ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Title: Scope Component Operational Process Enhancer Scope (SCOPE) A Knowledge Based Process Design Tool

Course:
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Abstract: This is a preliminary report for the development of a Rifle Scope Design/Manufacturing Knowledge-Based System for a company which designs, manufacturers and markets rifle scopes and other optical devices used for sport and target shooting. The proposed system will incorporate manufacturing requirements into the mechanical package design, reduce the feedback required, and thus reduce development time and costs.

SCOPE COMPONENT OPERATIONAL PROCESS ENHANCER SCOPE

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EMP - P9006

PORTLAND STATE UNIVERSITY

SCOPE COMPONENT OPERATIONAL PROCESS ENHANCER (SCOPE)

(A KNOWLEDGE-BASED PROCESS DESIGN TOOL)

A PROJECT PROPOSAL
SUBMITTED FOR

EMGT 510KB

DEPARTMENT OF ENGINEERING MANAGEMENT

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PORTLAND, OREGON

REPORT TO MANAGEMENT

LEUPOLD & STEVENS

The following document is a proposed, Request for Authorization, to proceed with development of a Riflescope Design/Manufacturing Knowledge-Based System to be produced and implemented at Leupold & Stevens, Portland, Oregon.

EXECUTIVE SUMMARY

The primary business of Leupold Stevens is the design and manufacture of riflescopes and other optical devices. Increased competition in the riflescope market has increased the emphasis on efficient new product design and early entry into the marketplace.

The development of a new product involves three distinct groups: optical design, mechanical packaging design, and manufacturing. The optical design is defined by the market needs. Once the optics are selected, then the mechanical components are designed. This process involves the actual engineering of the mechanical packaging; specifying geometry, surface finish, tolerances, etc. The Manufacturing group then selects materials, manufacturing processes and operation sequence based on the specifications of design. Because of this relationship, new product development is a sequential process which requires time and a large amount of feedback. The proposed system will incorporate manufacturing requirements into the mechanical package design, reduce the feedback required, and thus reduce development time and costs.

The proposed system will be a computerized knowledge based system. The system will be used by design engineers to ensure the manufacturability of mechanical package parts. The computer system will be menu-driven with the engineer selecting choices from the menus or inputting numerical data as required. The output will be the most efficient process to manufacture the part and an estimate of the costs.

Developmental costs of the system are projected to be $1.08 million. However, with the time saved, the system will allow more rapid introduction of products. The system is expected to pay for itself in just over two years.

I. INTRODUCTION

The primary business of Leupold & Stevens is the design, manufacture and marketing of riflescopes and other optical devices used for sport and target shooting. The company is well known in the marketplace as a quality leader and its products are priced at a premium level.

The market place is served by more than 200 hundred manufacturers ranging in size from multimillion dollar corporations to small companies with less than one hundred employees. The market has been stable for many years; recently however, there have been several new "deep pocket" entrants into the market. The impact of these new entrants is already evident in new product developments coming into the marketplace. The negative affect of these competitors on market share has led to increased emphasis on the importance of new product development for L&S. This concern is particularly valid based on a recent report in Business Week that stated that a McKinsey & Co. survey calculated that the first two companies to market with a new generation product get 80% of the business [4].

The development of new design for riflescopes involves several major types of components. These include glass lenses and prisms, machined parts made from a variety of metals and a selection of standard vendor parts such as fasteners and sealing devices. Glass and machined components typically account for 28% and 60% of product cost respectively. There are from 65 to 105 discrete parts in an average product. Of the total parts, 75% are machined parts designed at L&S. A survey of the product/part mix in the company is summarized in Table 1 in the appendix.

A. Product Design Process

The product design process typically consists of several distinct steps as shown in the following figure:

