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Lecture Notes on Requirements Elicitation

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Review and Approval

This report has been reviewed and is approved for publication.

FOR THE COMMANDER

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Lecture Notes on Requirements Elicitation

Abstract: Requirements elicitation is the first of the four steps in software requirements engineering (the others being analysis, specification, and validation). Software engineers use several elicitation techniques. To facilitate teaching these techniques, materials are provided to support an introductory lecture and four lectures on specific techniques: joint application design, brainstorming, interviewing, and the PIECES framework. A role-playing exercise is provided that allows students to experience each of the techniques. Information for instructors includes educational objectives, pedagogical considerations, additional exercises, and a bibliography.

Preface

Requirements engineering (consisting of requirements elicitation, analysis, specification, and validation) is an important aspect of any engineering project, including software engineering. In college and university computer science programs, instructors usually create the requirements specification; students are rarely involved in the process. It is even more rare for students to be taught the specific techniques that software engineers use for requirements elicitation. This can probably be attributed to the absence of these techniques from most computer science textbooks and the lack of familiarity with these techniques on the part of instructors.

This package of educational materials addresses these problems. It provides five student-oriented *lecture notes* documents to augment existing textbooks:

- Introduction to Requirements Elicitation
- Requirements Elicitation Using Joint Application Design
- Requirements Elicitation by Brainstorming
- Requirements Elicitation by Interviewing
- Requirements Elicitation Using the PIECES Framework

These documents can also be used by instructors as overviews of requirements elicitation and the four techniques.

The package is organized in three parts. The first is information for instructors. It begins with educational objectives for the lectures and a discussion of pedagogical considerations. Next is the description of a role-playing exercise that can be used to give students an initial experience with requirements elicitation using the four different techniques. Additional exercises and a list of references are also included.

The second part of the package consists of the five lecture notes documents. Each is a stand-alone document intended to be photocopied and distributed to the students.

The third part of the package contains masters for the student documents needed in the role-playing exercise and masters for making overhead transparencies.

Much of the material in this package is based on the course *Software Requirements Engineering* in the SEI Continuing Education Series. Gregory Zelesnik was the course designer and producer, and Sridhar Raghavan developed and delivered the segment of the course on requirements elicitation.

Comments on these materials are solicited. They may be directed to the Educational Products Program at the SEI, or sent via electronic mail to education@sei.cmu.edu.

Information for Instructors

1. Objectives

The overall objectives of the materials are to give students an understanding of the concepts of requirements elicitation and a minimal level of skill in using one or more specific requirements elicitation techniques.

1.1. Introduction to Requirements Elicitation

The objectives of this lecture are to enable students to

- understand the requirements engineering phase of software engineering, including requirements elicitation, analysis, specification, and validation;
- describe the different outcomes of good and poor requirements elicitation processes;
- describe and recognize the underlying difficulties of requirements elicitation;
- explain several generic categories of requirements elicitation techniques;
- identify several specific requirements elicitation techniques.

1.2. Requirements Elicitation Using Joint Application Design

The objectives of this lecture are to enable students to

- identify the underlying difficulties of requirements elicitation that are addressed by the Joint Application Design technique;
- describe in general terms how to elicit software requirements using the "JAD/Plan" part of Joint Application Design;
- identify the six kinds of participants in JAD/Plan sessions and describe their roles;
- identify and describe the customization, session, and wrap-up phases of JAD/Plan;
- describe the five classes of high-level requirements that are normally addressed in the JAD/Plan process.

1.3. Requirements Elicitation by Brainstorming

The objectives of this lecture are to enable students to

- identify the underlying difficulties of requirements elicitation that are addressed by the brainstorming technique;
- explain the brainstorming technique, including the generation and consolidation phases;
- explain Osborn's four rules for brainstorming sessions;
- identify the participants in a brainstorming session and their roles.

1.4. Requirements Elicitation by Interviewing

The objectives of this lecture are to enable students to

- identify the underlying difficulties of requirements elicitation that are addressed by the interviewing technique;
- describe the major steps and protocols in the interviewing process;
- give examples of the kinds of questions that should be prepared in advance of a requirements elicitation interview;
- describe several of the kinds of errors that can occur in an interview and explain how to recover from them.

1.5. Requirements Elicitation Using the PIECES Framework

The objectives of this lecture are to enable students to

- identify the underlying difficulties of requirements elicitation that are addressed by the PIECES framework technique;
- explain how using the PIECES framework augments general interviewing techniques;
- explain the six categories of requirements issues whose names are represented in the acronym "PIECES";
- give examples of the kinds of questions that might be asked to elicit requirements in the six categories.

2. Pedagogical Considerations

These materials are intended to be used either in a one-semester undergraduate course in software engineering or in a graduate course focusing on the early software life-cycle phases (requirements engineering and design). They may also be useful in other computer science courses that have a significant programming project, such as a compiler design or database systems course.

The material in the first lecture notes document, "Introduction to Requirements Elicitation," should provide sufficient background for an instructor preparing a single overview lecture on elicitation. (The instructor may want to read the other four lecture notes documents as well, even if the techniques will not be presented in detail.) To prepare a lecture that is more than just an overview, the instructor should also read some of the references listed in section 5 below.

Likewise, students should be able to gain a high-level understanding of the nature of requirements elicitation from reading the introductory lecture notes, and they can gain a superficial grasp of the techniques from reading the other lecture notes.

Learning to *use* the four techniques effectively is a different matter. The techniques can be taught and to some extent learned through lectures and reading, but skill in using them comes only through practice. If the instructor's objective is to give students that skill, then reading the four lecture notes is not enough. Additional background reading is necessary, and activities must be designed to give students the necessary practice, such as those in sections 3 and 4 below.

Section 3 describes a role-playing exercise in which the students act as the various participants in a requirements elicitation activity. Its objective is to develop the student's ability to apply one or more of the requirements elicitation techniques. Although the exercise is admittedly artificial, it can help establish in the minds of the students an appreciation of the difficulty of requirements elicitation and the need for additional training and practice in the techniques.

It is worth noting that requirements elicitation is more a *social* activity than a precise *technical* activity. This sometimes means that instructors are less comfortable teaching it and students are less comfortable learning it than is the case with the technical activities of computer science. Nevertheless, it is an important and necessary aspect of software engineering, and one that helps distinguish software engineering from computer science.

3. A Role-Playing Exercise

Requirements elicitation normally involves several developers (the requirements analysts and software engineers) and several customers (the buyers or users of the software). Each of these persons brings different knowledge and skills to the effort. The exercise described here allows students to experience the elicitation process in a group that is structured to ensure differences in knowledge on the part of the participants.

This exercise also allows different groups of students to gain experience with different elicitation techniques: Joint Application Design, brainstorming, interviewing, and the PIECES framework. The outcomes of the different techniques can be compared as part of a post-exercise discussion, and the students can draw conclusions about the relative effectiveness of the techniques.

To accomplish these goals, each student is asked to play a particular role in the process: customer, user 1, user 2, requirements analyst, or software engineer in the Software Services Group of the fictional Zooming Airplane Company. Each student is given a description of the software organization, a description of an avionics application within that organization, and a customer statement of need for a system software product needed by the application developers to support their development process. In addition, each student is given a description of the role he or she will play, specifying the body of knowledge about the software product that may be used during the exercise. These descriptions appear in section 3.3 below and as stand-alone documents near the end of this package.

3.1. Instructor's Guide to the Exercise

As the instructor, you need to take several steps to prepare for and conduct the exercise. These are described below.

3.1.1. Preparation

To prepare for the exercise, divide the class into groups of four or five students each, depending on the elicitation technique being used:

Technique	*Students*
Joint Application Design	5
Brainstorming	5
Interviewing	4
PIECES framework	4

It is important that all roles be played. If the class cannot be divided exactly this way, the group sizes can be reduced by one by asking a student to play the roles of both the customer and the second user (see the role definitions below). The size of the group using the Joint Application Design technique can be increased to six if necessary, with the extra student playing the role of session leader.

Inform the students of their group assignments and the elicitation technique to be used by each group. Either you or the students themselves should decide which student will play which role. Each student is then given copies of:

- the description of the Software Services Group
- the description of the application software project
- the customer statement of need

For the groups that will use the Joint Application Design and brainstorming techniques, each student is also given the description of the role he or she will play. For the groups that will use the PIECES framework and interviewing techniques, students receive the role descriptions *during* the exercise. It is important that these student not see the role descriptions ahead of time, so ask students in the other groups *not* to share their descriptions.

The preparation time for the role play should include approximately two hours of independent time for each student. For a class that meets two or three times per week, it is usually appropriate to hand out the role-playing materials during the class period immediately prior to the period in which the exercise is conducted.

We assume that lectures, discussions, and readings on the four techniques have already been completed. However, it is useful for members of each group to reread the reference material on the technique they will be using. The exercise descriptions include specific reading assignments, although you may wish to substitute other readings if the suggested books are not readily available.

Ask the students to prepare for their roles carefully. To make the exercise as realistic as possible, students should not share role information. Encourage the students to embellish the roles in creative ways, such as adopting the personality, attitudes, and attire of the persons they are portraying. The students should also be encouraged to bring their own knowledge to the roles wherever appropriate.

The exercise is designed to require 75 minutes of class time. For courses that do not meet this long each day, try to schedule a special class period or laboratory of this length.

One or more rooms for the exercise should be scheduled and prepared. Ideally, each student group will sit around a table and have access to a blackboard, whiteboard, or flip chart. Arranging student desks in a circle is also acceptable.

3.1.2 The Role-Playing Session

The exercise is conducted in two steps, a preparatory step and an implementation step. The time is allocated in this manner:

Technique	*Preparatory Step*	*Implementation Step*
Joint Application Design	15 minutes	60 minutes
Brainstorming	15 minutes	60 minutes
Interviewing	35 minutes	40 minutes
PIECES framework	35 minutes	40 minutes

At the start, distribute the appropriate exercise description to each group. Ask the students to read the descriptions and begin the exercise immediately. During the implementation step, wander around the room to answer questions. Avoid actually participating in any of the students' elicitation sessions, but support each of them by answering questions and clarifying details with respect to the elicitation techniques themselves. Keep in mind that the goal of the exercise is to expose the students to a real requirements elicitation activity rather than to get a perfect set of requirements. Support their learning of the techniques.

3.1.3. Follow-Up Activities

The exercise should be followed by a discussion. Ideally, it should be conducted immediately after the exercise, but in most cases it will have to be done in the subsequent class period. If time permits, make copies of the requirements documents from each group for distribution to the other groups.

To begin the discussion, ask each student group to spend up to five minutes summarizing the requirements they elicited. Then lead a discussion to compare and contrast these sets of requirements. Use the set of requirements provided in section 3.4 below as the basis for your participation in the discussion.

Then ask each group to spend another five minutes relating any good experiences, problems, and difficulties they encountered with the elicitation techniques during the exercise. Compare and contrast these experiences with those of the rest of the class. Try to come to consensus on which techniques worked and why, as well as which techniques fell short.

3.2. Descriptions of the Exercise

This section contains four descriptions of the exercise, one for each requirements elicitation technique. These same descriptions, formatted as stand-alone documents for students, appear near the end of this package.

3.2.1. Exercise Using Joint Application Design

Participant Roles

Customer
User 1
User 2
Requirements Analyst
Software Engineer
Session Leader (optional)

Preparation

Read chapters 3, 4, and 6 of [August91].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.
Read the description of your assigned role.

Description

Your group is to perform a requirements elicitation activity using the Joint Application Design (JAD) technique. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system. Due to time restrictions, an entire Multiterm JAD cannot actually take place. Therefore, the group should concern itself with performing a JAD/Plan session phase only.

You will be given 15 minutes to prepare. During this time, reread the description of your assigned role and start expanding on it. If you are the customer or a user, jot down your ideas about the requirements and expand upon the ideas in your role description. If you are the customer, plan what you will say during the JAD/Plan session phase orientation.

A JAD/Plan session phase normally consists of eight tasks through which the session leader guides the participants. Again, due to time restrictions, the group should concern itself with performing only five of them:

- conduct JAD orientation
- define requirements
- bound system scope
- document issues and considerations
- conclude session phase

If no student has been designated to play the role of session leader, that role should be played by the customer. The requirements analyst will document the agreed-upon detailed requirements, and the software engineer will document the issues and considerations.

Conduct JAD orientation: During this task, the session leader reiterates the main points of this description to familiarize the participants with the procedures and to define terms such as *issues* and *considerations*. [5 minutes]

Define requirements: For this task, follow the normal procedures for a JAD/Plan session, except change the category *Anticipated benefits* to *General requirements*. Don't concern yourself with anything outside the scope of the system itself, such as business and legal issues. Focus on the requirements for the software system, and make them as detailed as you can in the time allotted. Give all participants a chance to introduce new ideas. [40 minutes]

Bound system scope: For this task, the session leader leads the participants through a clarification of the scope of the system; the generated requirements are reevaluated with respect to that scope. Any requirements falling outside the scope are removed from the list of requirements and documented separately by the requirements analyst. [10 minutes]

Document issues and considerations: This activity is an ongoing one. The software engineer documents each of these as they are identified during the JAD/Plan session phase.

Conclude the JAD/Plan session: The session leader reviews the accomplishments of the JAD/Plan session with the participants. [5 minutes]

3.2.2. Exercise Using Brainstorming

Participant Roles

Customer
User 1
User 2
Requirements Analyst
Software Engineer

Preparation

Read pages 69-85, 96-103, and 107-113 of [Clark58].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.
Read the description of your assigned role.

