of 12.5 mm. This increases the surface area of the edge, which in turn reduces the pressure on the arm.

Another concern is the "feel" of the stylus on the drawing surface. Too little surface resistance will deny the user physical feedback (other than proprioceptive), while too great resistance may potentially be fatiguing.[39] This resistance is a function of the surface of the screen, and the construction of the stylus tip. Through the use of a non-glare glass which will provide some resistance and a hard plastic tip on the stylus, it is hoped that the sensation of drawing will be natural.

Sketch Configuration
- example

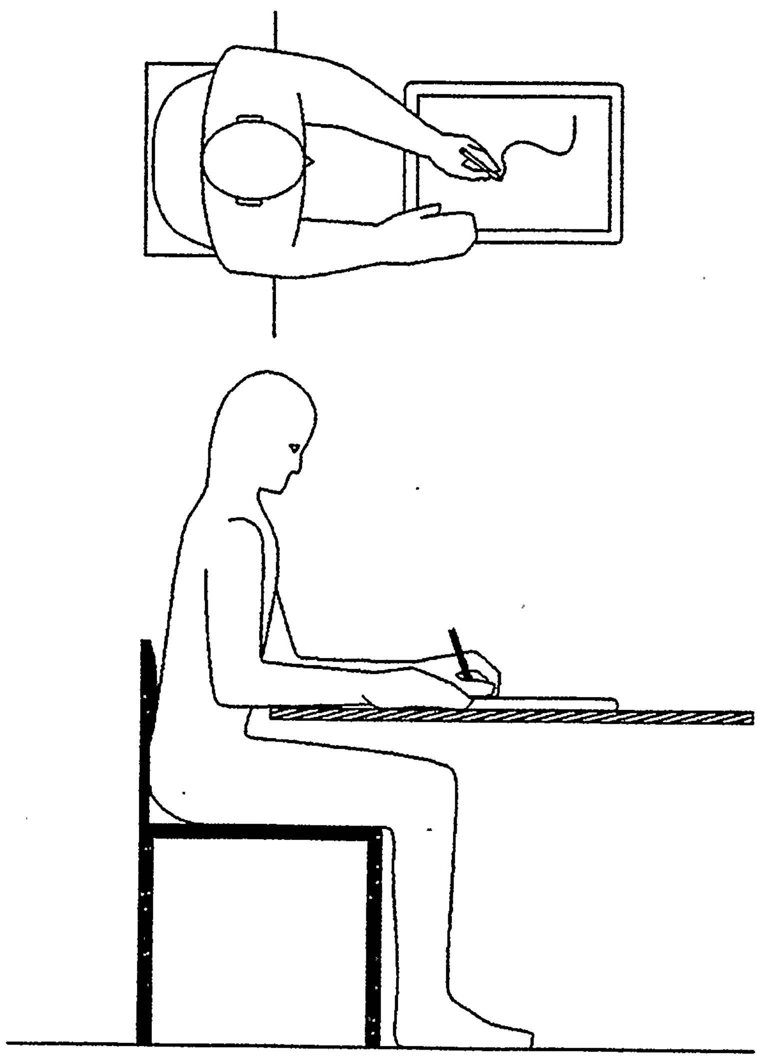


Figure 53

A.14 Human Factors Conclusion

Overall, the human factors requirements of this project have been met with success. There are instances, such as the fixed screen angle when digitizing and projecting, where optimal human factors solutions have been sacrificed for system function. These instances are few, with the majority of the system being correct in its human factors.

1) Joel S. Greenstein et. al., "Keyboards", in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), pp. 166-169.

2) Greenstein and Muto, p. 166.

3) D.G. Alden et. al., "Keyboard Design and Evaluation: A Review of the Major Issues", in Human Factors, 14, quoted in "Keyboards", Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), p. 166.

4) Hans Brunner et. al., "Effects of Keyboard Design and Typing Skill on User Keyboard Preferences and Throughput Performance", in Proceedings of the Human Factors Society 28th Annual Meeting, 1984, pp. 267-271.

5) Brunner et. al., p. 270.

6) Greenstein and Muto, p. 130.

7) R. Kinkead, "Typing speed, keying rates, and optimal keyboard layouts", in Proceedings of the Human Factors Society 19th Annual Meeting, quoted in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), pp. 130-131.

8) J. Noyes, "The QWERTY Keyboard: A review", in International Journal of Man-Machine Studies, 18, quoted in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), pp. 131-132.

9) Greenstein, p. 130.

10) T.M. Burke et. al., "Effects of keyboard height on typist performance and preference", in Proceedings of the Human Factors Society 28th Annual Meeting, quoted in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), p. 168.

11) W.H. Emmons et. al., "Thirty millimeter keyboards: how good are they?", in Proceedings of the Human Factors Society 26th Annual Meeting, quoted in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), p. 168.

12) Greenstein and Muto, p. 168.

13) Greenstein and Muto, p. 167.

14) A. Cakir et. al., Visual Display Terminals, quoted in Input Devices, ed. Sol Sherr, New York: Academic Press, 1988), p. 167.

15) David Doran, "Trackballs and Joysticks", in Input Devices, ed. Sol Sherr, (New York: Academic Press, 1988), pp. 253-258.

16) Neils Diffrient, et. al., "Humanscale 1/2/3", (Cambridge: The MIT Press, 1974).

17) Suzanne H. Rodgers et. al., Ergonomic Design for People at Work, (New York: Van Nostrand Reinhold Company), pp. 355-356.

18) Donald A. Norman, The Design of Everyday Things, (New York: Doubleday, 1988), pp. 197-198.

19) R.E. Christ, "Review and analysis of colour coding research for visual displays", in Human Factors, 17, quoted in Ergonomics at Work, David Oborne (Chichester: John Wiley and Sons Ltd., 1982), pp. 88-89.