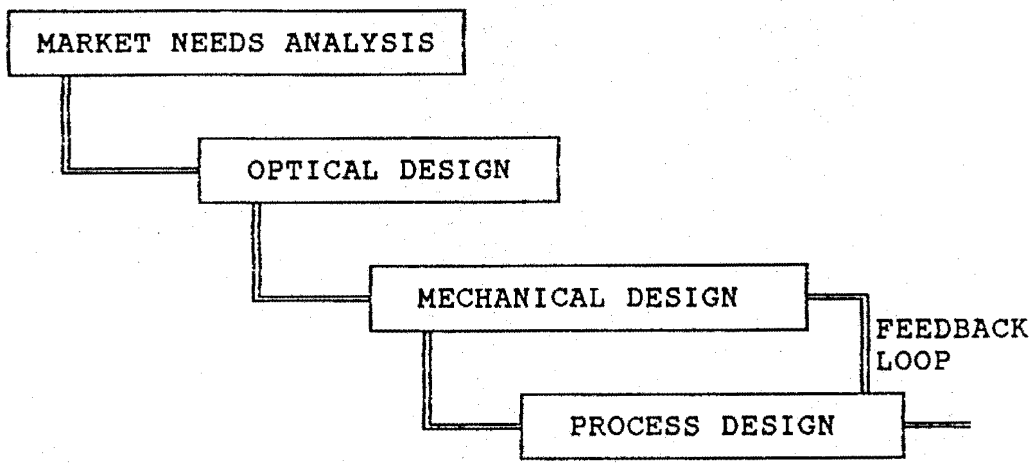


FIGURE 1.
PRODUCT DESIGN PROCESS

The product design process steps illustrated in Figure 1. include:

1. Market Needs Analysis
   Market input for characteristics such as field of view, magnification, product appearance, target price and introduction schedule and volume.

2. Optical Design
   Selection of optical system which defines the size, location and orientation of the glass lenses.

3. Mechanical Design
   An internal design process for the machined components to determine the geometry, surface finish and surface treatment.

4. Process Design
   Finally a manufacturing process selection step which determines the material, manufacturing process, machine selection and operation sequence to yield the finished part.

These steps are usually completed in a sequential fashion with several iterations required to obtain a material and a process that best satisfies the product requirements. The time to complete a new product design has ranged from six to twenty four months.

B. Problem Statement

The process of designing and introducing riflescopes into the marketplace in an efficient and timely manner with the existing system is hampered by the following problems:

1. Lost time due to the iteration process between the Engineering and Manufacturing groups.
2. Noisy and inefficient channels of communication.
3. Lack of standardized design procedures.
4. Lack of an established method to transfer product design knowledge to new employees.
5. Material selection is largely an empirical process.
6. Process technologies are rapidly changing.
7. Flexibility in production schedules requires alternative process plans for identical parts.
8. Lost time through duplicate design of similar parts.

Improving the speed and consistency of the product design process is essential to the continued success of the company. Alternate design processes are available that can help with this critical change.

C. Solution Alternatives:

1. Continue in the current situation but reduce new product introductions.

   The Corporate Mission requires 10% sales growth. Because of new competitive pressures much of this must come from an increased rate of new product development. The existing system has no further capacity for more new product design.

2. Create a set of design rules encoded in procedural handbooks.

   Essentially this type of system would be a manual knowledge based system. A set of manuals would contain written rules (knowledge base) with the inference engine encoded in the procedures. Long search times and the practical difficulty of interfacing with voluminous manuals render this impractical. In addition, the development and maintenance time would approach that of a comparable expert system.

3. Develop an algorithmic procedure set.

   The knowledge required for design of these components is not well suited for algorithmic solutions. Many factors and variables may effect a particular decision in one design situation. However a similar decision in a different case may require a completely different set of variables and factors. For example, aluminum alloy selection affects surface finish, tool design, process selection and anodizing results.

3. Develop a knowledge-based system.

   This solution is best suited for the type of problems facing Leupold & Stevens. It would allow the knowledge which currently resides in the various departments to be adequately represented and readily retrievable. Finally, development and use of this system would clean up the communications channels.

D. Expected Benefits from a Knowledge-Based System.

1 Reduced development cost as a result of needing fewer prototype parts.

2 Improved communication by eliminating nonproductive feedback loops between marketing, design and production leading to a synergistic approach to product development.

3 Reduced routine and noncreative work.

4. Reduced disruption to the factory because individual part features/characteristics could be physically modelled rather than complete parts.

5. Reduced product cost because of more optimum process selection.

II. SYSTEM OUTLINE

A. System Function

The system will function as an advisory system to help the design engineers select the best manufacturing process for a given product design. The major functions of the system are as follows:

1. Select the manufacturing process for any specific part.
2. Select the manufacturing process for the whole product.
3. Interface with the existing Honeywell Manufacturing Control System (HMS), to check if the advised process conflicts with current ongoing processes.
4. Built in explanation and help menus.
5. Built in mechanisms for modifying the knowledge-base during the run time.