Description

Your group is to perform a requirements elicitation activity using the brainstorming technique. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system.

You will be given 15 minutes to prepare. During this time, reread the description of your assigned role and start expanding on it. If you are the customer or a user, jot down your ideas about the requirements and expand upon the ideas in your role description.

You will have one hour to perform the brainstorming activities. Spend 20 minutes in the idea generation phase and 40 minutes in the consolidation phase.

For the idea generation phase, be creative but phrase the ideas in terms of requirements for the Multiterm system. If your ideas describe features, capture them in terms of functional requirements. If your ideas describe responses, capture them as behavioral requirements. Designate one person in the group to write down each complete idea on a single list.

During the consolidation phase, the requirements analyst reads through the list of requirements (ideas) one at a time. The entire group then classifies each requirement in two ways: first by practicality (good ideas that can be investigated immediately, ideas that need long range or involved study, and unusable ideas) and then by priority (ideas that absolutely must be implemented, those that are desirable but not urgently needed, and those that should be added only if time and money permit). Any new ideas generated in this phase should be considered for addition to the final list.

3.2.3. Exercise Using Interviewing

Participant Roles

Customer
User 1
User 2
Requirements Analyst

Preparation

Read pages 64-78 of [Bingham41].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.

Description

Your group is to perform a requirements elicitation activity using the interviewing technique. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system.

You will be given 35 minutes to prepare. For the first 30 minutes, discuss and write down sample questions that an interviewer might ask a customer and a user. Develop two lists of questions, one for the customer and one for the user. Deliberate not only about the questions themselves, but also the sequencing of the questions.

During the last 5 minutes of the preparation time, decide which role each group member will take and then distribute the descriptions of the roles. Study your role for the remainder of the time, expanding on your role and on the requirements enumerated in the description.

Next, the person playing the role of the requirements analyst conducts three ten-minute interviews, one with each of the other participant roles. The interviews can be done in any order, but each must be done in the absence of the other participants. Since the first interview will begin only five minutes after the descriptions of the roles are distributed, the first person interviewed will have to develop his or her role as the interview progresses. The others will have a chance to develop their roles before their interviews.

The interviewer starts with the questions developed during the preparation (in the interest of time), but he or she may generate new ones as the interviews progress. The interviewer writes down any elicited requirements on a separate sheet of paper, in complete sentences. After the interviews are complete, the interviewer should take ten minutes to finish writing down and organizing the elicited set of requirements.

3.2.4. Exercise Using the PIECES Framework

Participant Roles

Customer
User 1
User 2
Requirements Analyst

Preparation

Read pages 114-124 of [Wetherbe84].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.

Description

Your group is to perform a requirements elicitation activity using the PIECES framework. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system.

You will be given 35 minutes to prepare. For the first 30 minutes, discuss and write down sample questions that an interviewer might ask a customer and a user, using the PIECES framework as a start. Develop two lists of questions, one for the customer and one for the user. Deliberate not only about the questions themselves, but also the sequencing of the questions.

During the last 5 minutes of the preparation time, decide which role each group member will take and then distribute the descriptions of the roles. Study your role for the remainder of the time, expanding on your role and on the requirements enumerated in the description.

Next, the person playing the role of the requirements analyst conducts three ten-minute interviews, one with each of the other participant roles. The interviews can be done in any order, but each must be done in the absence of the other participants. Since the first interview will begin only five minutes after the descriptions of the roles are distributed, the first person interviewed will have to develop his or her role as the interview progresses. The others will have a chance to develop their roles before their interviews.

The interviewer starts with the questions developed during the preparation (in the interest of time), but he or she may generate new ones as the interviews progress. The interviewer writes down any elicited requirements on a separate sheet of paper, in complete sentences. After the interviews are complete, the interviewer should take ten minutes to finish writing down and organizing the elicited set of requirements.

3.3. Project Descriptions and Student Roles

This section contains the information that is given to the students for the exercise:

- a description of the software organization that is the setting for the project
- a description of the software project that has created the need for the new software
- the customer's statement of need for the new software
- background information for the student roles: customer, user 1, user 2, requirements analyst, and software engineer

These same descriptions, formatted as stand-alone documents for students, appear near the end of this package. Each of the role descriptions includes the following instructions to the students:

> *Note: You are to use this role to guide your actions during the role-playing exercise. The description provides only high-level guidance, however, and you are encouraged to embellish the role using your own experience and the background materials provided to you in this exercise.*

3.3.1. The Software Services Group

The Software Services Group within Zooming Airplane Company is responsible for the development of all new application, environment, and system-level support software for the entire company. The group has three divisions that operate autonomously, providing the software for various customers within the company (see Figure 1 on page 12). Each division is headed by a director, but right now one of the divisions is headed by a program manager who is really the deputy acting as director. The vice president in charge of the Software Services Group is David Greene, who has been at the site for five years and in charge of this particular group for one year. Rumor has it that he is looking forward to retirement in two years. Greene comes from a military background. He served in the Air Force for more than 20 years, attaining the rank of Captain. His background is in logistics, but he has worked in the computer field for the past eight years. He was previously director of the Environments Division within the group.

The Environments Division

This division is the smallest division in the Software Services Group and is headed by the program manager of the Case Tools program, Arnold Frost. He has been in his current position for about a year after being promoted into it when Greene was promoted to be the vice-president in charge of the group. He is acting as deputy director until a suitable replacement can be found. Frost spent his first ten years in the Army in a combat support role, and then he retired from the Army and switched over to the computer field for a total of six years of computer operations experience. He only understands the basics of operating a computer but is an excellent program manager. Arnold Frost has his sights set on becoming the permanent division director of the Environments Division. The Environments Division is responsible for maintaining a standard computing environment within the remaining divisions. It is largely composed

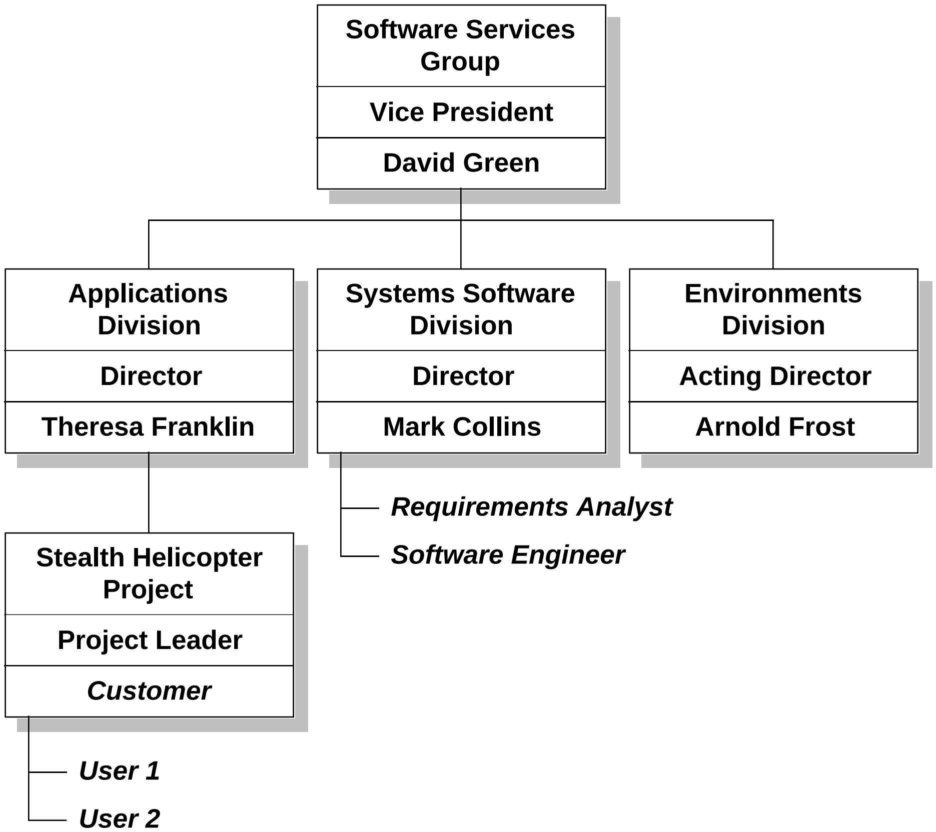

Figure 1. Organization chart for the Software Services Group

of computer operations specialists, ranging from general computer operators to specialized experts such as telecommunications specialists. The division employs roughly 20 software engineers, whose responsibilities entail writing software to facilitate the integration of CASE tools, purchased from different vendors, into the standard computing environment.

The Applications Division

This is the largest division in the Software Services Group and is headed by Theresa Franklin, who has been at the site for three years. An engineer by training, she has been working in the computer field for about 15 of her 20 years of experience. She was promoted to the level of division director when the previous director retired, approximately two months ago. This division handles all the applications for the company. In particular, the division is responsible for the avionics applications for each of the airplanes manufactured by the company.

The Applications Division enjoys a very good reputation within the group. It is composed of approximately 90 software engineers of various levels of experience, and they have a reputation of developing applications that meet their specifications on time and with only minor cost overruns. Part of the success of the division can be attributed to the extensive use of CASE tools and system-level support software within the group's standard computing environment. The Applications Division either purchases commercial off-the-shelf (COTS) support software or has it custom made by the System Software Division if no COTS software can satisfy the particular need. The Applications Division then works with the Environments Division to integrate the support software into the standard computing environment for the group.

The System Software Division

Because of the complex nature of the software developed by the Applications Division, COTS software that can meet their special support software needs is not generally available. Therefore, the Applications Division subcontracts to the System Software Division to have much of their support software custom made. The System Software Division, the second largest division in the Software Services Group , is headed by Mark Collins, who has only recently become involved in the computer field. He spent most of his 20-year career as the Chief Liaison Officer at a Strategic Air Command (SAC) Air Force base. He retired from the Air Force three years ago and has been working in the computer field since. Collins was bitten by the computer bug while in college, and has always been interested in software systems; so after retiring from the Air Force he acquired a master's degree in software engineering.

This division is composed of approximately 45 computer scientists and software engineers of various levels of experience, although it is starting to attract a significant number of younger staff. The division is viewed as being composed of largely inexperienced software “hackers.” They have a reputation of being difficult to work with and of not always delivering what was originally requested by the customer. In addition to this, they often miss delivery deadlines and run over budget.

3.3.2. The Stealth Helicopter Avionics Project

The avionics system of the new Stealth Helicopter is being developed by the Stealth Helicopter Project within the Helicopter Program of the Applications Division. It is being developed in Ada and is composed of multiple independent threads of execution (programs), each dedicated to a single microprocessor in the helicopter. The threads of execution run simultaneously, communicating with each other to complete their tasks.

Early in the design of the system, project management decided to develop the software on a VAX 8600 minicomputer and later port it to the target microprocessors within the helicopter. Their rationale was that, because Ada is a standard language, porting problems would be small in comparison to the problems and cost associated with testing and debugging the system on the target hardware. Project management, however, also knew that the members of the Stealth Helicopter Project did not have the appropriate computing equipment to perform adequate integration testing of the multiple threads of execution in the system.

To perform integration testing on the VAX 8600, an engineer would need the capability of running, monitoring, and debugging all of the independent threads of execution simultaneously on the minicomputer. This capability can easily be provided on a VAXStation II workstation running the same version of VMS operating system and using the same Ada compiler as those used on the VAX 8600. In this scenario, the engineer has access to multiple windows from the same keyboard. Each independent thread can be set up to execute in one of the windows, allowing the engineer to test and debug the entire application from a single computer. However, because of the prohibitive cost associated with giving every engineer a workstation, only one in ten Applications Division staff members has one. The other nine staff members have VT220 *paging* terminals hooked to a VAX 8600 running VMS. Since Digital Equipment Corporation (DEC) does not supply VMS owners with even a primitive windowing capability for such terminals, the only way an engineer without a workstation can test the avionics system is to go to a place where there is more than one VT220 terminal and set the tests up from as many VT220 terminals as is necessary. Running such tests this way, however, is next to impossible with only one or even a few engineers.

To solve this problem, the Applications Division investigated the availability of software that might provide their staff with a primitive windowing capability for VT220 terminals. After having no success in the commercial market, the Applications Division decided to subcontract to the System Software Division to solve this problem. The System Software Division accepted the contract and set up a project called Multiterm within the Operating Systems Program. When the project was established and a sufficient number of staff was hired, the Applications Division presented the Multiterm Project with a statement of need. This officially signaled the start of the project.

3.3.3. The Customer Statement of Need

The Stealth Helicopter Project of the Applications Division, hereafter referred to as the *contractor*, has the need to run, monitor, and debug multiple, autonomous, simultaneously executing, communicating Ada threads of execution (programs) from a single VT220 terminal on a VAX 8600 running VMS version 5.1.

The Multiterm Project of the System Software Division, hereafter referred to as the *subcontractor*, will provide a software system, hereafter referred to as the *software*, that enables the contractor to have this capability.

The software provided by the subcontractor must have a decidedly VMS-like look and feel; must have an unobtrusive user interface; must allow the customer to operate the VMS symbolic debugger, the VMS EDT and TPU editors, the VMS mail program, and other VMS applications while debugging application software; and must exhibit the same keystroke-to-display response time that VMS already provides typical user sessions on a VAX 8600 from a VT220 terminal. The software provided by the subcontractor must also allow the customer to supply input (from the keyboard) to and view the output from any application program currently being run, monitored, or debugged.