20) Empirical observation of frequency of use in electronic devices.

21) David J. Oborne, Ergonomics at Work, (Chichester: John Wiley and Sons Ltd., 1982), p. 99.

22) Norman, p. 82.

23) Diffrient, Humanscale 1a.

24) Diffrient, Humanscale 1b.

25) Rodgers, p. 351.

26) Rodgers, p. 292.

27) Davies, p. 191.

28) Rodgers, p. 146.

29) Diffrient, Humanscale 1b.

30) Davies, p. 192.

31) Rodgers, p. 30.

32) I. Benbasat et. al., "The influence of color and graphical information presentation in a managerial decision simulation", Human Computer Interaction, 1986, quoted in "Investigating the Effects of Color", Ellen D. Hoadley, Communications of the ACM, February 1990, p. 121.

33) Ellen D. Hoadley, "Investigating the Effects of Color", Communications of the ACM, February 1990, pp. 120-125.

34) Diffrient, Humanscale 1a.

35) Diffrient, Humanscale 1a.

36) Oborne, p. 165.

37) Oborne, p. 165.

38) Oborne, p. 165.

39) Norman, pp. 27-28.

40) E. J. McCormick and M.S. Sanders Human Factors in Engineering and Design, (New York: McGraw-Hill Book Company, 1982), p. 305.

Appendix B

Production Technology

This section will address the materials and processes used in the production of this product. Those technologies discussed previously will not be addressed here.

C.1 Component Cases

The system proper, the keyboard and the digitizer, are similar in the functional demands they place on the structure of their cases. Fundamental to the success of their construction is the selection of material used in their manufacture. In order to make some decisions as to the most appropriate material for these components, it was first necessary to form criteria against which the various materials can be judged. Those criteria are as follows:

1) impact resistance - protect product from blows,
2) rigidity - reduce risk of internal damage due to product torque,
3) dimensional stability - retaining component fit over time,
4) abrasion resistance - maintenance of surface quality,
5) good mechanical properties - release mechanisms, etc. and,
6) good shielding potential - EMI/RFI levels kept low.

Based on these criteria, injection-molded ABS has been selected as the material to be used in the construction of the cases for the system, the keyboard, and the digitizer. ABS has been chosen for its ability to endure adverse conditions, and accept surface shielding treatments.

In reality a polymer alloy, ABS uses combinations of acrylonitrile, butadiene, and styrene (hence ABS) to achieve the desired physical qualities. Acrylonitrile provides chemical resistance and heat stability, butadiene provides impact resistance and toughness, and styrene provides rigidity and processing ease. It is in the relative mixture of these polymers that the desired material qualities are achieved.[1] It would be through consultation with a plastics engineer that the appropriate mix of these polymers would be selected.

Because of its ability to be tailored for different applications, ABS will enable an optimization of the six criteria outlined. ABS is somewhat unique in this ability.

"..ABS can cover a wide range of strengths and impact resistance, with a change in either property at the expense of the other. It is the high balance of both, along with excellent processability and appearance, that distinguishes ABS from other materials."

Kleinert, 1990[2]

Even with the need to make some trade-offs in the tailoring of the material, ABS remains the most suitable for this application.

C.1.1 Shielding

Another key issue in the design of electronic products such as this one is the reduction of electromagnetic and radio-frequency interference (EMI/RFI). Regulatory bodies such as the Federal Communications Commission (FCC) in the United States havespecified maximum levels for EMI and RFI. To satisfy these requirements, it becomes necessary to provide some method of shielding in the case structure.

For this application, shielding will be provided through internal compounding, the adding of conductive modifiers such as carbon or metals to thermoplastics. Through the addition of such materials, surface and volume resistivity of thermoplastics can be lowered so that they dissipate electrostatic charges and provide EMI/RFI shielding.[3]

In this case, fine-diameter stainless steel strands (7 microns) 12 mm in length will be added to the ABS. This material is known commercially as Celstran S. Through the addition of stainless steel, the shielding of the product is supplied with a minimal reduction in the impact resistance of the material. The principle drawback of this material is that it does not deliver high gloss surfaces.[4]

C.1.2 Surface Treatment

The surface finish of this material will be textured. By selecting a textured surface, a number of advantages are gained. First, it becomes possible to use larger particles of polybutadiene, increasing the toughness of the material.[5]

Secondly, the issue of losing surface quality due to the addition of stainless steel is diminished. The texture in the surface would disguise any imperfections created by the stainless steel.[6]

Thirdly, as this product will likely be used in less than ideal situations, using a textured surface will help disguise any marks that will almost certainly be made on the product. A gloss treatment would make maintaining the product's surface appearance extremely difficult.

Finally, a textured surface increases the tactile quality of the product, an important issue for an object that is to be held. Although not a technical issue, it does have a bearing on the product image.

C.1.3 Color

In order that flaws in the molding of these components be least visible, it is necessary to select a light color. Dark colors such as black tend to emphasize surface flaws, and further emphasize the existence of the stainless steel fibers by their significant shade contrast. To alleviate these concerns, a medium gray has been selected.

C.2 Small Fittings

In the manufacture of small fittings, such as the release mechanisms, ABS will once again be used. In this case, however, a general purpose grade will more than suffice. ABS is a good choice for such fittings, as it has excellent molding characteristics, and is especially useful in situations where dimensional stability is important.[7]

C.3 Projector

C.3.1 Case

Unlike the other components, the projector case has to deal with the high heat produced by the halogen light bulb. In the selection of material, four other issues needed to be considered:

1. the material must be able to resemble that of the other components which are made of ABS,
2. it must be able to withstand significant heat without breaking down,
3. the material must be heat resistant, to reduce the potential hazard of the product,
4. and it must remain dimensionally stable under these heat conditions.