B. System Input/Output

The system input will include the part geometry, surface finish, surface treatment, marketing information (eg. part quantity and time requirements), and so on. The output will be one or several suggested manufacturing process along with the estimated cost for product. Input will be menu driven, with typical menus shown in the following example section.

C. Knowledge Representation (Knowledge Base)

The knowledge representation is the core of the an expert system. The basic function of any "knowledge representation"[1] system is to represent a body of knowledge. It may be looked upon as "formal reconstruction of knowledge and its implementation". Knowledge Representation schemes can be generally classified as:

1. Formal logic: propositional or predicate logic. This is the classical approach. It allows the use of theorem proving techniques.

2. Semantic nets: consisting of nodes, representing objects, concepts, and events, and links between nodes representing interrelationships.

3. Production System: consisting of a database of rules. This is helpful in controlling the interaction between declarative and procedural knowledge.

4. Frames: contains facts and their properties in a predefined internal relations. They are useful in representing stereotypical concepts of events.

There are other special knowledge representation methods in addition to the popular ones mentioned above. This issue of representation is important because success of a project may depend on the selection of a formalism for specific applications.

The major products of Leupold and Stevens are riflescopes, binoculars and spotting scopes. Each product is comprised of more than 65 component parts. These component parts all share basic features including: characteristics of manufacturing process, eg. surface finish, finish process, tolerance, and material to be used; part geometry, eg. part diameter and length; and market information, eg.quantity of parts required and time constraints.

In order to fit in our proposed system's domain knowledge, we will use frames to represent the relationships between the products and their function area, the relationship between the function area and its corresponding component part, the relationship between component part and its critical characteristics. We use the production rules to link the critical characteristics of part to the machine to be used to manufacture that part, and then to the classified process.

D. Structure of Knowledge Base

1. As mentioned above, we will use the frame and production rule as our knowledge representation scheme. So we will use a menu system to indicate the relationship among the products, the parts and their corresponding characteristics, the menus consist of the following parts (the overall relationship between menus are as shown in Fig 2.:

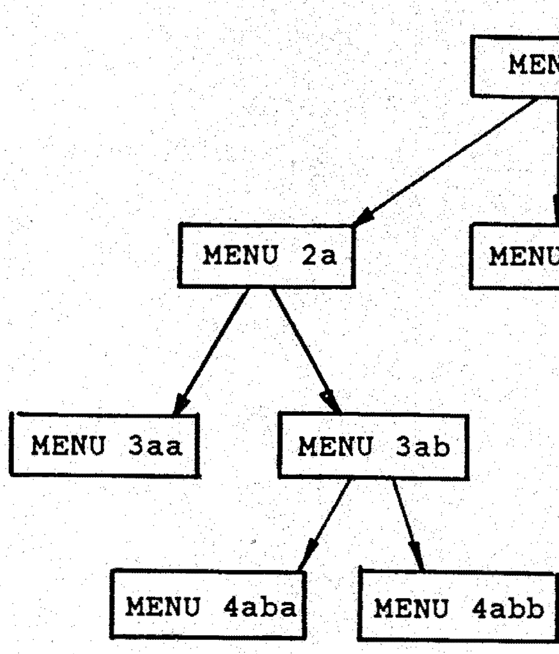


FIGURE 2
MENU STRUCTURE

a. MENU 1... The set of products. In this menu all possible products will be included.

b. MENU 2X... Function area of products. In this menu we will divide the product into its function areas. Here the X (a,b,c) indicates the products in menu 1 would be product a, or product b, ... So we can see there are is a relationships between Menu 1 and Menu 2 (ie. Menu 2 is a member of Menu 1). The remainder of the menus have a similar relationship.

c. MENU 3XY... The set of component part of products (Menu 3XY). In this menu we will subdivide the function area into component parts, with Y indicating the function area in Menu 2.

d. MENU 4XYZ... The critical characteristics for each part or part family (Menu 4XYZ). In this menu we will describe the part by its geometry feature, manufacture feature and marketing information feature. Here Z represents the corresponding selection made in Menu 3.