3.3.4. The Role of the Customer

You are the customer. The customer for the Multiterm system is the technical team leader for the Stealth Helicopter Project within the Applications Division. You have been with the Applications Division of the Zooming company for seven years and with the Stealth Helicopter Project since its beginning one year ago. You have 15 years of software development experience on large projects and were awarded the technical team leadership position on the current project as a result of displaying outstanding commitment, leadership, and design and development abilities on your past two projects.

You are a very intelligent, experienced, capable software designer and developer who consistently produces software that meets or exceeds the quality, performance, and functional requirements of the customer. Because of this, you are extremely confident in your judgment and can rarely be persuaded to look at alternatives unless an extremely sound argument is presented. You have the uncanny ability to abstract away from the details of a problem and design a system that not only solves the problem but incorporates cutting-edge technology and innovative features into the solution. However, you evolve a design over time and rarely write it down until you must. Not all ideas come at once, therefore, and sometimes the ideas can even be general and conflicting. The following paragraphs describe your general requirements for the delivered software system.

The capability of the software system must *at the very least* mirror the capabilities provided on the DECStation running DECWindows under VMS version 5.1. This means that the software must support multiple windows on the VT200 or VT300 terminal simultaneously. It must provide the capability of running the DEC symbolic debugger, TPU and EDT editors, and the DEC electronic mail software in any window. This, however, is the minimum requirement. It would be nice to be able to run *all* VMS software and utilities in any window.

The software system must be able to allow creation and deletion of windows. It must be able to allow input to be directed to any desired window. It must be able to connect a desired window to the terminal display so that the user can see output from the process running in that window (i.e., it must support switching among windows).

The user interface should be unobtrusive, and it should present the user with the look and feel of VMS wherever possible. Performance should not be noticeably different from the performance on the DECStation (with respect to keystroke response times).

The software system must be developed in Ada.

You have not thought about these requirements to any lower level of detail. For any question or discussion, your responses should be consistent with your own personal concepts regarding windowing systems, operating systems, dumb terminals, etc.

3.3.5. The Role of User 1

You are a user for the Multiterm software system. You are one of the software developers on the Stealth Helicopter project within the Applications Division. You have been with the Applications Division of the Zooming company for three years and with the Stealth Helicopter project for about six months. You have five years of software development experience on large projects and were given a software development position on the current project as a result of demonstrating tremendous productivity and superior problem-solving skills on your last project.

You are a very intelligent, capable software developer who consistently produces software solutions that are creative, innovative, and elegant. You have a genius intelligence quotient (IQ), are highly productive, and prefer to work alone because you often get impatient with others who do not understand your solutions. Because of this, you are extremely confident in your abilities and are never afraid to experiment with new data structure designs and new algorithms. You utilize every available language construct at your disposal in each of the languages you use to develop software, namely C and Ada. You are often labeled a “hacker,” but your skills are those of a software engineer; your code adheres to strict software engineering principles. You have much respect among your peers and your ideas carry much weight.

With respect to the Multiterm software system, you are not as concerned about basic windowing functionality as you are about using the software to perform integration testing of the Stealth Helicopter avionics software. You are more interested in acquiring functionality that will make the testing not only possible, but also easier. The paragraphs below describe your general requirements for the delivered software system.

You agree with the customer that the capability of the software system must *at the very least* mirror the capabilities provided on the DECStation running DECWindows under VMS version 5.1. However, you desire some more interesting functionality and features. When creating a window under Multiterm, the software system should support starting either the DEC Command Language (DCL) interpreter or a VMS executable image. You do not know if it is possible, but you would like to be able to send keystrokes from the keyboard to more than one window simultaneously. You wish to be able to record input to and output from any and all windows under Multiterm control to keep as logs for debugging purposes. It would also be nice to have the ability to have input scripts to bring a Multiterm session to a predetermined, desired state. Output from windows not attached to the terminal display must not be lost.

You agree with the customer with respect to user interface and performance requirements.

You have not thought about these requirements to any lower level of detail. For any question or discussion, your responses should be consistent with your own personal concepts regarding windowing systems, operating systems, dumb terminals, etc.

3.3.6. The Role of User 2

You are a user for the Multiterm software system. You are one of the software developers on the Stealth Helicopter Project within the Applications Division. You have been with the Applications Division of the Zooming company for six months, and you have just joined the Stealth Helicopter Project. You have two years of software development experience, all within the Zooming company, and were given a software development position on the current project as a result of your experience with VMS. You acquired all of your software development skills in college on DEC VAX systems using VMS, and you have worked on VMS systems since you joined the company.

You are a budding young software developer who shows much promise. You gained high marks in school in all of your software engineering classes. You were hired onto the

Stealth Helicopter project because of your high marks in school and because your two years of software development experience were with Ada, on DEC workstations running VMS. The software that you produced on your last project adhered to the principles of software engineering you were taught in school, and the result was well-structured, well-documented code.

Because you lack software development experience in general, though, your code was not easily integrated with the rest of the system. However, your project manager has every confidence that your skills will improve as you gain experience. The project manager felt that you best represent the typical, intended user of the Multiterm software system and asked that you participate in the requirements definition activities.

With respect to the Multiterm software system, you are concerned about maintaining a VMS look and feel and supporting VMS functionality within the windows under Multiterm control. You would like to see VMS command recall within each window preserved. In fact, if it is possible, you would like to see any VMS command, entered in any window, be recallable and executed in any other window under Multiterm control. You would not like to see borders on the windows; it takes up too much space. You want each window to have full control of the terminal display (each window uses the entire terminal display, overlapping every other window completely). You want to see Multiterm support VMS top-level DCL processes as well as DCL subprocesses in a window. You want the Multiterm commands to be simple sequences of keystrokes, not echoed back to the terminal screen. You want a quick help screen to refresh your memory about these keystroke sequences. You want VMS messages (such as "You have new mail.") to come through Multiterm to processes running under it.

You have many more thoughts about user interface requirements at lower levels of detail. For any question or discussion, your responses should be consistent with your own personal concepts regarding the VMS operating systems, dumb terminals, etc.

3.3.7. The Role of the Requirements Analyst

You are a requirements analyst for the Multiterm Project in the System Software division. You have been with the Zooming company for seven years and with the Multiterm Project since it began three months ago. You have ten years of software development experience on large projects and two additional years of experience as a requirements analyst. You were given your current position on the Multiterm Project as a result of demonstrating superior communication and problem-solving skills on your last project, where you were the principle requirements analyst.

Your undergraduate degree is in mathematics, and you initially gained experience in programming by writing statistical analysis programs in FORTRAN for your assignments in college. When you graduated from school, the job market was tight for mathematicians, but there were plenty of jobs for programmers. Your first job was as a FORTRAN programmer in a telephone company. While you were there, you picked up some limited experience with C. After three years of working with the telephone company, your project delivered its software system and you were laid off because of a lack of available work. At that time, the Zooming company was entering full-scale development on three of its projects and hired you because of your C experience.

Over the next seven years, you were proficient and productive enough to continue to find work within Zooming. You learned Ada and gained much experience in both C and Ada. Over the years, however, you became more interested in the human aspects of software development and less interested in developing code. As a result, you enrolled in a program at the local university to obtain a master's degree in behavioral psychology, and you are about to graduate. Two years ago you applied for and obtained a position as a systems analyst on a management information systems project within the Applications Division. You knew immediately that you had found a home. You became extremely productive because communicating with people was easy and fun, and you did it well. Your first project as a systems analyst was extremely successful in that the delivered software met or exceeded every expectation of the customer and users. You were instrumental in the project's success because you were able to get the customer and users to communicate their needs, and you captured an accurate understanding of them.

Your success inspired you to pursue more requirements-related work within Zooming; you, therefore, learned some requirements elicitation techniques on your own.

With respect to the Multiterm software system, all you know is what you have read from the customer's statement of need; you are, nevertheless, excited to get started on this project. You plan to use one of the requirements elicitation techniques you know to get started with gathering the requirements for Multiterm. You are also confident that your previous development experience will help you resolve technical conflicts that might arise.

3.3.8. The Role of the Software Engineer

You are a software engineer on the Multiterm Project, hired to perform high-level design of the system. You have been with the System Software Division in the Zooming company for four years and were just brought on board the Multiterm Project last week. You have six years of software development experience in all; your first two years were spent writing application programs in the Applications Division at Zooming, which hired you directly from college. You were given a software design and development position on the current project as a result of your knowledge of VMS and the software design skills that you demonstrated on your last project, a software simulator for the embedded computer aboard the Stealth Fighter.

You are a very methodical software designer and developer with a reputation for producing software systems that meet their specifications. You are very thorough, investigating every alternative design and weighing the benefits and risks associated with each. This gives you a reputation for working slightly slower than other engineers, but this is acceptable because you produce systems that work and that contain few errors.

You have read the statement of need supplied by the customer and have done some initial investigation, experimentation, and prototyping in VMS to answer questions that came to mind while reading it. You know that using Ada increases the risk that keystroke-to-display response times will be longer than is acceptable. You know that there are VMS library routines, accessible from Ada programs, that will allow a program to create multiple, dependent subprocesses in VMS. You know that it is possible to open I/O channels to each of these subprocesses via pseudo-terminal device drivers. In short, you know that VMS will support your creation of a windowing system for dumb terminals. The risks are with the performance that Ada will provide.

3.4. Example of the Results of the Exercise

This exercise is based on a project given to a group of students in the Master of Software Engineering program at Carnegie Mellon University. Those students used a form of a group development method similar to joint application design, although its implementation was much more ad hoc. The requirements created by those students are shown below. They are organized into three classes: functional, user interface, and performance requirements.

Functional Requirements

1. The software system shall have the ability to make multiple displays available for use from a single terminal.

2. The software system shall have the ability to start a process running a program specified by the user.

3. The software system shall have the ability to start a process running the Digital Equipment Corporation (DEC) Command Language (DCL) if no program is specified by the user.

4. The software system shall have the ability to bind one display with one process on the host processor system.

5. The software system shall have the ability to record all user input and all process output that occurs during a user session (similar to the SET HOST/LOG capability in the DEC VAX/VMS operating system). The session inputs and outputs shall be stored in a single log file. In addition, the software system shall be able to take such a log file as input to a session and execute the previously recorded user inputs as if they were being typed at the keyboard by the user.

6. The software system shall allow line lengths for both input and output formatting to be determined by the terminal device characteristics.

7. The software system shall support the binding of a defined input stream to a process from a predesignated process.

8. The software system shall support the binding of a defined output stream to a display from a predesignated process.

9. The software system shall provide for editing of typed system commands prior to invocation.

10. The software system shall have the ability to recall, at any arbitrary display, command line input to any other display, including itself, up to the last 20 command lines entered.
11. The software system shall provide for selective broadcast of command lines to multiple processes using a single system command line.
12. The software system shall provide help information compatible with the VMS help utility in terms of the file structure, information format, and interaction style used.
13. The software system help facility shall be accessible to any process running DCL.
14. The software system help facility shall be accessible to any process running the software system.
15. The software system shall provide functionality to terminate any process under its control.

User Interface Requirements

1. The software system shall have the ability to support input and output viewing of multiple processes on DEC VT220 and VT320 terminals.
2. The software system shall provide the ability to select the process to which keyboard input is routed.
3. The software system shall have the ability to have multiple displays updated from their predefined output streams, regardless of whether or not a given display is selected for input from a keyboard.
4. The software system shall require at most one key (any number of keys that can be depressed simultaneously that return a single value) on the keyboard to be bound for its use when the keyboard is connected to displays running other applications. That key shall provide an escape to the system command-processing software.
5. The software system shall provide a means for rebinding the system escape key to any key (or combination of keys depressed simultaneously) that generates a one-byte character code (e.g., any character, digit, or control character). The same binding shall apply to all processes and displays under system control.
6. The software system shall be transparent to processes under its control running:
   - Ada programs using TEXT_IO
   - DCL
   - the VMS symbolic debugger
   - the EDT editor
   - the TPU editor or other editors derived from it (EVE, LSE, etc.)

The behavior of these programs shall appear to be identical to that observed when they are run on an independent terminal device, except for the binding of the system escape key.

Performance Requirements

1. The software system shall support the use of the DEC VT220 and VT320 terminal devices.

2. The software system shall transfer keystroke input to the destination process within 0.5 seconds with the CPU load at 50% of capacity on a VAX 8600 running the VMS operating system, version 5.1 or greater.

4. Small Elicitation Exercises

The role-playing exercise described in the previous section requires a substantial commitment of time, on the part of both the instructor and the students. For that reason, it is perhaps most useful in a graduate-level course on requirements engineering, rather than in a one-semester undergraduate course that covers “all” of software engineering. In this latter setting, smaller exercises are more appropriate. Suggestions for such exercises are described below.

Requirements elicitation by interviewing can be practiced by each student, provided there is a customer to interview. Instructors can often arrange with colleagues, graduate students, or others within the university to play the role of customers. For example:

- Interview a professor to determine requirements for an online electronic gradebook.
- Interview a graduate student to determine requirements for a software system that would support his or her thesis research.
- Interview the appropriate campus administrator to determine requirements for a system that schedules classrooms.

Requirements elicitation by brainstorming can be practiced by small groups of students. The systems to be discussed should be ones that might actually be useful to students, so that they can easily put themselves in the role of users. For example:

- A class electronic bulletin board system that would allow the instructor and the students to present information of value to the whole class.
- A system to permit electronic submission of programming assignments and receipt of instructor’s comments on the programs.
- A personal productivity system, such as an online appointment calendar, “to do” list, or address book.
- A system to keep track of a music collection on records, tapes, and CDs.