The material selected in the manufacture of this component is known as Bulk Molding Compound, or BMC. BMC is created by blending resin, catalyst, powdered mineral filler, reinforcing fiber, pigment, lubricants, and other additives. This material would be used in an injection-molding process.

> ***"The material is characterized by high heat resistance, strength, rigidity, and good dimensional stability, electrical properties, and processability."***
>
> Nunnery, 1990[8]

This material, used in such applications as steam iron bases, halogen head-lamp housings, and microwave cook-ware, is capable of withstanding continuous operating temperatures of up to 450 degrees Fahrenheit. Its good molding ability and improving color qualities make it an excellent candidate for this application.

C.3.2 Reflector

To make efficient use of the projector's light source, it is necessary to have some form of reflector within the projector body around the light source. Rather than use a separate reflector, it was felt that applying a reflective coating to the Projector case itself.

The technique for this application is known as Sputtering, the deposition of metals under high vacuum onto prepared plastic surfaces. A large number of metals can be deposited in this process. The surface to be metallized is bombarded with ionized molecules. Metal atoms within the chamber are attracted to the surface, where over time they form a thin, uniform, and brilliant metallic film. Due to the thinness of the film, it is of utmost importance that the surface being metallized is as smooth as possible for greatest reflectance.[9]

C.4 Keypads

As discussed in the human factors appendix, the keyboard keys are made from a single sheet of injection molded thermoplastic elastomer (TPE), in particular, engineering TPE. This particular material has been selected because of the compatibility of its physical properties with the demands of a keyboard.

Engineering TPEs, commonly known as ETEs, are highly elastic materials which are useful in applications which require recovery from impact, isolate shock, or flex continuously. This is almost exactly the conditions of using a keyboard. Further, ETEs have an interesting ability in that they function like structural plastic in thick section, while they become elastic in thin section. As figure 52 demonstrates, this is ideal for the design of this keypad; the keys remain rigid, while the "springs" are elastic.[10]

The ability of the material to act as a spring is also critical.

> ***"The resins offer exceptional flex-life, "spring" properties, and resistance to creep."***
>
> Sheridan, 1990[11]

This material is capable of surviving literally millions of flex cycles, without any significant loss of its mechanical properties.

Co-injection molded to each keypad is a small contact point, which closes a circuit. This pad may again be made of ETE, with a conductive additive which allows the material to close the circuit.

Keypad Cross- Section

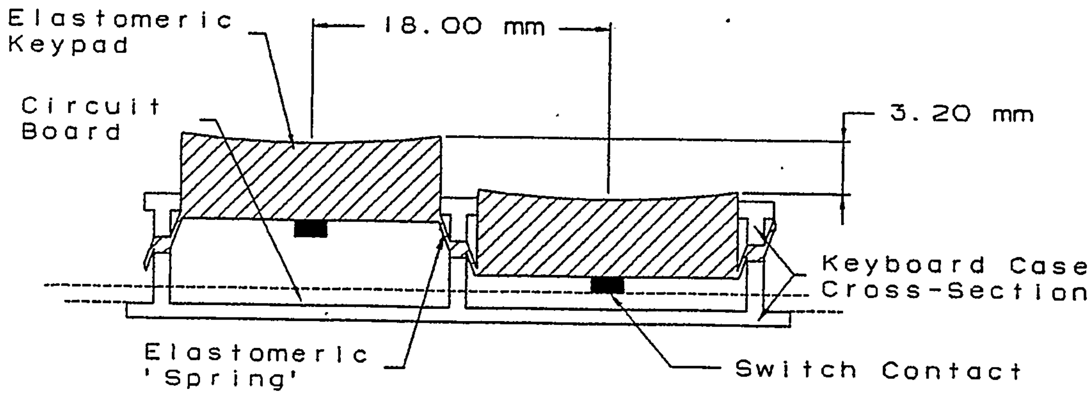


Figure 54

C.5 The Stand

Owing to its relatively small size and the need for significant strength, the screen stand will be constructed out of a pressure die cast aluminum, likely a 6061 grade. Die casting allows for great dimensional accuracy, with an ability to include all details such as pivot holes and detentes. This, as well as the excellent surface quality of the process, reduces considerably the amount of post-process work.[12]

6061 grade aluminum was selected for its light weight, its strength, and its ability to be colored in a durable manner. Coloring will be through the anodizing of the aluminum surface, with an oxide layer of perhaps 10 microns. This thickness should be sufficient for the types of environments that the stand will be subjected to. The color of the stand will be tailored to match that of the other components, a medium gray.[13]

C.6 The Stylus

C.6.1 Body

The stylus body is constructed of four parts; three structural components of aluminum, and an elastomeric grip. Figure 53 shows their configuration.

The three structural components; the tail, center, and tip housings, are each made from 6061 grade aluminum. They are all constructed using pressure die casting, which enables the inclusion of such details as threads in initial production. This keeps the need for any post-production to a minimum. As this tool is to be held in the hand for extended periods of time, it would be appropriate to remove completely any mold flashing or markings from the exterior surface. This would be achieved by lathing down the external part surfaces.

C.6.2 The Grip

The grip of the stylus is simply an extruded piece of TPE, cut to length and placed over the center section. TPEs are appropriate for this application, because of their rubber-like qualities, their processability, and their resistance to chemicals and oils. Beyond its performance as a grip surface, this material is also serving as a low demand seal of the stylus interior from the environment.