2. The relationships between part geometry and machine characteristics are identified by the size (usually dia and length), surface finish, tolerance, material to be used and so forth as we standardized surface finish and tolerances:

a. The surface finish is classified into grades A, B, C,... where

A = 32 RMS
B = 64 RMS
C = 125 RMS

b. The tolerances were classified into A, B, C,... grades, where

A = +/-0.0003 in
B = +/-0.003 in
C = +/-0.001 in

3. The sample of rules for these relationships:

```
Rule 1  IF Dia <= 1 4/5 in
        and Length <= 4 in
        and Surface Finish is C
        and Tolerance is C
        and Material is 6061-T6
        THEN Machine = TMC2M

Rule 2  IF Dia  <= 1 5/8 in
        and Length <= 4 in
        and Surface Finish is A
        and Tolerance is A
        and Material is 6061-T6 or 7075-T351 or
            2021-T3
        THEN Machine = GS42

Rule 3  IF Dia <= 1 3/16 in
        and Length <= 2 in
        and Surface Finish is B
        and Tolerance is B
        and Material is 2021-T3 or 2075-T351
        THEN Machine = C29

Rule 4  IF Dia <= 1 1/16 in
        and Length <= 3 in
        and Surface Finish is A
        and Tolerance is A
        and Material is 6061-T6
        THEN Machine = MS25

Rule 5  IF Dia <= 1 5/8 in
        and Length <= 4 in
        and Surface Finish is B
        and Tolerance is A
        and Material is 2075-T351
        THEN Machine = TMC2
etc.  .....
```

4. Once the machine is selected, the next step is to select the complete process. This is determined by the part features, e.g., finish process, time constraints and quantity requirements.

Examples of the processes are given below.

a. The standard process:

Process A: MS25-->Brush-->Anodize-->Complete
Process B: TMC2-->Drill Press-->Mill-->Anodize
-->Complete
Process C: TMC2M-->Mill-->Anodize-->Complete
Process D: C29-->Drill Press-->Brush-->Anodize
-->Complete
Process E: GS42-->Anodize-->Complete

b. Part features include:

Holes
... Axial
... Non Coaxial

Flats

Threads
... Internal
... External

Corner Breaks
... Chamfer
... Radii

c. The finish processes are as follows:

Paint
Anodize (black, color, other)
None

The relationships between the machines to be used and the features and processes can be incorporated in Production Rules. Some examples are listed below:

```
Rule 6    IF Machine = MS25
          and Part is "1st erector lens holder"
          and Finish Process is anodize
          and Anodize is black
          and Quantity <= 4200/mo
          and Part Feature is flat
          THEN Process = A.

Rule 7    IF Machine = TMC2
          and Part is "1st erector lens holder"
          and Part Feature is holes
          and Holes is noncoaxial
          and Finish Process is anodize
          and Anodize is color
          and Quantity <= 3200/mo
          THEN Process = B.

Rule 8    IF Machine = TMC2M
          and Part is "1st erector lens holder"
          and Part Feature is flat
          and Finish Process is anodize
          and Anodize is other
          and Quantity <= 1600/mo
          THEN process = C

Rule 9    If Machine = GS42
          and Part is "1st erector lens holder"
          and Part Feature is holes
          and Holes is noncoaxial
          and Finish Process is anodize
          and Anodize is other
          and Quantity <= 2800/mo
          THEN Process = E

Rule 10   IF Machine = C29
          and Part is "1st erector lens holder"
          and Part Feature is holes
          and Holes is noncoaxial
          and Finish Process is anodize
          and Anodize is color
          and Quantity <= 5600/mo
          THEN Process = D
```

5. The next step for our proposed system is to determine if the selected process will conflict with the existing schedule. The knowledge-based system will select the required data from the Honeywell Management System (HMS). If the selected

process and time frame are currently scheduled on HMS for use, then a new process must be selected.

Once the process is determined, the cost data from HMS will be used to estimate the part cost.