The requirements for embedded control systems can sometimes be elicited by observing the behavior of existing systems. For example, students might:

- Observe the operations of an automatic teller machine, a vending machine, or an automobile cruise control to "reverse engineer" the requirements for those systems.
- Observe the behavior of the traffic lights at one or more complex intersections to elicit requirements for a new software-controlled traffic light system.

The requirements for enhancements to existing systems can often be elicited from experienced users using either interviewing or brainstorming. Instructors should choose as the object of such an exercise a system with which the students are very familiar. Examples might be an electronic mail system, word processing system, or text editor.

The results of elicitation exercises are difficult for an instructor to evaluate. Although each exercise may produce a document containing a list of requirements that an instructor can read, the real objective of the exercise is to build the students' requirements elicitation skills. To determine whether this objective has been met requires observation of the exercise. To some extent, this can be done.

One approach is to conduct the exercises in a laboratory setting, where the instructor or laboratory staff can observe the students' behavior. As was suggested in the role-playing exercise of the previous section, the instructor can walk around the room to observe each student group for a few minutes. For exercises involving interviewing, the instructor can also ask to see the list of questions prepared in advance of the interview.

A second approach is to use teaching assistants or graduate students as observers. This is especially useful for graduate students in software engineering programs, because they can not only report results to the instructor, but they can increase their own requirements elicitation skills by observing several student exercises.

A third approach is to have each student group designate one or more "process observers" whose role is to observe (silently) the exercise, report on the good and bad aspects of it, and make recommendations for improvement.

5. Suggestions for Further Reading

The lecture notes documents included in this package are derived in great part from the books below. Instructors who are preparing to teach requirements elicitation for the first time are encouraged to read the relevant parts of these books.

If the role-playing exercise is being used, students will also need to read more than just the lecture notes. The exercise descriptions indicate appropriate readings from these books.

August91 August, J. H. *Joint Application Design: The Group Session Approach to Systems Design*. Englewood Cliffs, N. J.: Prentice-Hall, 1991.

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The author is one of the originators of the JAD techniques. In this short (169 pages) book, she presents a highly readable description of all phases of JAD, including examples of the many kinds of documents produced in JAD sessions.

Bingham59 Bingham, W. V. D.; & Moore, B. V. *How To Interview, 4th Revised Edition*. New York: Harper & Brothers Publishers, 1959.

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The first four chapters of this book provide a good introduction to the process of interviewing and to some of the psychological principles on which that process is based. Chapter 3 is especially useful in its detailed description of how to prepare for and conduct an interview.Brackett90

Brackett, J. W. *Software Requirements* (Curriculum Module SEI-CM-19-1.2, ADA235642). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1990. Internet ftp host ftp.sei.cmu.edu, file /pub/education/cm19.ps.

Abstract: *This curriculum module is concerned with the definition of software requirements—the software engineering process of determining what is to be produced—and the products generated in that definition. The process involves requirements identification, requirements analysis, requirements representation, requirements communication, and development of acceptance criteria and procedures. The outcome of requirements definition is a precursor of software design.*

This module may be useful to an instructor designing a course or course segment on requirements engineering. It helps put requirements elicitation in context.

Clark58 Clark, C. H. *Brainstorming, the Dynamic New Way to Create Successful Ideas*. Garden City, N. Y.: Doubleday & Company, Inc., 1958.

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1 The Difference an Idea Makes
2 The Stork Doesn't Bring Them
3 Brainstorming? What's That?
4 Mixing the Witch's Brew
5 Keep 'em Rolling
6 After the Storm is Over
7 Ideas? In my Company?
8 The Preaching Practiced
9 Solos and Small Combos
10 It Comes in King Size, Too
11 Take it Home to Mama
12 The Shoe Fits, Put it On
13 Troubles are a Brainstormer's Best Friend
14 The Compleat Brainstormer
15 Secrets of a Successful Idea Man
16 America's Last Frontier

This book presents a very detailed description of brainstorming and how it can be applied to creative problem solving. It is also entertaining, with many "war stories," and it should be enjoyable to both instructors and students.

Davis93 Davis, A. M. *Software Requirements: Objects, Functions, and States*. Englewood Cliffs, N. J.: Prentice Hall, 1993.

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1 Introduction
2 Problem Analysis
3 The Software Requirements Specification
4 Specifying Behavioral Requirements
5 Specifying Nonbehavioral Requirements
6 Requirements Prototyping
7 Some Final Thoughts

This book seems to be becoming the textbook of choice for courses on software requirements engineering. It also contains an exhaustive, annotated bibliography of the requirements engineering literature.

Keen80 Keen, P. G. W. “Adaptive Design for DSS.” *Database 12* (Fall 1980): 15-25.

This paper discusses the adaptive loops framework.

Osborn53 Osborn, A. F. *Applied Imagination; Principles and Procedures of Creative Thinking.* New York: Charles Scribner’s Sons, 1953.

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1 The all-importance of imagination
2 Indispensability of creativity in science
3 Careers depend largely upon creativity
4 Creativity in leadership and in professions
5 Imagination can improve personal relations
6 Universality of imaginative talent
7 Ways by which creativity can be developed
8 Our new environment—its effect on creativity
9 Other factors that tend to cramp creativity
10 Creative and non-creative forms of imagination
11 The processes of ideation vary widely
12 Orientation calls for setting our sights
13 Preparation and analysis go hand in hand
14 The value of thinking up plenty of hypotheses
15 Periods of incubation invite illumination
16 Synthesis, evolution and verification
17 The effect of emotional drives on ideation
18 The effect of effort on creativity
19 The element of luck in creative quests
20 Devices designed to help activate imagination
21 Questions as spurs to ideation
22 Adaptation, modification, and substitution
23 Addition, multiplication, subtraction, division
24 Rearrangement, reversal, and combination
25 Creative collaboration by teams
26 Creative collaboration by groups

The author starts from the premise that people all possess the power of imagination and then describes a variety of techniques to develop and apply that power. Brainstorming is one of the techniques.

Rockart79 Rockart, J. F. “Critical Success Factors.” *Harvard Business Review* (Mar.-Apr. 1979): 81-91.

SEI91 *Requirements Engineering and Analysis Workshop Proceedings* (Tech. Rep. CMU/SEI-91-TR-30, ADA250415). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1991. Internet ftp host ftp.sei.cmu.edu, file /pub/documents/91.reports/tr30.91.ps.

Wetherbe84 Wetherbe, J. C. *Systems Analysis & Design: Traditional, Structured, and Advanced Concepts and Techniques*. St. Paul, Minn.: West Publishing, 1984.

Wood92 Wood, D. P.; & Kang, K. C. *A Classification and Bibliography of Software Prototyping* (Tech. Rep. CMU/SEI-92-TR-13, ADA258466). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1992. Internet ftp host ftp.sei.cmu.edu, file /pub/documents/92.reports/tr13.92.ps.

Abstract: *Prototyping, the creation and enaction of models based on operational scenarios, has been advocated as a useful software engineering paradigm because it lends itself to intense interaction between customers, users, and developers, resulting in early validation of specifications and designs. An extensive and widespread interest in software prototyping in recent years has resulted in a daunting amount of literature and dozens of proposed methods and tools. As with any immature and growing technology, the expanding literature and approaches have resulted in correspondingly expansive and confusing terminology.*

This report presents an overview of technology and literature relating to the creation and use of software system prototypes. In addition to an annotated bibliography of recent prototyping literature, a technology framework, taxonomy, and series of classifications are provided. The intent of this report is to provide a basic road map through the available literature and technology.

Lecture Notes

Introduction to Requirements Elicitation

Requirements Elicitation Using Joint Application Design

Requirements Elicitation by Brainstorming

Requirements Elicitation by Interviewing

Requirements Elicitation Using the PIECES Framework

Introduction to Requirements Elicitation

1. Introduction: A Tale of Three Students

Once upon a time there were three students of computer science: Pat, Terry, and Chris. In their programming class, the professor gave this assignment:

> Write a program that will read in a list of 100 positive integers, sort them into ascending order, display the sorted list, and display the average of those values.

These are the *requirements* that the software must satisfy, and the three students had no difficulty in writing the program. Chris and Pat began with pencil and paper, sketching out the algorithm and writing a first draft of the code. Terry went immediately to the keyboard and started typing in the program.

Now our three students, with new computer science degrees in hand, are beginning their first jobs. Pat has gone to work for Consolidated Flange and Widget, a large manufacturing company. One day, Pat and the rest of the software engineering department are called to a meeting where the company's vice president for sales and marketing gives them this assignment:

> Develop an automated system that will allow us to process orders at least 24 hours sooner, on the average, and will allow us to ship our products to customers at least three days sooner than currently.

Terry has taken a job with Zooming Airplane Company and is assigned to the team developing the avionics software for the new Z-676 airliner. The team has just been given this task:

> Develop the software that will allow the Z-676 to land itself, without pilot intervention, at major airports.

Chris has gone to work for Megabuck Codemeisters, a company specializing in personal productivity software for small computers. The company president has called all the new software engineers together and given them this assignment:

> Develop a new product that will sell at least one million copies at a retail price of at least $200.

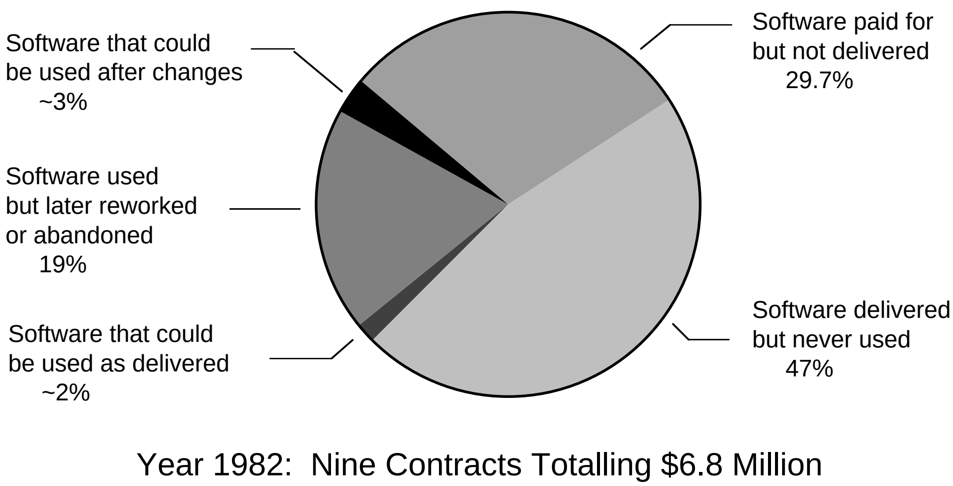

Figure 1. Results of GAO survey of software contracts

Unlike the situation in their programming class in school, neither Pat, Terry, nor Chris can head for the keyboard. They need a lot more information on what the software actually must do. How do they get that information? The answer is *requirements elicitation*.

To understand requirements elicitation, we first take a high-level look at the elicitation process: what terminology is used, who participates, and what the basic procedures are. We examine and compare the outcomes of a good elicitation process and a poor elicitation process. We then discuss the underlying difficulties of requirements elicitation. Finally, we sketch several different elicitation techniques that are currently in use by software engineers.

2. The Requirements Elicitation Process

Requirements elicitation is one of the most critical steps in a software engineering project. Experience over the last 30 years has shown that incorrect, incomplete, or misunderstood requirements are the most common causes of poor quality, cost overruns, and late delivery of software systems. The ability to employ a systematic process for requirements elicitation is therefore one of the fundamental skills of a good software engineer.

As an example of the importance of understanding the user's requirements, consider the results of a General Accounting Office (GAO) survey shown in Figure 1. If we ignore the software that was never delivered to the users, virtually all of the software purchased under these contracts could not satisfy the users' needs.

2.1. Terminology

There are many terms that are used in describing the process of understanding requirements for a software system. We use *requirements engineering* as a general term encompassing all the activities related to requirements. In particular, requirements engineering comprises four specific processes:

requirements elicitation	the process through which the customers, buyers, or users of a software system discover, reveal, articulate, and understand their requirements.
requirements analysis	the process of reasoning about the requirements that have been elicited; it involves activities such as examining requirements for conflicts or inconsistencies, combining related requirements, and identifying missing requirements.
requirements specification	the process of recording the requirements in one or more forms, including natural language and formal, symbolic, or graphical representations; also, the product that is the document produced by that process.
requirements validation	the process of confirming with the customer or user of the software that the specified requirements are valid, correct, and complete.

In an actual situation, these four processes cannot be strictly separated and performed sequentially. All four are intertwined and performed repeatedly. For example, the expression of requirements in a formal or graphical representation is often helpful in identifying conflicting or missing requirements, and the validation of some requirements often elicits requirements or details that the users had not previously recognized or stated.

We should note that the term *elicitation* is not universally accepted for the process described above. Some software engineers use terms such as requirements *identifying*, *gathering*, *determining*, *formulating*, *extracting*, or *exposing*. Each of these terms has different connotations. For example, *gathering* suggests that the requirements are already present somewhere and we need only bring them together; *formulating* suggests that we get to make them up; *extracting* and *exposing* suggest that the requirements are being hidden by the users. There is some truth to all of these connotations, as we will see in our discussion of requirements elicitation.

2.2. A General Elicitation Procedure

By far, the most common kind of requirements elicitation effort is one that gets information directly from the people who will use the system. In such cases, the elicitation procedure can be described in very general terms as five steps:

1. Identify relevant sources of requirements (the users).
2. Ask them appropriate questions to gain an understanding of their needs.