Stylus Construction

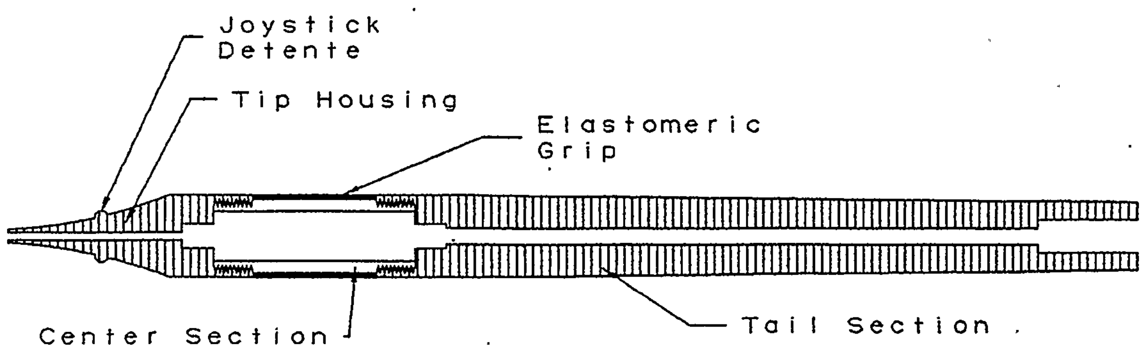


Figure 55

C.7 The Screen

As previously stated, the technology selected for the system screen is known as Field Emission Displays, or FEDs. Developed at the Stanford Research Center, field-emission displays are based on the same principle as the cathode ray tube (CRT). The major difference between FEDs and current CRTs is the replacement of the bulky, high-voltage "hot-cathode" electron gun with micron-sized cone-shaped structures called "cold cathodes" or "field-emission cathodes", which can excite electrons with voltages much lower than those required by traditional CRT electron guns. They are called "cold-cathode" because they also generate much less heat.[14]

The construction of this technology is as follows: two glass plates are separated by a space which is evacuated to a pressure of 10-6 torr. The face-plate contains a phosphor screen, much the same as in a conventional CRT, while the baseplate contains the array of cold-cathode field emitters. Around the array of field emitters are row and column driver chips, which together address the individual field emitters. Up to 100 emitter tips are deposited at each intersection of the row and column drivers, which provide significant redundancy, and therefore high production yields.

The field emitter tips then emanate electrons through holes in the baseplate which are 1 micron in diameter. The electron beam which results from this strikes the phosphor screen in much the same way as in a conventional CRT.

The result is a full color (16.5 million colors) display that exceeds the highest CRT resolutions. Currently, a screen of the size required for this product will consume approximately 4 W of power, which will only decrease as the technology develops.[15]

Field-Emission Display Assembly

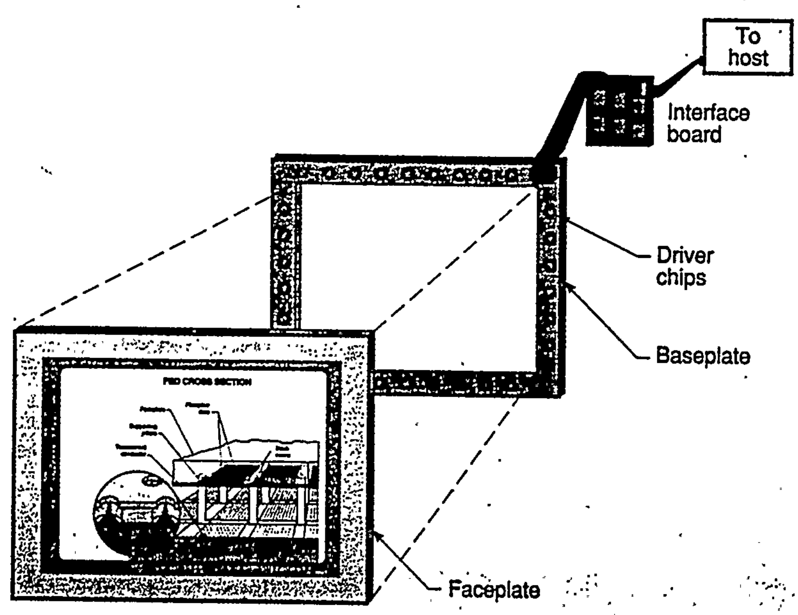


Figure 56 (from Byte Magazine, February 1991)

Field-Emission Display Cross-Section

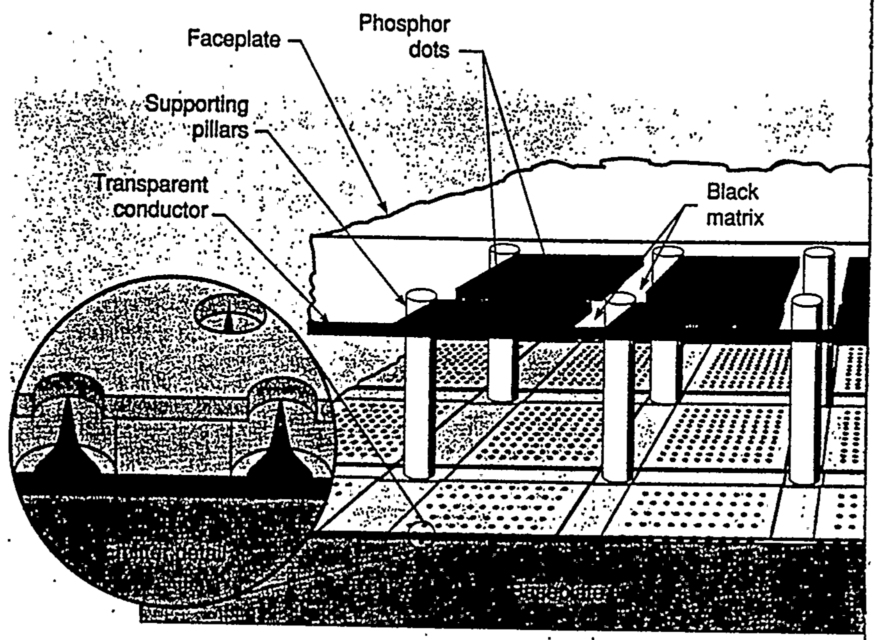


Figure 57 (from Byte Magazine, February 1991)

C.8 Carrying Case

The purpose of the carrying case is to provide both protection and a comfortable method of carrying the system while in transit. The demands on the case are not great, other than it be durable, can be closed, and provide a handle. Because of its sense of quality, and its suitability to the functional requirements, leather has been chosen for the construction of this component.