E. Example Usage

1. First, we begin from the menu system:

```
------------------MENU 1--------------------
|               Select Products             |
|-------------------------------------------|
|        a) Riflescopes                     |
|        b) Binoculars                      |
|        c) Spotting Scope                  |
|___________________________________________|
```

2. Selecting choice a, produces Menu 2a.

```
-----------------Menu 2a-------------------
|   Select Function Area to be Designed    |
|------------------------------------------|
|           a) Eyepiece                    |
|           b) Erector                     |
|           c) Objective                   |
|           d) Windage / Elevation adj.    |
|__________________________________________|
```

3. Next, selecting choice b, produces Menu 3ab

```
-----------------MENU 3ab-----------------
|      Select the component part for      |
|               Riflescope                |
|-----------------------------------------|
|         a) F LENS CAM HOLDER            |
|         b) F LENS CAM FOLLOWER          |
|         c) ER LENS CAM FOLLOWER         |
|         d) ER LENS CAM SCREW            |
|         e) SCREW, EREC LENS CAM         |
|         f) ST SCREW STK RD 3/16         |
|         g) 1ST ERECTOR LENS HOLDER      |
|         h) 1ST EREC LENS HOLDER         |
|         i) CAM                          |
|         j) CAM TUBE VARX 2              |
|         k) PIVOT TUBE                   |
|                .                        |
|                .                        |
|                .                        |
|_________________________________________|
```

4. Selecting choice g produces Menu 4abg.

```
----------------MENU 4abg---------------
| Identify the Critical Characteristics |
|              for part                 |
|---------------------------------------|
|   a) Size (Dia, Length)               |
|   b) Tolerance                        |
|   c) Surface Finish                   |
|   d) Material                         |
|   e) Finish Process                   |
|   f) Part Features                    |
|   g) Quantity                         |
|   h) Time                             |
|        .                              |
|        .                              |
|        .                              |
|_______________________________________|
```

At this time the user will step through each section, i.e., a, b, c, etc. and answer the computer generated questions. The following shows a typical example:

```
<select a:>
 >Size ?: Dia = <1 in>, Length = <2 in>
<select b:>
 >Tolerance (A, B, C,...) ? <A>
<select c:>
 >Surface Finish (A, B, C, ...) ? <B>
<select d:>
 >Material (list of material) ? <6061-T6> or <2075-T351>
<select e:>
 >Finish Process (list of this process) ? <anodize>
  What kind of anodize (List of anodize) ?<color>
<select f:>
 >Part Feature (List of possible part features) <holes>
  What kind of holes ? <noncoaxial>
<select g>
 >Quantity ? <3000>
<select h>
 >Time <3 month>
```

Using forward chaining, the reasoning process is as follows:

```
Rule2 ==> Rule9 (backtrack) ==> Rule4 ==> Rule6
(backtrack) ==> Rule5 ==>Rule7 ==> Process B
```

So the system will propose process B. After we get the Process B, the knowledge based system will run HMS to check if there any conflict with the existing process within the give time frame of 3 month. If no conflict, The system will finally propose process B and its associated cost.

III. SYSTEM DEVELOPMENT

The following section presents the organizational and project developmental stages for the design and implementation of a Knowledge Based System for riflescope, engineering and manufacturing phases at Leupold & Stevens.

The section covers Project Organization, including an Organizational Chart, Functional Description of the project team members, and a Responsibility Interface Matrix. Also included is a listing of the Developmental Stages of the project and a Preliminary Project Schedule. In addition an analysis follows which presents estimated system developmental engineering costs along with the expected pay-back period.

A. Project Organization

1. General Overview

The organization of a Project Development Team for the development of a Riflescope Design/Manufacturing Knowledge Base System is illustrated on the following Organizational Chart.

The Development Team consists of a Project Manager reporting directly to the Management of Leupold & Stevens, two (2) Knowledge Engineers whose responsibilities include exploitation of the Leupold & Stevens knowledge base, a computer programmer with expertise in programming knowledge base systems, and a data entry whose clerk function is the entering of design and manufacturing information obtained by the Knowledge Engineers into a data base.

In addition the team consists of Leupold & Stevens Experts from Engineering, Manufacturing, Marketing, and Sales, who possess the existing knowledge within the company, and an Advisor with expertise in the development of Knowledge Base Systems. An elaboration of the qualifications roles, and responsibilities of the team are given in Sections III.A.2 & III.A.3.

2. Organization Chart

Figure 3 shows the proposed project team organizational hierarchy.