3. Analyze the gathered information, looking for implications, inconsistencies, or unresolved issues.

4. Confirm your understanding of the requirements with the users.

5. Synthesize appropriate statements of the requirements.

Specific elicitation techniques have evolved from this general procedure by defining detailed processes, specific questions or categories of questions to ask, structured meeting formats, specific individual or group behaviors, or templates for organizing and recording information. We sketch some of these techniques in section 5.

2.3. Participants in Requirements Elicitation

A requirements elicitation effort normally involves many people. The software engineer who is responsible for producing the requirements specification (sometimes designated a *software requirements engineer*) leads the effort. He or she is often supported by other software engineers, documentation specialists, or clerical staff.

The potential users of the software are also involved. In a typical information system project, such as that encountered by Pat at Consolidated Flange and Widget, there are many kinds of users who will use the system directly: sales representatives, order processing personnel, shipping department personnel, and accounting personnel. Department managers and company executives are also involved, especially those who have authorized the building of the new system.

At Zooming Airplane Company, Terry sees a different kind of user. The engineers designing the Z-676 airliner know how the various subsystems of the aircraft work and how the avionics software interacts with those subsystems. They are the users who can answer questions about what the software must be able to do. In addition, because the U. S. Federal Aviation Administration (FAA) certifies civilian commercial aircraft and operates the air traffic control system, there are government regulations and standards that must be considered as software requirements. FAA representatives may need to be part of the requirements elicitation effort. Airline pilots also need to be involved, especially in the elicitation of user interface requirements.

Chris faces still different problems at Megabuck Codemeisters. If the new software package they decide to build is a "new and improved" word processor or spreadsheet, a representative sample of users of existing packages should participate in the requirements elicitation process. They can be asked about their likes and dislikes for the packages they now use, and about new features that they would like to have. On the other hand, if the new package is an unprecedented kind of system, it is more difficult to elicit detailed requirements. Market research may identify the need for the system, and hence identify very general requirements, but the detailed requirements may have to come from a series of prototypes and user tests.

The lesson to be learned is simple: no one person knows everything about what a software system should do. There are always many participants in a successful requirements elicitation effort.

3. Outcomes of Requirements Elicitation

The tangible result of requirements elicitation is a set of requirements that can be used by the software development team. However, there are many other intangible outcomes of the process that can affect the overall success of the project. Those outcomes differ, depending on whether the elicitation process was conducted well or poorly.

3.1. Outcomes of a Good Process

The buyers or users of a software system often come to the requirements elicitation process with only a vague idea of what they really need and with little idea of what software technology might offer. A good elicitation process helps them explore and fully understand their requirements, especially in the separation of what they *want* and what they *need*. Their interactions with the software engineer help them understand the constraints that might be imposed on the system by technology, organizational practices, or government regulations. They understand alternatives, both technological and procedural, that might be considered in the proposed system. They come to understand the tradeoffs that might need to be made when two requirements cannot both be satisfied fully.

Overall, the buyers and users have a good understanding of the implications of the decisions they have made in developing the requirements. This results in fewer surprises when the system is built and delivered. The buyers and users share with the software engineer a vision of the problems they are trying to solve and the kinds of solutions that are feasible. They feel a sense of ownership of the products of the elicitation process. They are satisfied with the process, feel informed and educated, believe their risk is minimized, and are committed to the success of the project.

Similarly, the software engineers and developers who have participated in the requirements elicitation process are solving the right problem for the users. This is obviously the most important result of a good process; otherwise the whole project will fail. The developers have clear, high-level specification of the system to be built.

The developers are also confident that they are solving a problem that is feasible from all perspectives, not only technical but human. They know that the customers will be able to use the system, like it, make effective use of it, and that the system will not have undesirable side effects. They have the trust and confidence of the customers; they know the customers will cooperate if clarifications are needed during development, but they also believe such interaction will be minimal.

The developers have gained knowledge of the domain of the system; they have a variety of peripheral or ancillary information about the system that will be useful later when making low-level tradeoffs and design decisions. However, they do not feel that the system is overly specified; they are comfortable that they have freedom to make implementation decisions.

3.2. Outcomes of a Poor Process

The most serious outcome of a poor requirements elicitation process is that the developers are solving the wrong problem. This guarantees the failure of the whole project. (Take another look at Figure 1 at the beginning of section 2.)

Even if the developers are solving essentially the right problem, a poor elicitation process can have other negative outcomes. The buyers and users can be dissatisfied; this often happens if the developers did not really listen to them, or if the developers dominated the process and tended to force their own views and interpretations on the buyers and users. Dissatisfaction may result in less effective participation by the buyers and users, resulting in less complete answers to the developer's questions. The dissatisfaction can continue to affect the project through development and delivery of the software.

A poor elicitation process often leads to a chaotic development process. The developers may discover that they are missing important information, resulting in additional meetings with the buyers and users. The developers may make the wrong decisions or tradeoffs because of a lack of understanding of the users' needs. Requirements may change more often, resulting in greater need for configuration management, or in delays or wasted effort in design and implementation. The result is cost and schedule overruns, and sometimes failed or canceled projects.

All of these effects can result in a loss of money for the company developing or buying the software, loss of reputation or credibility for the developers, and a decline in the developers' morale.

4. Underlying Difficulties of Requirements Elicitation

Requirements elicitation is an imprecise and difficult process. To do it successfully requires that we overcome the underlying difficulties. In this section we discuss those difficulties, and in the next section we see some of the elicitation techniques that have been created to overcome the difficulties.

Throughout this discussion, we use the term *user* to mean both the actual user of the software (in the case where there is a human user) and the buyer or customer. For example, at Consolidated Flange, the users of Pat's software are the sales staff and the clerical staff that process orders. Terry's "users" might be considered to be the pilots or passengers of the Z-676 airliner being flown by the software, but the "customers" are really the engineers designing the flight controls for the aircraft. At Megabuck Codemeisters, the ultimate users of the new package that Chris is developing are the unknown buyers of the package, but the customers who understand the requirements are the people within the company who have done the market research to determine what kind of package is likely to be a big seller and who have examined competitors' products to identify how the Codemeisters product can be better.

4.1. Articulation Problems

The first class of difficulties includes those related to the articulation of the user's needs. These include problems both with the user's expression of needs and the developer's understanding.

1. The users of a proposed software system may be aware of their needs, but they are unable to articulate them appropriately. This is analogous to a situation where you recognize you are hungry and go into a restaurant. If you cannot decide what you want to eat, or if you cannot understand the menu, you cannot articulate your requirements. Telling the waiter "I'm hungry" is a statement of need but not a sufficiently articulate requirement to which the waiter can respond.

2. The users may not be aware of their needs. They may not understand how the technology may be able to help them. For example, the sales staff at Consolidated Flange may not know that with portable computers, modems, and appropriate software, they could send orders via telephone lines back to the main office during a sales trip, rather than waiting until they returned.

3. The user may be aware of a need but be afraid to articulate it. For example, a relatively new user at Consolidated Flange knows that he has trouble remembering all the part numbers when filling out customer order forms. He would like the system to display the part numbers in a menu, rather than having to type them in. However, he knows the other users don't have this problem, and he believes they would think him to be incompetent if he articulated his need. So he says nothing.

4. Users and developers misunderstand concepts or relationships because they have different meanings for common terms. Words like *system* and *integration* are widely used but understood differently by developers and users in many domains. To the developer, the word *implementation* means the writing of source code. To the user it means the process of making the software system operational in an organization, including the associated changes in human behavior, management procedures, and accounting procedures.

5. Users cannot make up their minds on some issues because they don't understand the consequences of the decision or they don't understand the alternatives.

6. No single person has the complete picture. No matter how articulate a user may be in expressing needs, other users may have different or additional needs or different priorities. This is especially true for complex systems, where each individual user may have only a limited view or perspective of the system to be built. For example, some users of a word processing system may never have produced a document with an index and therefore will probably not ask for this feature. Only a few users might think of features like text change bars or switching from portrait to landscape mode in the middle of a document.

7. Developers may not really be listening to the users. The developers don't hear all the detailed information that the users are providing. This usually happens when the

developers believe they already understand the user's needs, or when they begin to think ahead to particular designs and implementations.

8. Developers may fail to understand, appreciate, or relate to the users. They may not empathize with the user's problems or be able to see the problems from the user's perspective. In such situations, the developers will not understand the users' context, issues, or concerns.

9. Developers tend to overrule or dominate the users. They may have an overly assertive style, projecting an image of knowing all about the technology and the buyers' domain. The users feel threatened and are unable to articulate their actual requirements.

4.2. Communication Barriers

Many requirements elicitation difficulties are a direct result of differences in communications among users and developers.

1. Users and developers come from different worlds and have different professional vocabularies. The users may come from a financial, engineering, aeronautics, or manufacturing domain. Developers belong to the software domain. A term such as *process an order* might be well understood by the user but not by the developer.

At Zooming Airplane, Terry and the other developers discover that the users give them a blank stare when they start discussing class hierarchies and module cohesion. Terry has a similar reaction when the users mention VOR radials and RF interference.

2. The users have different concerns from those of developers; these are usually high-level attributes like usability and reliability. In contrast, developers are concerned with low-level technical issues, such as resource utilization, algorithms, and hardware/software tradeoffs.

3. Problems exist with each form or medium of communication. Natural languages, such as English, are inherently ambiguous. This often proves useful in normal communication but it is a significant problem for requirements communication. So why would we choose natural language for requirements elicitation? Usually, it is the only common communication medium between developers and the users.

Other forms of communication, such as diagrams, charts, pictures, and artificial languages, can sometimes be used. However, every form has some things it communicates well and some that it communicates poorly. It is usually helpful to use several forms in order to cover all the blind spots.

4. Requirements elicitation, by its very nature, has significant social interaction, and the people involved are all different. Some are assertive, some are submissive; some deal with details and others with abstraction. Incompatible styles of interaction can lead to a breakdown of communication. The elicitor must try to recognize the incompatibilities and adjust the communication appropriately.

5. There are different personality types and different value systems among people. This can lead to unexpected difficulties in communication, as was discovered by a company that contracted to build an information system for a university. The project leader was a high-level person in the company, and he would only talk to comparably high-level people in the university—deans and vice presidents. The developers on the project would only talk to the lower level clerical staff in the university who would actually use system.

4.3. Knowledge and Cognitive Limitations

Buyers, users, and developers are human beings, and each brings some knowledge and cognitive limitations to the process. They vary from person to person.

1. The requirements elicitor must have adequate domain knowledge. A common error is that the team of users and the developers don't have adequate domain knowledge, so they make wrong decisions. Developers should not make domain tradeoffs, and the users should not make technical tradeoffs.

2. No person has perfect memory. The users and developers may not remember exactly what was said or decided. Furthermore, we all interpret oral and written communications differently. Even if we believe we are being careful to record what was decided, we may misinterpret that information later.

3. We often try to use quantitative information and statistics to express needs and requirements. However, informal or intuitive statistics are frequently interpreted differently by different people because of our own experiences and biases.

4. People sometimes have difficulty with scale and complexity. As problems become larger, we deal with them in different ways. Some people try to simplify the problem, but not always in a valid way. Some people simply ignore parts of the problem because they can't deal with them. Our perspective of the problem can become distorted.

5. We often have a preconceived approach to the solution of a problem that affects our ability to state the problem clearly. We tend to state the problem in terms of the favored solution.

6. Some people develop a kind of "tunnel vision" when discussing a problem—they quickly focus all their attention on a few narrow aspects of the problem, usually those aspects that they believe they understand best or that affect them most directly.

7. On large systems, we usually need to explore a variety of novel formulations of the problem before reaching consensus on the nature of the problem. Some people are uncomfortable or impatient with this kind of exploration.

4.4. Human Behavior Issues

Requirements elicitation is a social process, so human behavior issues are involved.

1. There are sometimes conflicts and ambiguities in the roles that the users and developers play in the requirements elicitation process. Each user may assume that it is some other user's responsibility to tell the developers a particular aspect of the requirements, with the result being that no one tells the developer. The developer may assume that the user is a domain expert and will give all the needed domain information, and the user may assume that the developer will ask appropriate questions to get the domain information. This misunderstanding often leads to gaps in the requirements.

2. The development of a software system to support an organization usually results in an expectation or fear that installation of the software will necessitate all kinds of changes in behavior of individuals and groups (including the potential loss of jobs). This can cause individuals to withhold information from the developers or, in extreme cases, actively sabotage the development effort.

4.5. Technical Issues

There are many other difficulties that we might characterize as *technical* that must be overcome by the requirements elicitation process if it is to be successful. Some of the more important of these are summarized below.

1. Problems to be solved by software systems are becoming increasingly complex. The requirements of these systems are based on increasingly detailed knowledge of the user's domain. The impact of the systems on society must be considered, but neither the users nor the developers may be skilled at identifying that impact.

2. Requirements change over time. The requirements elicitation process itself is a learning experience for users, and ideas discussed at one point may cause them to change their minds about prior decisions. We must be careful to avoid having a set of requirements that is obsolete by the time the elicitation process is completed.

3. Software and hardware technologies are changing rapidly. A technological advance may make feasible a requirement that was unacceptably complex or expensive yesterday.

4. There are many sources of requirements. The users of a system are not necessarily aware of all the requirements that the system must satisfy. There may be requirements best elicited from computer operators or users' support personnel. Corporate management may have guidelines for performing certain tasks or constraints that must be satisfied. There may be government regulations or industry standards for particular aspects of a system. The marketing and sales departments may have requirements that would help improve the commercial viability of a product, especially when there are already similar competitors' products on the market.