The case will be constructed as a soft-sided valise, which is closed with a zipper and has handles at either side. Provision will be made on the outside of the case for a small compartment for carrying paper and other objects associated with conventional work. This enables the user to work in a conventional manner, and collect documents for later storage.

1) Bruce E. Kleinert, "ABS", in Modern Plastics Encyclopedia '90, pp. 102-104.

2) Kleinert, pp. 102-103.

3) S.R. Gerteisen, "EMI shielding and electrostatic discharge by internal compounding", in Modern Plastics Encyclopedia '90, pp. 404-405.

4) Celstran S: Long-fiber Reinforced Conductive Thermoplastics, technical brochure, Polymer Composites Inc., 1990.

5) Kleinert, p.102.

6) Gerteisen, p. 405.

7) Kleinert, p. 102.

8) Larry E. Nunnery, Jr., "Bulk molding compounds (BMC), in Modern Plastics Encyclopedia '90, p. 215.

9) B. Dafonte, "Electroplating and Sputtering", in Modern Plastics Encyclopedia '90, pp.394-395.

10) Charles P. Rader et. al., "Introduction to TPEs", in Modern Plastics '90, p. 122.

11) Thomas W. Sheridan, "Engineering TPEs", in Modern Plastics '90, p. 125.

12) Paladin, "How Things Work", in Metals Resource Guide, Faculty of Environmental Design, The University of Calgary, p. 55.

13) author unknown, "aluminum as a structural material, Metals Resource Guide, Faculty of Environmental Design, The University of Calgary, p. 88.

14) Nick Baron, "LCDs and Beyond", in Byte Magazine, February, 1991. pp. 234-236.

15) Baron, pp. 234-236.