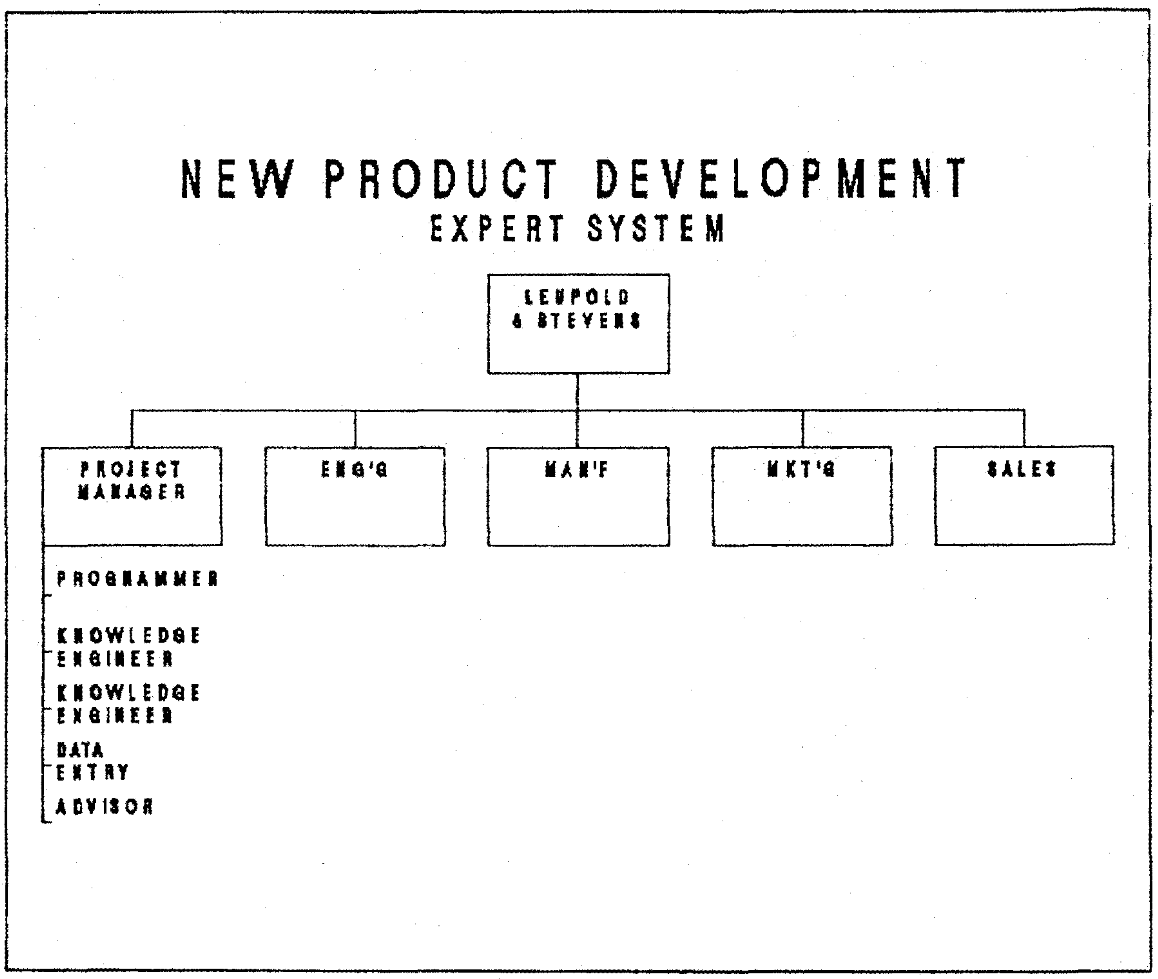


Figure 3.

3. Functional Descriptions

a. Project Manager

The Project Manager is a staff member of Leupold & Stevens with a working understanding of knowledge base systems and a thorough knowledge of both the products and design/manufacturing processes of the company.

The Project Manager's functions will include:

- Interfaces directly with Management
- Directs team members
- Develops & monitors Project Budget and Schedule
- Reviews, approves, modifies questions developed by the Knowledge Engineers
- Reviews, approves, modifies response synthesis

b. Knowledge Engineers

Two (2) Knowledge Engineers will be required for the projects. These individuals must be system analysts having expertise in manufacturing methods, and knowledge base systems. Given the qualifications it is anticipated these individuals will be contract employees hired specifically for this project.

Functions of the Knowledge Engineers will include:
- Develops questions for Leupold & Stevens Experts
- Interviews Experts
- Develop and collects Knowledge base
- Synthesize responses
- Develop the software design for Computer Programmer

c. Programmer

The Computer Programmer will take the software design developed by the Knowledge Engineers and prepare the program to operate the system.