5. The nature or novelty of the system often imposes constraints on the elicitation process. A new system that is very similar to several other systems previously built by the development team may be able to benefit from previous requirements elicitation efforts and feedback from users of the previous systems. An unprecedented system requires a much more substantial requirements elicitation effort.

Requirements elicitation for a one-of-a-kind system built for a specific customer can normally assume that the customer is the ultimate authority on what is needed. On the other hand, if the system will be offered for sale to customers other than the original buyer, the developers should look also at competing systems and additional or different requirements from those other customers.

Requirements elicitation for a typical shrink-wrapped, personal productivity software package depends heavily on market research, examination of competing products, and some kind of communication with a sample of typical users. A software system that goes through many versions over many years needs a continuing elicitation process to identify defects in the current version and to track users' requests for enhancements.

For a real-time control system, requirements elicitation often includes detailed collaboration with hardware and systems engineers to decide what functionality will be implemented in hardware (computer or otherwise) and what in software.

5. Overview of Requirements Elicitation Techniques

The requirements elicitation techniques that have been developed and used by software engineers have usually been designed to overcome one or more of the underlying difficulties. Some address communications difficulties, while others address human behavior or technical difficulties. Some are high-level, in that they are broad frameworks for a process that elicits general requirements; some are low-level, in that they provide specific tactics for eliciting details about a particular part of the system or from a particular user.

We can, to some extent, describe requirements elicitation techniques in broad, generic categories:

Asking. Identify the appropriate person, such as the buyer or user of the software, and ask what the requirements are.

Observing and inferring. Observe the behavior of users of an existing system (whether manual or automated), and then infer their needs from that behavior.

Discussing and formulating. Discuss with users their needs and jointly formulate a common understanding of the requirements.

Negotiating with respect to a standard set. Beginning with an existing or standard set of requirements or features, negotiate with users which of those features will be included, excluded, or modified.

Studying and identifying problems. Perform investigations of problems to identify requirements for improving a system. For example, if a system is too slow, it may require complex performance monitoring to identify the requirements to change the system. For a system with thousands or millions of users, a statistically valid survey using questionnaires may be needed to identify significant problems with the system.

Discovering through creative processes. For very complex problems with no obvious solutions, employ creative processes involving developers and users.

Postulating. When there is no access to the user or customer, or for the creation of an unprecedented product, use creative processes or intuition to identify features or capabilities that the user might want.

To illustrate these generic techniques, let's reconsider the software engineering projects described in section 1 and ask which of these techniques are Pat, Terry, and Chris likely to find most useful or least useful.

Pat faces a relatively common requirements elicitation task. The best technique is probably discussing and formulating requirements with the users. Joint Application Design, described below, is this kind of technique, and it is widely used for information systems. Postulating requirements would probably be the least useful technique in this situation, especially since Pat is new to the company.

Terry will certainly have to discuss and formulate requirements with the hardware engineers who understand the flight characteristics and controls of the aircraft. Observing pilots landing might also be helpful. Because this kind of software is almost unique and unprecedented, negotiating requirements with respect to a standard set is not possible, nor is studying and identifying problems with an existing system.

Chris may have the most difficult task, although the resulting requirements may not be as complex as those of Terry's project. Postulating the requirements may be necessary if Codemeisters decides to create an unprecedented product. If they instead choose to build a product that will compete head-to-head with those of competitors, it will be useful to study the existing systems to identify their weaknesses. The least useful techniques might be asking and discussing with users, because the users have not been identified.

We should note that no one technique is sufficient for realistic projects. A software engineer must be able to choose an assortment of techniques that best fit the kind of system being built.

We take a brief look at several techniques below. For each, we try to identify some of the underlying difficulties of requirements elicitation that are addressed by the technique.

5.1. High-Level Techniques

High-level requirements elicitation techniques are broad frameworks for processes that elicit general requirements.

5.1.1. Joint Application Design

Joint Application Design (JAD) is a technique for promoting cooperation, understanding, and teamwork among buyers, users, and developers. It provides a process that facilitates creating a shared vision of what the system should be. Using that process, the developers help the users formulate problems and explore solutions, and the users gain a feeling of involvement, ownership, and commitment to the success of the system.

There are four main tenets of JAD: group dynamics (using facilitated group sessions to enhance the capabilities of individuals); the use of visual aids to enhance communication and understanding; maintaining an organized, rational process; and a “what you see is what you get” documentation philosophy (using standard document forms that are filled in and endorsed by all participants in a session).

JAD has two major steps, called *JAD/Plan* and *JAD/Design*. The first step addresses requirements elicitation and specification, and the second addresses software design.

Each step in JAD consists of three phases: *customization, session,* and *wrap-up*. The customization phase consists of preparation tasks for the session. This includes organizing the team, tailoring the process for the particular system to be built, and preparing materials. The session phase consists of one or more structured and facilitated meetings involving the developers and users. It is during these meetings that the requirements (or the design) are developed and documented. The wrap-up phase is devoted to converting the information from the session phase into its final form, such as the requirements specification document.

By bringing users and developers together in a structured process, JAD can help overcome many of the articulation problems, communications barriers, and human behavior issues of the requirements elicitation process. Through the use of standard document forms, JAD can also address some of the cognitive limitations of the participants in the process.

5.1.2. Adaptive Loops Framework

The adaptive loops framework is similar in spirit to JAD, in that it provides a process framework that closely links the users, developers, and system. It derives its name from the idea that the users’ requirements can be elicited by an adaptive process of learning cycles or loops.

There are three learning cycles, as shown in Figure 2. The developers are assisted by the users in gaining new viewpoints about their requirements, and through reformulating the requirements, the user learns more about them. The system receives pressure for evolution as the users learn more about how it can be used, and the system induces that learning on the users. The system evolves by actions of the developers, who in turn gain enhanced understanding of the system through that evolution.

The requirements elicitation process using the adaptive loops framework focuses on addressing, supporting, and facilitating these learning cycles. It is especially useful when there are requirements articulation problems, and it is helpful in overcoming some of the technical issues of requirements elicitation for the evolution of complex systems.

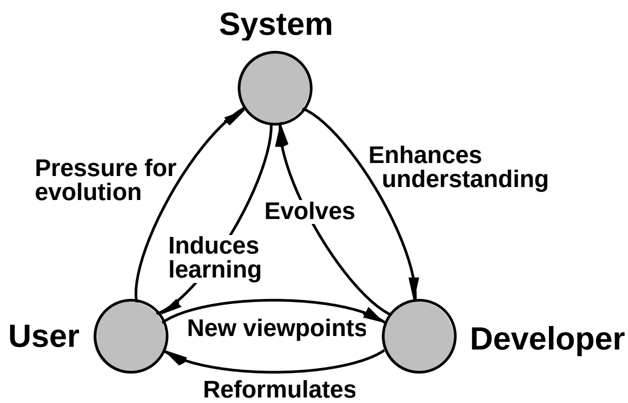

Figure 2. Adaptive loops learning cycles

5.1.3. Prototyping

In some situations, users may be better able to understand and express their needs by comparing those needs to an existing or reference system. When there is no similar existing system, prototyping can be used to create a system that illustrates the relevant features. By examining prototypes, the users can learn what their needs really are.

The prototyping process begins with a preliminary study of user requirements. Next comes an iterative process of building a prototype and evaluating it with the users. Each iteration allows the users to understand their requirements better, including understanding the implications of the requirements articulated in previous iterations. Eventually, a final set of requirements can be formulated and the prototypes discarded.

We sometimes distinguish the terms *prototype* and *mock-up*, with the former being something that demonstrates *behavior* of a part of the desired system, and the latter being something that demonstrates the *appearance* of the desired system. Mock-ups of user interfaces are especially common.

Clearly, prototyping of a system is beneficial only if the prototype can be built substantially faster than the actual system. For this reason, the process has sometimes been called *rapid prototyping*. Many software tools have been developed to facilitate building prototypes and mock-ups.

We also note that prototyping should *not* be viewed as a euphemism for trial-and-error programming or "hacking." These are wasteful practices. Prototyping is properly used to elicit and understand requirements; it is followed by a structured and managed process to build the actual system. Software engineers need to be careful to avoid making an inappropriate commitment to any prototype as the basis for full development.

When properly used, prototyping can be remarkable in overcoming articulation problems and communication barriers. At one time or another, we have all had experiences that cause us to think "I don't know what I want, but I'll know it when I see it," or "I didn't know I wanted one of those until I saw one." Prototyping provides this kind of experience during requirements elicitation.

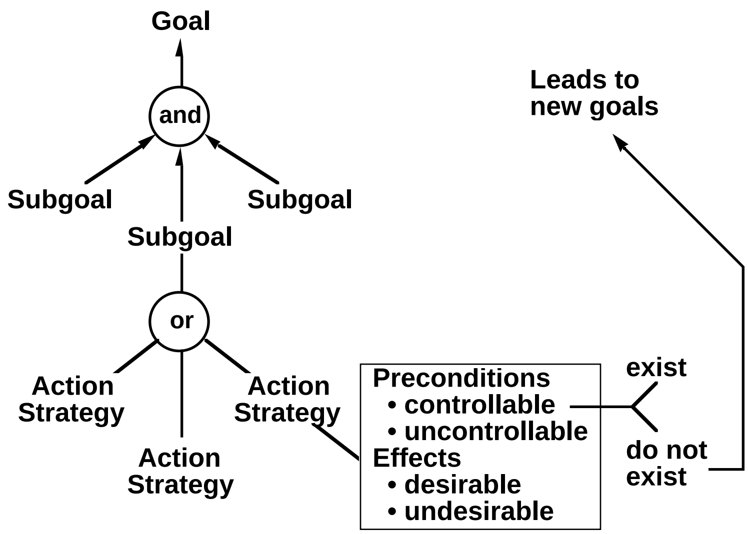

Figure 3. Goal-directed elicitation process

5.1.4. Critical Success Factors Analysis

The basic premise of this techniques is that the effectiveness of a system typically depends on a small set of critical factors. A strategy for ensuring success is to enhance performance of the system relative to those factors, and thus an effective requirements elicitation approach is to identify and concentrate on those factors.

The process has six major steps:

1. Understand the operation of the system.
2. Identify the factors that are critical for the effectiveness of the system.
3. Identify the strengths and weaknesses of the system with respect to each of these factors.
4. Identify areas of problems and opportunities.
5. Gather relevant details for enhancing system performance relative to these critical success factors.
6. Formulate requirements using these details.

A goal-oriented structuring process can be used for eliciting details. Typical primitive objects in such a process are goal, subgoal, action strategy, constraint, precondition (controllable, uncontrollable), effect, and implementation mode. The critical success factors are used to identify goals, and then the elicitation process works its way down through the subgoals, etc., as shown in Figure 3.

This technique is widely used in building information and decision support systems. It provides a systematic elicitation process, although identifying the right critical success factors can be challenging. It is especially useful in addressing some of the difficult technical and cognitive issues of requirements elicitation.

5.2. Detailed Techniques

The detailed techniques for requirements elicitation generally provide operational-level tactics and guidelines. They usually focus narrowly on specific aspects of the elicitation process.

5.2.1. Brainstorming

Brainstorming is a simple group technique for generating ideas. It allows people to suggest and explore ideas in an atmosphere free of criticism or judgment.

A brainstorming session works best with four to ten people. One person is the leader, but the role of the leader is more to get the session started than to constrain it.

The session consists of two phases. In the *generation* phase, participants are encouraged to offer as many ideas as possible, without discussion of the merits of the ideas. In the *consolidation* phase, the ideas are discussed, revised, and organized.

For purposes of software requirements elicitation, brainstorming can be helpful in generating a wide variety of views of the problem and in formulating the problem in different ways. It is especially useful very early in the elicitation process.

Good brainstorming sessions are very helpful in overcoming some of the cognitive limitations of participants by allowing (or forcing) them to expand their thinking. The lack of criticism and judgment during the generation phase also helps overcome some of the communication barriers of requirements elicitation.

5.2.2. Interviewing

Interviewing is an important technique for eliciting detailed information from an individual. It is commonly used in requirements elicitation for large systems as part of some of the high-level elicitation techniques. It can also be used for small projects as the only requirements elicitation technique

Interviewing is not simply a matter of asking question. It is a more structured technique that can be learned, and software engineers can gain proficiency with training and practice. It requires the development of some general social skills, the ability to listen, and knowledge of a variety of interviewing tactics.

A skilled interviewer can help the user to understand and explore software requirements, thus overcoming many of the articulation problems and communications barriers.

5.2.3. The PIECES Framework

Often the main problem for an inexperienced requirements analyst is determining how to get started. It is not at all clear what questions should be asked to elicit requirements from the users. The PIECES framework helps solve this problem by providing a set of categories of issues that can help the analyst structure the elicitation process.

PIECES is an acronym for the six issue categories: performance, information and data, economy, control, efficiency, and services. In each category there are several issues that the analyst should explore with the users. The framework can be tailored to include initial or seed questions that are especially appropriate for the kinds of systems that an organization is likely to build.

The PIECES framework is best used for analyzing existing systems, whether manual or automated. It is especially appropriate for eliciting requirements for enhancing or improving information systems. As with interviewing, it helps overcome articulation problems and communications barriers.

5.2.4. Market Analysis

Market analysis is a common activity performed by almost all companies who make products for sale. Clearly, if there is little market for a particular product, there will not be many sales, so the companies need to know the market before building the product. This activity is often used for software requirements elicitation when the product is a personal productivity software package for small computers, or a business support product that will be marketed to many companies.