Appendix C
Dimensioned Drawings

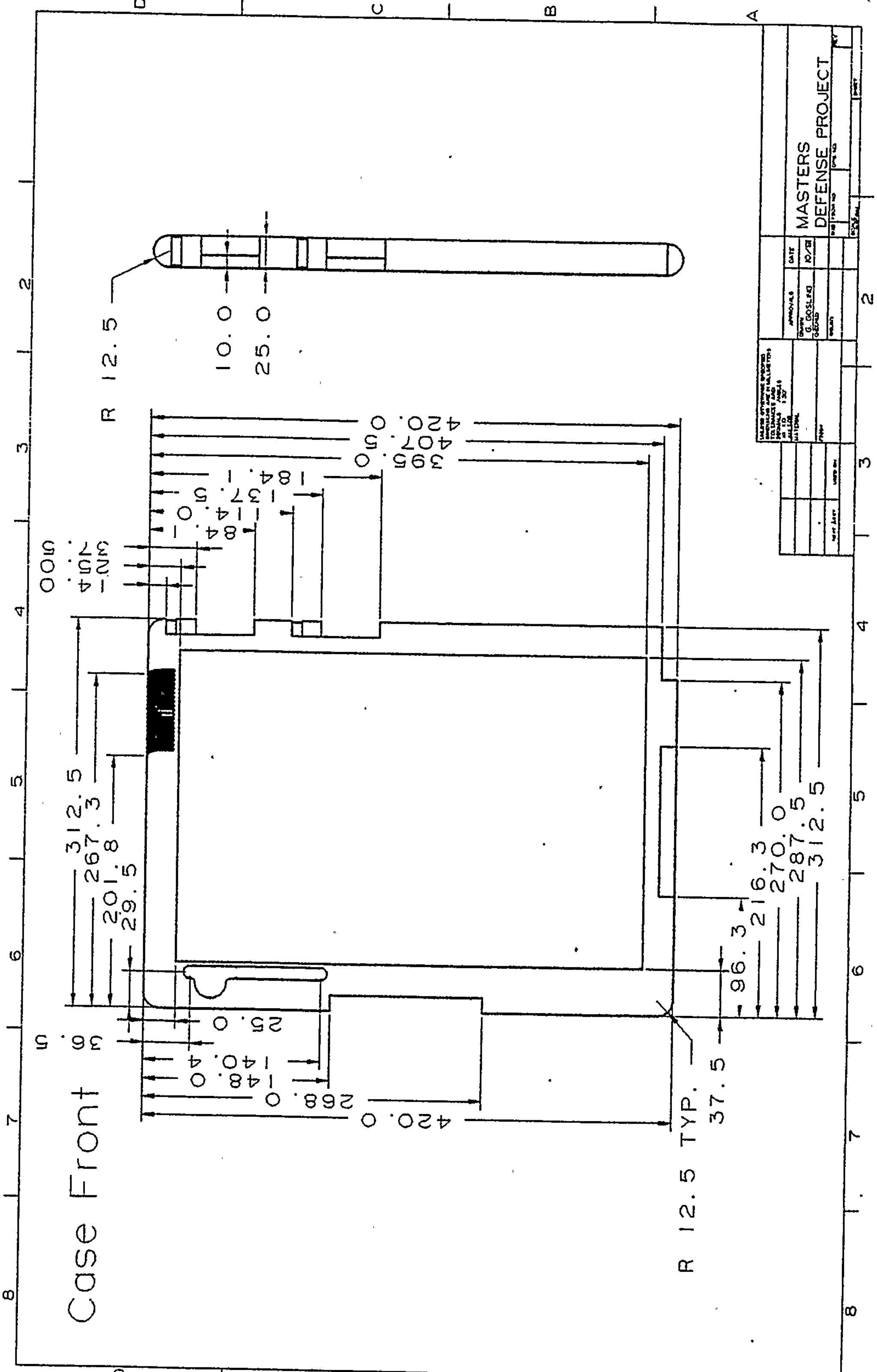


Figure 58

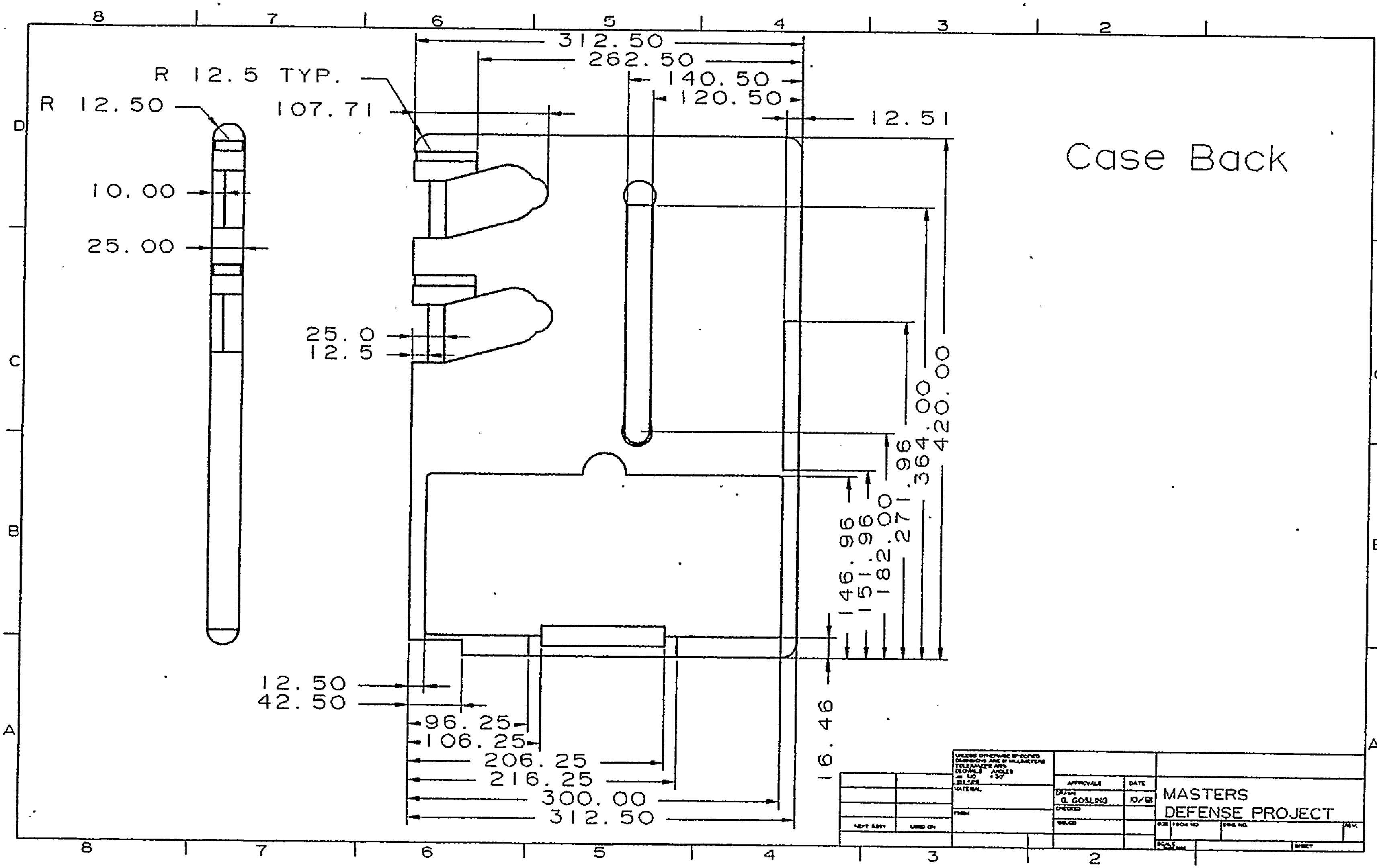

Case Back
R 12.5 TYP.
R 12.50
107.71
312.50
262.50
140.50
120.50
12.51
10.00
25.00
25.0
12.5
420.00
146.96
182.27
16.46
12.50
42.50
96.25
106.25
206.25
216.25
300.00
312.50
G. GOSLING
MASTERS
DEFENSE PROJECT