It is recommended that besides being a qualified computer programmer this position in addition be filled by an individual with an understanding of knowledge base systems. As such it is anticipated the position will be filled by a contract employee.

d. Data Entry Clerk

The Data Entry Clerk will be a staff member of Leupold & Stevens capable of entering data obtained the Knowledge Engineers into a computer as well as assisting them interview the Experts.
Duties to include:

- Assists Knowledge Engineers
- Enters knowledge base data

e. Leupold & Stevens Knowledge Personnel (Experts)

This group is the collective body of Leupold & Stevens staff personnel, knowledgeable of the engineering design, manufacturing processes, marketing, and sales functions involved in the total production effort to produce a product. Their function is the transference of their system knowledge to the knowledge engineers.

f. Advisor

The Advisor is an expert in knowledge base systems and manufacturing processes. His function will be providing additional guidance and counsel throughout the project as required.

B. Developmental Stages

1. Project Conceptualization
   a. Problem Identification & Definition
   b. Knowledge Base Identification
   c. Project Goal & Objective Statement

2. Preliminary Discussions with
   a. Management
   b. Engineering
   c. Manufacturing
   d. Marketing
   e. Sales

3. Refinement of Goals

4. Budget & Schedule Development

5. Report to Management
   a. Project approval
   b. Project modifications

6. Knowledge Base Research
   a. Understanding of design & manufacturing processes by Knowledge Engineers
   b. Written documentation reviewed & analyzed
   c. Interviews with Leupold & Stevens Experts
   d. Documentation of Knowledge Base

7. Synthesis
   a. Convert interviews into coherent set of rules
   b. Resolution of conflicting rules

8. Data Entry

9. Prototype Development & Operation

10. Prototype Verification & Review

11. Prototype Modifications & Retesting

12. Production System Development

13. Training

14. System Integration into Production

15. Monitoring

C. Responsibility Interface Matrix

Developmental Stages	A	B	C	D	E	F	G
Project Conception	1	2			2	2	
Preliminary Discussions	1	2			2		
Goal Refinement	1	2			2	2	
Budget & Schedule	1	2			2	2	3
Report to Management	1	2					
Management Review/Approval	4						1
Knowledge Research	4	1		2	2	2	5
Synthesis	4	1			2		5
Data Entry Clerk	3	2	2	1			
Prototype Development	3	2	1			2	4
Prototype Testing	3	1	2		2		4
Production System Development ..	3	2	1			2	4
Training	2	1					3
System Integration	2	1					3

Legend:

A... Project Manager
B... Knowledge Engineer
C... Programmer
D... Data Entry Clerk
E... L.& S. Experts
F... Advisor
G... L.& S. Management