Large companies employ market analysis specialists, who have skills in the social sciences and statistics. Smaller companies are more likely to hire consultants when contemplating a market analysis task.

There are several aspects of market analysis. *Competitive analysis* looks carefully at similar products of competing vendors to identify strengths to be copied and weaknesses to be avoided. (Note that copying a competitor's strengths too accurately often leads to copyright or patent infringement lawsuits.) *Market research* usually involves collecting statistical data on products being purchased, and then identifying trends in that data to predict the need for future products. *Customer questionnaires*, when carefully designed by experts, can elicit very detailed information about the needs of potential buyers and users of a software package.

Market analysis helps address the technical issues of requirements elicitation for new or enhanced mass-market products.

6. Summary

We have seen that a good requirements elicitation process is critical for a software project to succeed. The process must be more than just an information-gathering activity; it must be a collaborative effort that allows all the participants to become better informed about the system and thus to make better decisions about it.

We have also seen that there are many underlying difficulties in performing the requirements elicitation process. Awareness of these difficulties is the first step toward improving the elicitation process.

Many techniques are used by software engineers in requirements elicitation. Each has advantages and disadvantages. A good software engineer understands several of these techniques and knows when to use each.

Requirements Elicitation Using Joint Application Design

Joint Application Design (JAD) is a technique for promoting cooperation, understanding, and teamwork among buyers, users, and developers. It provides a process that facilitates creating a shared vision of what the system should be. Using that process, the developers help the users formulate problems and explore solutions, and the users gain a feeling of involvement, ownership, and commitment to the success of the system.

JAD was developed at IBM in 1977, and it has been applied successfully on hundreds of projects. It has been best used on information systems projects, particularly for identifying system requirements, package requirements, and modification requirements for existing products. IBM reports that the use of JAD has resulted in 20% to 60% gains in productivity.

There are four main tenets of JAD: group dynamics (using facilitated group sessions to enhance the capabilities of individuals); the use of visual aids to enhance communication and understanding; maintaining an organized, rational process; and a "what you see is what you get" documentation philosophy (using standard document forms that are filled in and endorsed by all participants in a session).

As its name implies, JAD is a technique for software *design*. However, it is understood that the design effort involving both developers and users must be based on a set of software requirements that are well understood by both the developers and the users. Therefore, JAD has two major steps, called *JAD/Plan* and *JAD/Design*. The first step addresses requirements elicitation and specification, and the second addresses software design. We focus on the first step.

Each step in JAD consists of three phases: *customization, session,* and *wrap-up*.

The customization phase consists of preparation tasks for the session. This includes organizing the team, tailoring the process for the particular system to be built, and preparing materials.

The session phase consists of one or more structured and facilitated meetings involving the developers and users. It is during these meetings that the requirements (or the design) are developed and documented.

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The wrap-up phase is devoted to converting the information from the session phase into its final form, such as the requirements specification document.

Participants in JAD

There are six kinds of participants in JAD, although not all participate in all the phases.

The *session leader* is responsible for the overall success of a JAD effort and is the leader and facilitator at meetings. He or she must be familiar with all aspects of JAD, have good meeting management skills, and have sufficient experience in the application area to be able to plan and understand the various JAD tasks and outputs.

Although all participants require training in JAD techniques, the session leader must be especially competent. In choosing employees to be trained as session leaders, an organization usually chooses individuals who have good interpersonal skills and who have shown general leadership qualities. Through practice and experience, session leaders develop the ability to

- understand and facilitate group dynamics;
- initiate and focus discussions;
- recognize when meetings are getting off the track and to put them back on track;
- deal effectively with different personalities and behaviors of participants;
- remain enthusiastic through sometimes long and difficult meetings.

The session leader also needs some general management skills, because he or she is also responsible for planning the JAD process, estimating resource requirements, and tracking the process.

The *analyst* is the participant who is most directly responsible for the production of the output documents of the JAD sessions. However, this is *not* simply a clerical role. The analyst must be an experienced developer who can understand the technical issues and details that are discussed during the sessions. Analysts should be selected also because they have the ability to organize ideas and to express them clearly in writing. They should also be skilled in the use of any software tools that are needed, such as document production or software prototyping tools.

The *executive sponsor* is the manager or executive who has ultimate responsibility for the product being built. He or she has two major responsibilities in the JAD process. The first is giving the other participants high-level or strategic insight into the system being built, such as why it is needed and how the organization is expected to be improved by the use of the system. The second responsibility is making executive-level decisions and commitments, such as resource allocations, that can affect the requirements and design of the new system.

User representatives are people in the organization who will use the new software system. During requirements elicitation, user representatives are often managers or key people within the organization; they tend to have a better view of the whole system and how it will be used. During design, user representatives may also include a variety of other users, so that their particular needs can be addressed as well.

User representatives should be selected on the basis of their knowledge of their own needs within the organization, an understanding of how their departments interact with other departments, and some knowledge of software-based systems. In addition, user representatives should be innovative and creative thinkers, and they should not be afraid to speak up in meetings.

Information systems representatives are people that are very familiar with the capabilities of information systems. Their role is to help the users understand what is and is not reasonable or feasible in the new system. In some cases, this involves educating the users about new hardware or software technologies, so that the users can "think big" and define a significant, forward-looking system. In other cases, the information systems representatives can help users understand tradeoffs among various approaches to solving a problem. This is important when there are two or more approaches that are equally satisfactory from the user's point of view, but very different in cost or complexity from the implementor's point of view.

A *specialist* is a person who can provide detailed information on a narrow, well-defined topic. A specialist from the user community, for example, might be the one person in the organization that handles a particular kind of order or uses a specific report. Thus, no one else in the organization would know the requirements for such orders or reports. A specialist from the developer community might be someone who knows the details of an organization's internal network, such as its hardware connections or message protocols. Participation from this person would be required when defining networking aspects of a new system.

The JAD/Plan Customization Phase

The JAD technique provides a general structure for requirements elicitation. To be most effective, it should be customized for each particular software project. This is the responsibility of the session leader, with the assistance of one or two analysts. The steps in the customization are outlined below.

Conduct orientation. By the time the executive sponsor has authorized a JAD/Plan effort, some thought has already been given to the purpose of the new software system. Usually this has occurred in the user community, because the users are the first to recognize a potential need for the system. The first step for the session leader and the analysts is to gain an understanding of what has been accomplished so far, what kind of system is being discussed, and what, if any, commitments or decisions have already been made. This typically requires short meetings with one or more users, and perhaps a meeting with the sponsor.

The session leader and analysts may also need to familiarize themselves with the organization or department for whom the system is being built. A company organization chart can be helpful in identifying the key people who will ultimately contribute to the JAD effort.

Organize the team. The session leader next selects the participants for the session. The executive sponsor may already have identified some of the participants, but the session leader has the final responsibility for ensuring that all the needed people are identified and invited.

The session leader also should prepare the participants for the session. In addition to telling them the date, time, and location of the session, the leader gives them a list of questions to think about before the session. The questions are chosen to match the high-level requirements addressed in the session (objectives; anticipated benefits; strategic and future considerations; constraints and assumptions; and security, audit, and control), and they are tailored to the particular system. The participants are asked to address the issues from their own perspectives; for example, the users address constraints from the business point of view and the information systems representatives address constraints from the technology point of view. The participants are asked to make notes on these issues to bring to the meeting.

Tailor the process. The session leader uses experience and judgment to adjust the general JAD process to the system being built. Typically this includes deciding how much time and how many meetings will be required for the session phase. It also includes tailoring the generic JAD document formats to match the needs of the current system.

Prepare materials. The session leader makes the necessary logistical arrangements for the session, including reserving and setting up a meeting room. Visual aids and supplies are ordered and placed in the room; these typically include blank transparencies, flip chart paper, marking pens, and “magnetics”—vinyl magnetic rectangles that can be written on and moved around on a whiteboard to facilitate visualization of the system.

To facilitate the smooth running of the session, the session leader also prepares several overhead transparencies or flip charts in advance. These include a welcome message, a meeting agenda, a review of the JAD process, a review of high-level requirements categories and system scope issues (described below), and the blank forms required by the JAD process for recording information, decisions, and issues.

The JAD/Plan Session Phase

The JAD/Plan session consists of one or more group meetings to define the high-level requirements for the new system and to define its scope. The subsequent JAD/Design is also planned in the session.

All the participants bring different ideas and views of the system to the session. Through carefully facilitated discussions, these ideas and views are presented, analyzed, and refined, so that by the end of the session, everyone is in agreement. To achieve this goal, the session follows a well-defined process, as outlined below.

Conduct orientations. The session begins with a welcome to the participants from the executive sponsor and from the session leader. All the participants are introduced. The executive sponsor gives a brief summary of the history of the effort to date and describes the expectations of the participants during the session.

The session leader then gives an overview of the JAD process, including the amount of time to be spent on each task. However, this overview is *not* a detailed training course. As each new task is begun, the leader provides more detailed information about the task. This includes the purpose of the task, the roles of the participants, how the task is performed, and how the output is recorded and formatted.

Define high-level requirements. The session leader facilitates the group discussion that elicits the high-level requirements. Five major topics are addressed:

1. Objectives: what is the reason for building this system; what purpose will it serve?
2. Anticipated benefits: what benefits (quantifiable or unquantifiable; tangible or intangible) will be derived from the use of this system?
3. Strategic and future considerations: how can this system help our company in the future; how will it give us a competitive or strategic advantage over our competitors?
4. Constraints and assumptions: what constraints exist for the system we are building (resources, organizational structure, standards, laws); what constraints exist for the project that is developing the system?
5. Security, audit, and control: are there internal or external security requirements for the system and its data; are their audits or controls that will be required?

Typically, to begin the discussion the leader asks general questions (that have been prepared in advance) on each of these topics. As requirements are identified by the participants, they are recorded by the analyst on flip charts or transparencies, which remain available throughout the discussion. The participants discuss, refine, and assess the requirements.

Bound the scope of the system. The discussion generates a large number of requirements. The next step is to begin to organize the requirements and agree on the scope of the system to be built. For an information system, a helpful way to proceed is to identify who will actually use the system and what major tasks the system will help them do. For example, sales representatives may be identified as users, and the major task for them is submitting an order from a customer. Note that it is also important to identify tasks that are outside the scope of the system. The goal is to bound the scope, so that the system is large enough to meet its objectives but not so large as to be too costly or complex to build.

It is in this step that the magnetic visual aids can be most useful. The names of tasks can be written on the magnetics, which are then placed on a whiteboard and connected with arrows that represent data flows. As the discussion proceeds, the shape of the system changes, and the magnetics can be moved to show the evolving system.

At this point, the requirements elicitation part of the JAD/Plan session is essentially complete. The next three parts of the session identify information that will be needed in the JAD/Design step.

Identify and estimate JAD/designs. A critical step in the planning for a software project is estimating resource needs (especially people and time). Some estimating techniques (including one called *function point analysis*) depend on estimates of the number of inputs to the system (input files or data entry screens) and the number of outputs from the system (output files or reports). This kind of information is also useful in predicting how much time will be needed for the JAD/Design step.

The session leader conducts a discussion in which this kind of estimating is done by the group. The data is recorded and estimates for the length of the JAD/Design step are made.

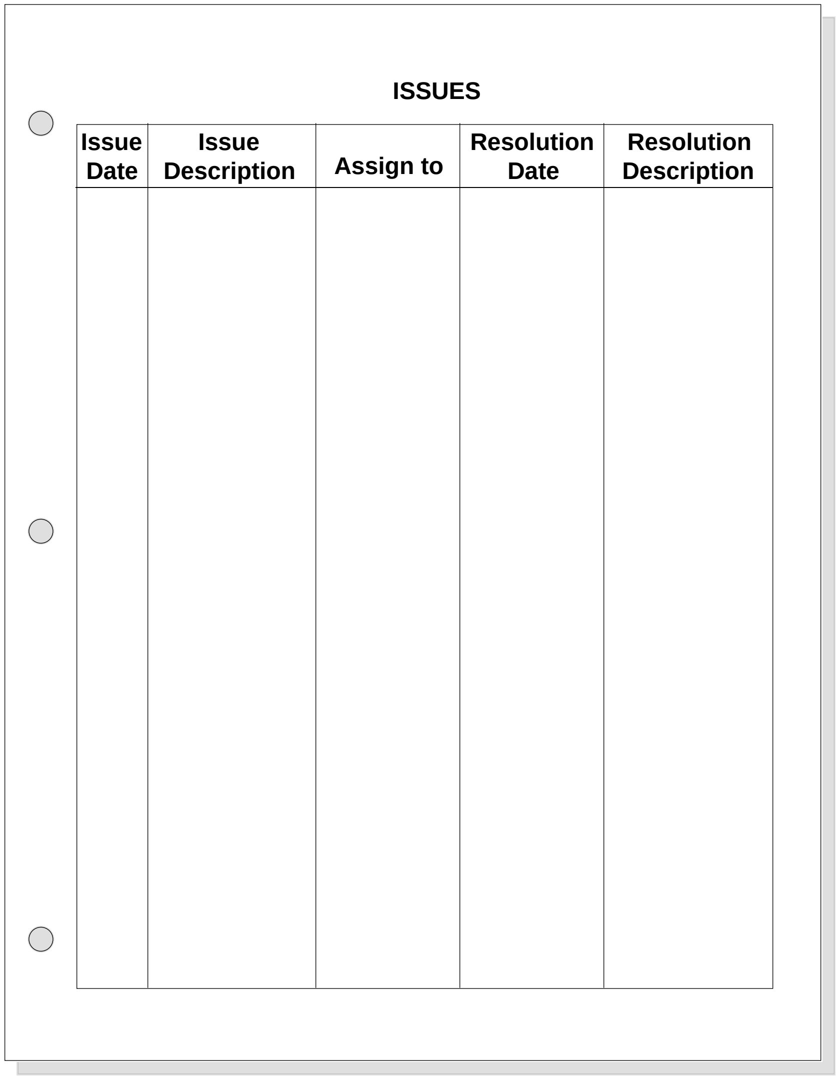
Identify participants for JAD/Design step. The group next determines who should participate in the JAD/Design step. It may be desirable to have different design steps for different subsystems. Different user representatives and specialists may be needed for each subsystem.