Figure 59

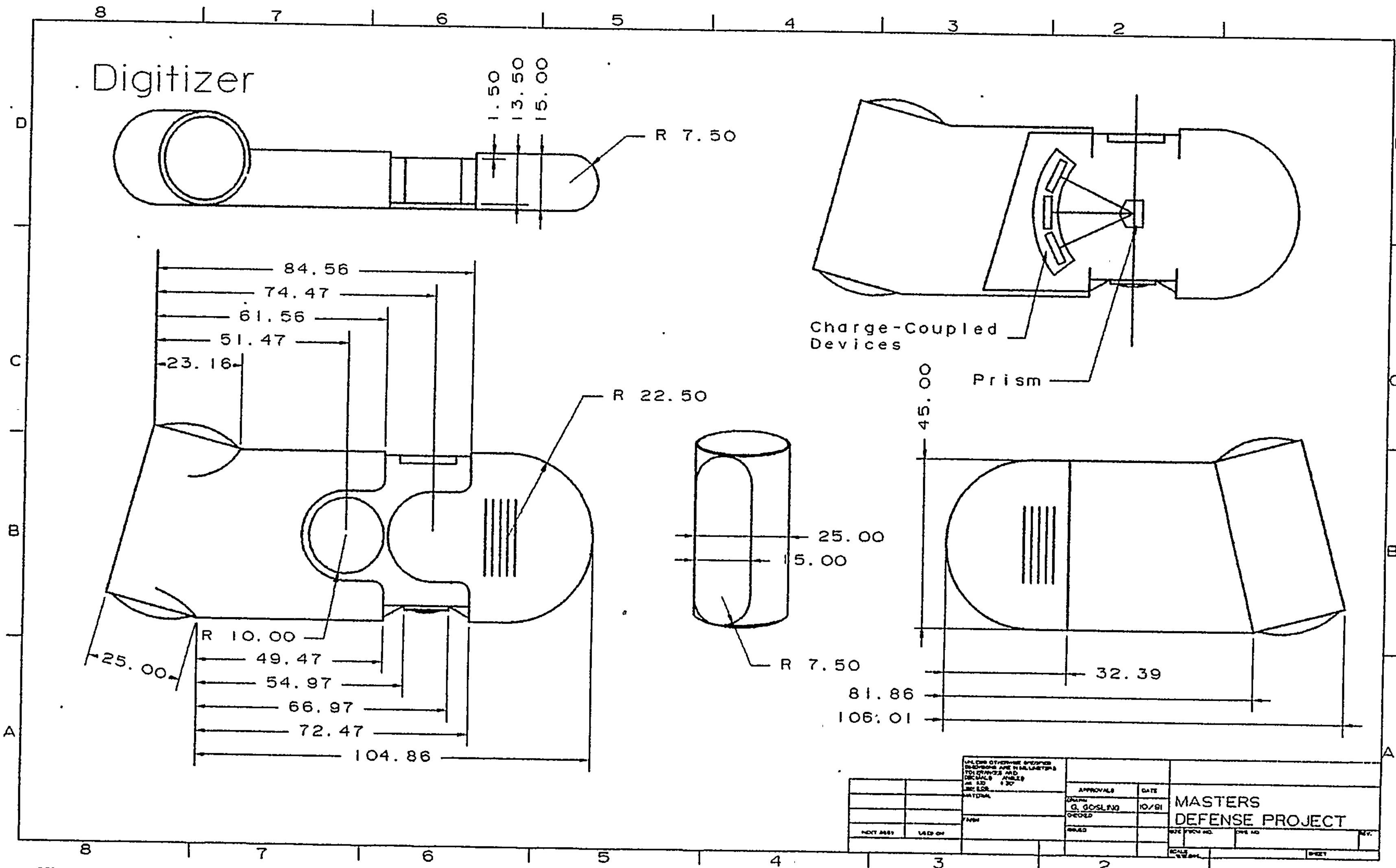

Digitizer
1.50
13.50
15.00
R 7.50
84.56
74.47
61.56
51.47
23.16
R 22.50
R 10.00
25.00
49.47
54.97
66.97
72.47
104.86
25.00
15.00
R 7.50
Charge-Coupled Devices
Prism
45.00
32.39
81.86
106.01
G. GOSLING
10/91
MASTERS
DEFENSE PROJECT