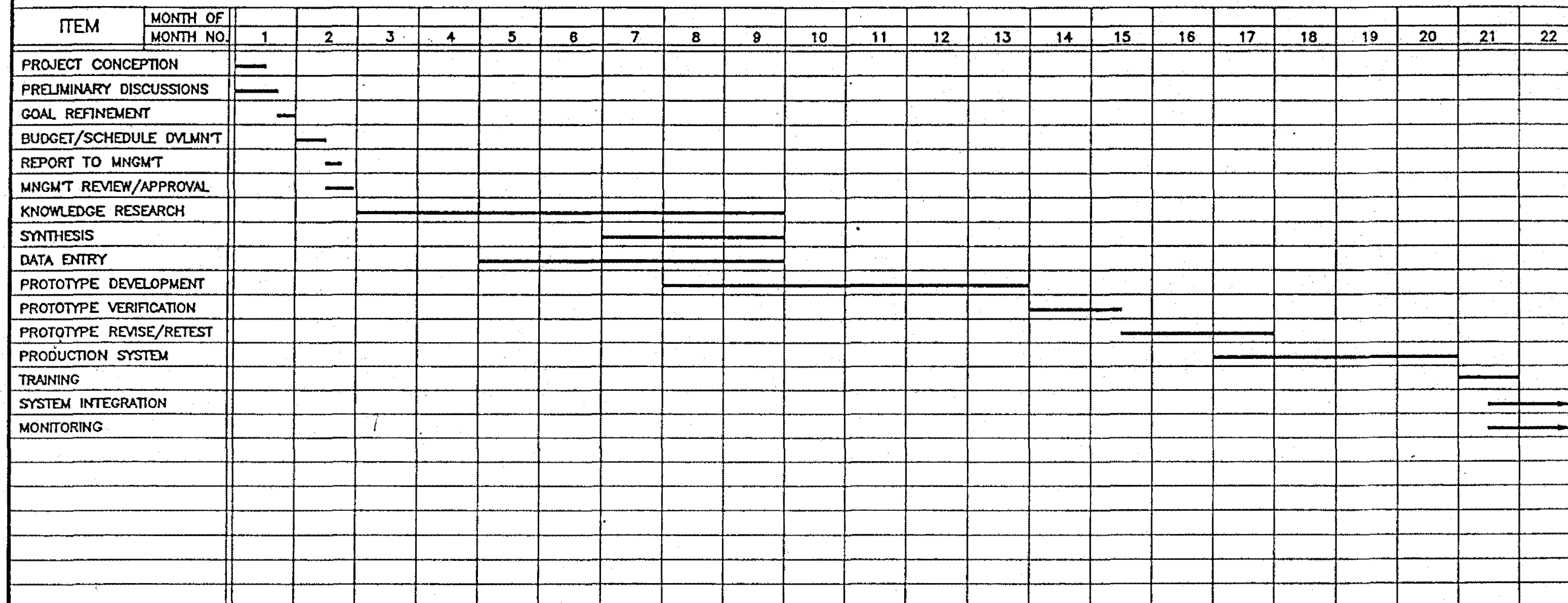
1... Primary Responsibility
2... Support Responsibility
3... Approval Responsibility
4... Notification Required
5... Occasional Notification Required

D. Preliminary Project Schedule

The following project schedule is a time scale, graphical representation of the preceding project developmental stages.

The total project is anticipated to last 20 months from project conception to system integration, followed by a continued monitoring and updating of the data base as required.

PROJECT SCHEDULE



PROJECT SCHEDULE

KNOWLEDGE BASED SYSTEM
RIFLE SCOPE DESIGN
LEUPOLD & STEVENS

EMGT 510KB.52590.1

E. Cost/Pay-Back Analysis

1. Projected Developmental Costs .

a. Staffing

Title	No.x	Mo's x	hr/mo x	$/hr	=	$ Total
Project Mgr	1	20	173	41	=	141,860
Knowledge Engr's	2	20	173	75	=	519,000
Programmer	1	13	173	75	=	168,675
Data Entry Clerk	1	5	173	35	=	30,275
Advisor	1	4	173	75	=	51,900
L & S Experts	5	2	173	41	=	70,930

b. Computer Hardware/Software 20,000

c. Office Space... Provided by L.& S. 0

d. Miscellaneous supplies & contingencies 80,000

Total $1,082,640

2. Projected Pay-Back

a. Typical average scope eng'g/design:

(3) Dsg'n Engg's @ 2,000 hrs total @ $40/hr = 80,000
(4) Man'f Engg's @ 6,000 hrs total @ $34/hr = 204,000

Total = $284,000

b. Total projected yearly savings @ an estimated 40% time savings per project

Design Engg's 40%(2000 x 40) = 32,000
Man'f Engg's 40%(6000 x 34) = 81,600

Total = $113,600

c. Savings per scope $170,400

d. Total savings per year @ (3) scopes/yr = $511,200

e. Projected Pay-Back = 1,082,640 / 511,200 = 2.1 yrs

3. Staffing requirements in Section 1. are estimated based on the Constructive Cost Model, calculated using the following formula:

$$MM = 2.4(KDSI)^{1.05}$$

Where: MM = Project development man months required.

KDSI = Thousands of delivered sources instructions.

= (1500 x 20)/1000

= 30

based on a system with 1500 rules each with 20 delivered sources instructions.

Therefore: $MM = 2.4(30)^{1.05}$

= 85 man months

APPENDIX

Type of component	Units per Product	Product Design Hours/unit	Process Design Hours/unit	Process $/unit
Machined parts	75	16	48	3000
lenses/prisms	4	8	2	600
Vendor parts	14	8	2	250
Adhesives/ lubricants	4	2	8	50

TABLE 1
PRODUCT COMPOSITION

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