Figure 60

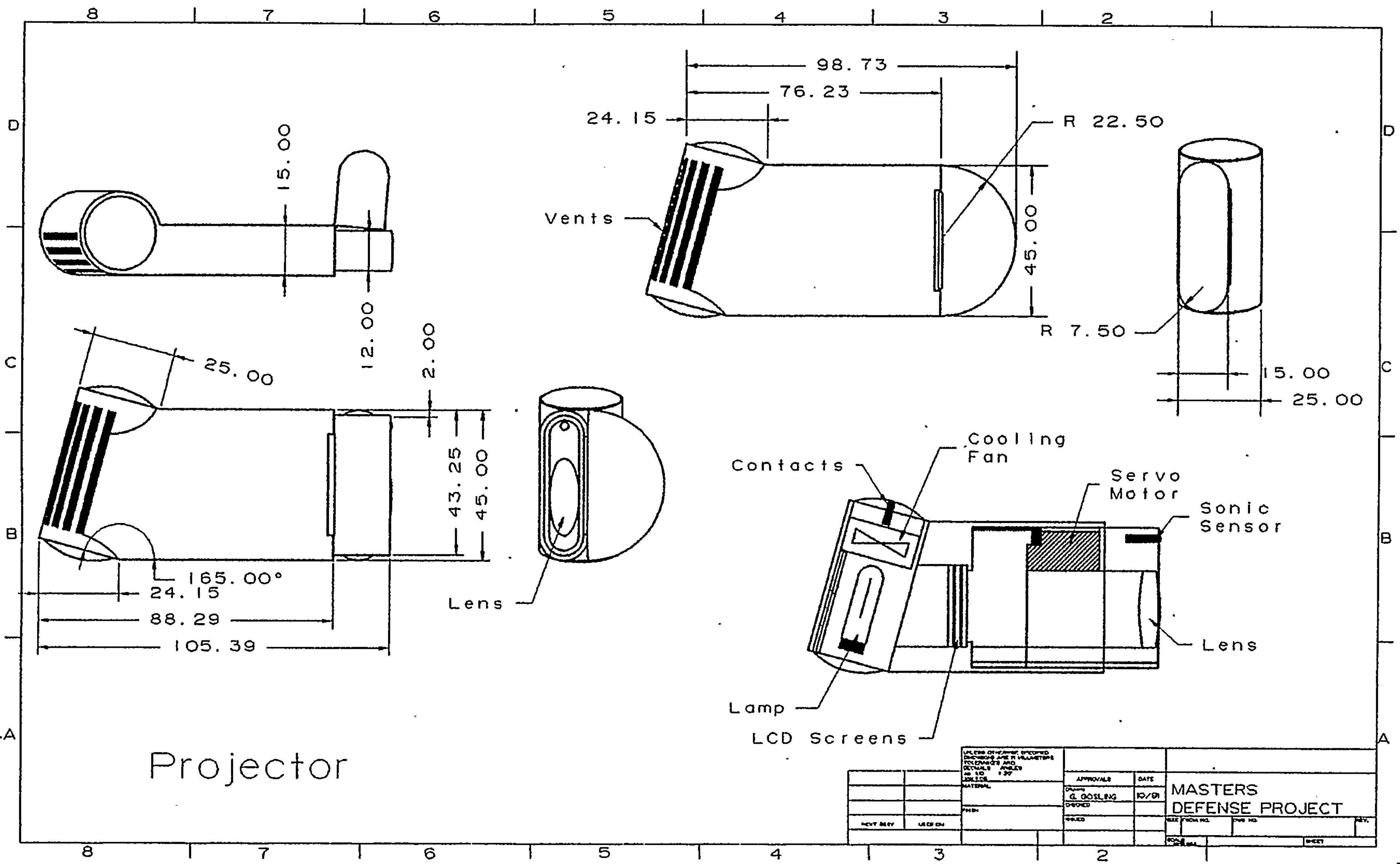
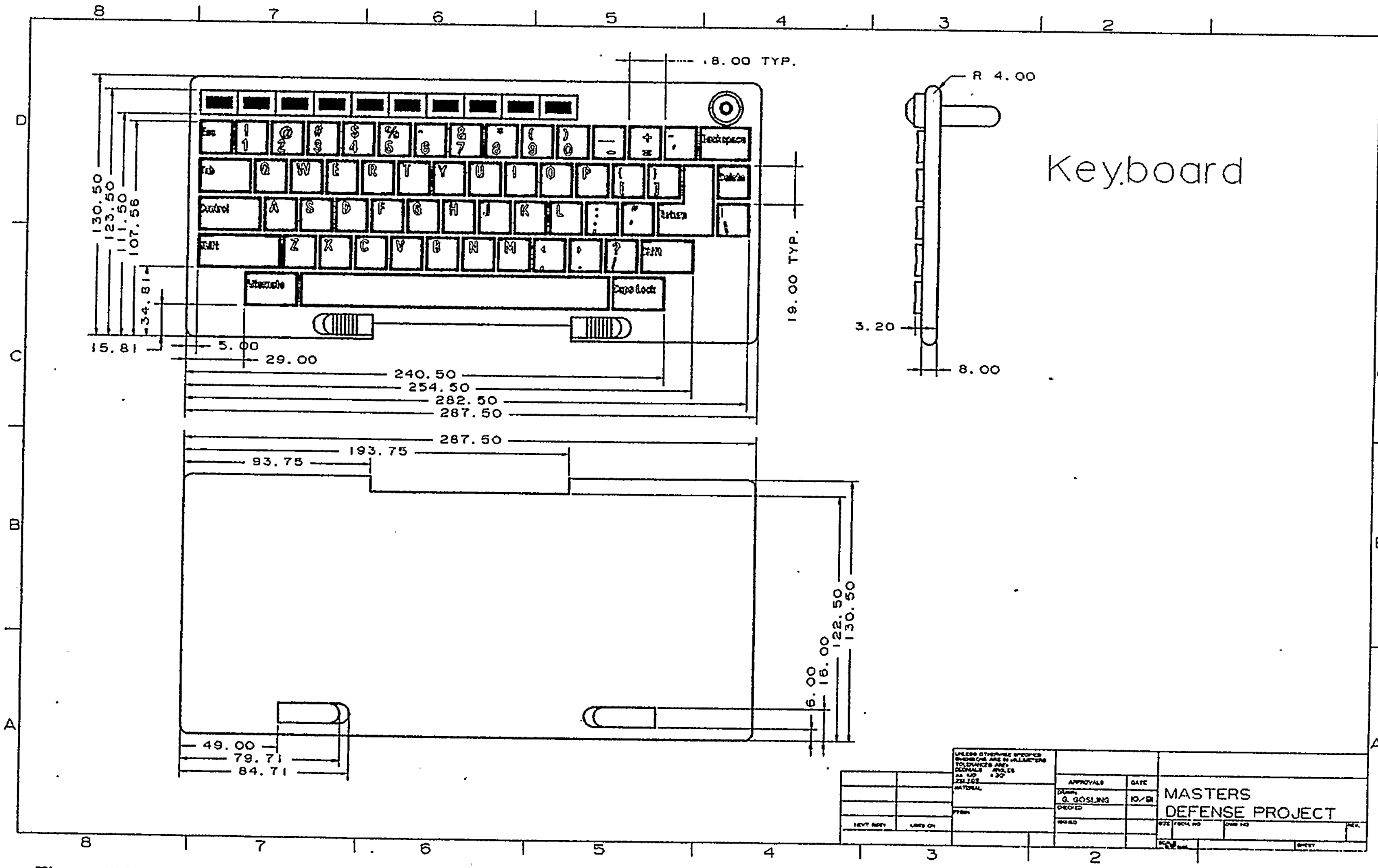

98.73
76.23
24.15
R 22.50
15.00
Vents
45.00
R 7.50
12.00
2.00
25.00
15.00
25.00
43.25
45.00
165.00°
24.15
88.29
105.39
Lens
Contacts
Cooling Fan
Servo Motor
Sonic Sensor
Lens
Lamp
LCD Screens
Projector
APPROVALS
DATE
G. GOSLING
10/91
MASTERS
DEFENSE PROJECT

Figure 61



Keyboard
8.00 TYP.
R 4.00
19.00 TYP.
3.20
8.00
130.50
123.50
111.50
107.56
34.81
15.81
5.00
29.00
240.50
254.50
282.50
287.50
287.50
193.75
93.75
130.50
122.50
16.00
6.00
49.00
79.71
84.71
G. GOSLING
MASTERS
DEFENSE PROJECT

Figure 62

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