Schedule JAD/Design meetings. The group discusses the structure for the JAD/Design step. This is particularly important in sequencing several design steps for subsystems. Some organizations choose to have sequential design steps, while others interleave the phases (customization, session, and wrap-up) of the separate design steps.

Document issues and considerations. During the course of the session, there arise *issues* that affect the requirements for the system, but for which none of the participants has the necessary information or the authority to resolve. It is important that these be documented and resolved. Sometimes there arise *considerations* that don't affect the current JAD process, but that can affect how the system is built or how it is used in the organization. These are also be documented for later reference.

The JAD process specifies document forms for recording issues and considerations. Figure 1 (page 7) shows an example of an issue recording form. Note that each issue is assigned to a person for resolution by a particular date. Considerations are generally recorded simply as a list.

Conclude the session phase. The session leader concludes the session by reviewing with the participants the information collected and the decisions made. Each participant is given an opportunity to express any remaining concerns about the requirements. The session leader conducts this discussion so that everyone gains a sense of ownership of and commitment to the requirements that have been documented. Concluding the session on a psychologically high note helps ensure future productive contributions from everyone involved.



ISSUES

Issue Date	Issue Description	Assign to	Resolution Date	Resolution Description

Figure 1. Issue recording form

The JAD/Plan Wrap-Up Phase

The main goal of the wrap-up phase is to transform the transparencies, flip charts, and other handwritten documents from the session phase into formal planning documents, including the software requirements specification. The analysts work full time during this phase, assisted by the session leader. The phase has three distinct parts.

Complete the JAD/Plan document. An organization normally has a set format for a JAD/Plan document, although it may be customized somewhat for a particular software project. The analysts are responsible for translating the outputs of the session into a document that conforms to this format.

Review the JAD/Plan document. After the analysts have produced a complete JAD/Plan document, all participants in the session are given an opportunity to review and comment on it. Usually, this can be done by giving each participant a copy of the document and asking for written comments.

If there are substantive comments from the reviewers, a meeting is called to discuss the comments. All the participants in the original session are invited, so that changes in the document are agreed to by everyone.

Obtain executive sponsor approval. After the analysts have revised the plan document to reflect the comments of the reviewers, the session leader submits it to the executive sponsor for approval. Such approval gives the weight of authority to the document and brings closure to the JAD/Plan process. All of the session participants are then given copies of the final document.

Professional Facilitation Services

Facilitating a group process is considerably more difficult than it sounds. A large company that builds many systems over a long period of time can benefit from an investment in training of their own staff members to be JAD session leaders and facilitators. Other companies can employ consultants, skilled in facilitating JAD sessions, to work with company users and developers during the JAD sessions. This can greatly improve the success of the JAD process.

Suggested Reading

This book is perhaps the most detailed description of the JAD technique.

August, Judy H. *Joint Application Design: The Group Session Approach to Systems Design*. Englewood Cliffs, N. J.: Prentice-Hall, 1991.

Requirements Elicitation by Brainstorming

Brainstorming is a simple group technique for generating ideas. It allows people to suggest and explore ideas in an atmosphere free of criticism or judgment.

A brainstorming session works best with four to ten people. One person is the leader, but the role of the leader is more to get the session started than to constrain it.

The session consists of two phases. In the *generation* phase, participants are encouraged to offer as many ideas as possible, without discussion of the merits of the ideas. In the *consolidation* phase, the ideas are discussed, revised, and organized.

For purposes of software requirements elicitation, brainstorming can be helpful in generating a wide variety of views of the problem and in formulating the problem in different ways. It is especially useful very early in the elicitation process. When used correctly, it can help overcome some of the underlying difficulties of requirements elicitation:

- It stimulates imaginative thinking to help users become aware of their needs.
- It helps build a more complete picture of the users' needs.
- It can avoid the tendency to focus too narrowly too soon.
- For some personality types, it provides a more comfortable social setting than some of the more structured group techniques.

Brainstorming also has the advantage that it is easy to learn and requires very little overhead With practice, the participants can become very good at it. On the other hand, because it is an unfacilitated and relatively unstructured process, it may not produce the same quality or level of detail of some other processes.

Conducting a Brainstorming Session

Preparation for a brainstorming session requires identifying the participants, designating the leader, scheduling the session with all participants, and preparing the meeting room.

The participants are those who normally participate in requirements elicitation: customers, buyers, and users who need the software, and the software engineers who will

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develop the software. The outcome of the session depends on the ideas generated by the participants, so it is essential to include people with knowledge and expertise appropriate to the system being built.

The leader opens the session by expressing a general statement of the problem. This *seed* expression should be general, but still sufficiently focused to put the session on the right track.

The participants are then free to generate new ideas relevant to the problem expression. Some leaders prefer to give each participant in turn an opportunity to express one idea, going around the table as many times as necessary. Other leaders take ideas from participants in any order, selecting them on the basis of a raised hand. The process continues as long as ideas are being generated.

Alex F. Osborn, a researcher and writer on creating thinking, offers four rules for the generation phase of the session:

1. Criticism of ideas is absolutely forbidden. Participants must feel totally free to express any idea.

2. Wild, offbeat, or unconventional ideas are encouraged. Such ideas often stimulate the thinking of participants in unintended and unpredictable directions, which can lead to really creative approaches to the problem.

3. The number of ideas generated should be very large. The more ideas proposed, the more good ones are likely to be present.

4. In addition to suggesting totally new ideas, participants should be encouraged to combine or embellish ideas of others.

To facilitate this last rule, it is necessary for all ideas to remain visible to the participants. Several techniques can be used to do this; the technique used may depend on the equipment available in the meeting room.

- One person, either the leader or a *scribe,* is designated to record all ideas on a whiteboard or large sheets of paper. Unless the meeting room has wall-to-wall whiteboards, flip chart pads are probably better. As each sheet is filled, it is posted in view of all participants.

- Participants step to the whiteboard or flip chart to record their own ideas.

- Several smaller sheets of paper are used, and they are placed in the middle of the table where all participants can reach them. When an idea is proposed, it is added to any of the sheets.

The generation phase can conclude in either of two ways. If the leader believes that not enough ideas are being generated, the meeting can be stopped. The group reconvenes and continues at another time when people (and their ideas) are fresh. If enough ideas have been generated and recorded, the leader can move the meeting to the next phase.

The consolidation phase permits the group to organize the ideas in ways that they can best be used. It is in this phase that evaluation of ideas takes place.

The first step is usually to review the ideas for the purpose of clarification. It may be necessary to reword some of the ideas so that they are better understood by all participants. During this step, it is also common for two or more ideas to be recognized as being essentially the same, so they may be combined and reworded to capture the sense of the originals.

Next, the participants can usually agree that some of the ideas are too wild to be usable. These are discarded.

The remaining ideas are then discussed with a goal of ranking or prioritizing them. In the case of software requirements, it is often necessary to identify those that are absolutely essential, those that would be nice but not essential, and those that might be appropriate for a second or subsequent release of the system.

After the session, the leader or other designated person produces a record of all the remaining ideas, along with their priorities or other relevant comments from the consolidation phase.

Tools to Support Brainstorming

There is an area of research called *computer-supported cooperative work* (CSCW) that is developing tools and techniques by which people can work together without necessarily being located in the same room or building. A few tools are starting to appear that could be applied to brainstorming.

Videoconferencing tools are an example. With appropriately configured and networked workstations, the participants in a brainstorming session could remain in their offices and still be seen and heard by all other participants. The ideas could be entered by the individual participants or by a scribe, with each participant seeing the ideas immediately on the workstation screen.

The effectiveness of these tools is still uncertain. Some people believe the tools may first be useful in the consolidation phase, which involves editing and reordering the statements of the ideas. Doing this online provides the group an opportunity to evolve the final idea list during the session.

Suggested Reading

These books contain detailed discussions of brainstorming, although not in the context of software requirements elicitation.

Clark, C. H. *Brainstorming.* Garden City, N. Y.: Doubleday & Company, Inc., 1958.

Osborn, Alex F. *Applied Imagination, Principles and Procedures of Creative Thinking.* New York: Charles Scribner's Sons, 1953.

Requirements Elicitation by Interviewing

Interviewing is an important technique for eliciting detailed information from an individual. As a software engineer, you will use it in requirements elicitation for large systems as part of some of the high-level elicitation techniques. For small projects, you may also use interviewing as your only requirements elicitation technique.

Interviewing is not simply a matter of asking questions. It is a more structured technique that you can learn, and you can gain proficiency with training and practice. It requires the development of some general social skills, the ability to listen, and knowledge of a variety of interviewing tactics.

Interviewing has four phases: identifying candidates, preparing, conducting the interview, and following up. We discuss these phases in detail below.

Identifying Candidates for Interviewing

Requirements elicitation by interviewing begins with identifying the people to be interviewed. You usually start with the person who has authorized or is sponsoring the project to build the software system; this is often a manager or executive. The organization chart for a company helps identify other relevant people—those who report to that manager. These are the people who know why the system is being built and who will use it.

A requirements elicitation effort may involve interviewing many people, but it is not necessary to identify all of them before starting the interviews. One line of inquiry in each interview is the determination of other people who should be interviewed. This is done with questions such as:

- “Who else should I talk to?”
- “Who else may use the system?”
- “Who will agree with you on this?”
- “Who will disagree with you on this?”

You should also consider people who may not be actual users of the system to be built, but who interact with the users. Those interactions may be changed or disrupted after the system is installed, and you want to minimize these negative effects. You can ask:

• "Who else interacts with you?"

Preparing for an Interview

There are two major activities in preparing for an interview: making arrangements with the people to be interviewed and preparing a list of questions.

Interviews must always be scheduled in advance, both as a matter of courtesy and to allow the interviewees to be prepared. You should make them aware of the goals of the interview, agree on the length of the interview, and give them any relevant materials they will need in order to prepare. You should also remind them of the interviews a day or two in advance; this can help ensure that they do the preparation.

Interviews are sometimes recorded on audio or video tape. Because taping makes some people nervous and thus affects the quality of the information gained from the interview, you should secure permission of the interviewees in advance.

Prepare in advance a list of questions to be asked at the interviews. Because interviewing is used to elicit detailed software requirements, you already have general ideas of the kind of system to be built. These general ideas will guide you in the preparation of questions. On the other hand, you cannot prepare *all* questions in advance. Information that you get during the interview will open new areas of inquiry, and you will need to create additional questions as you go.

Organize the list of questions into a logical order and arrange it as groups of questions about related issues. Finally, decide how much time to devote to each issue.

Interview Process Protocol

Beginning the interview. To get the interview started, introduce yourself (assuming you do not already know the interviewee). Next, review the goals of the interview: why you are here, what will be done with the information collected, the kinds of issues that will be covered, and the time allocation among the issues. During this review you can assess the extent to which the interviewee is prepared. In rare instances, the lack of preparation by the interviewee will necessitate stopping and rescheduling the interview at a later time.

Software requirements are often expressed in mathematical or graphical notations, such as data flow diagrams or state transition diagrams. If you are using any such notations, you should explain them at the start of the interview in order to be sure they are understood.

General guidelines. During the interview, you of course ask your prepared questions. However, there are oral communication skills and strategies that you can use to increase the quality of the information received.

First, you should keep in mind the fact that a person's first answer to a question will not necessarily be complete and correct, nor will it necessarily be expressed in language that you understand as clearly as the interviewee. You will need to explore most answers to improve your understanding. Some of the best ways to do this are to summarize, rephrase, and show implications of what you hear, so that the interviewee can confirm your understanding.

Summarizing is useful throughout the interview, not just at the end. It helps confirm understanding and it can elicit useful generalizations and higher level abstractions.

Rephrasing answers—stating information in your own words—is an important strategy for dealing with ambiguity in language. It helps you understand an issue by forcing you to translate the understanding into words. Rephrasing also helps uncover misunderstandings of specialized terminology.

For interviews in the context of software requirements elicitation, you as the software professional bring a range of technical knowledge to the interview that the interviewee does not have. This often gives you insight into the implications of a particular user requirement. It is helpful to explain those implications to the user, who may then decide that is not what was wanted after all.

Be an active listener during the interview. Look at the interviewee when he or she is speaking. When making notes, avoid the tendency to stop listening. If necessary, you can ask the interviewee to pause while you are writing.

Be courteous during the interview and try to keep the interviewee at ease. Avoid questions that might seem threatening, such as "I want an answer! Yes or no?"

You should allow the interviewee the opportunity to answer questions fully. Sometimes this results in wandering from topic to topic. This is acceptable, but you then must choose your next questions carefully to bring the interview back on track. You must remain in control of the interview.

You can also make use of some non-verbal communication techniques during interviews. In particular, body language can be an important indication of the mood of the interviewee. If body language suggests that he or she is becoming closed or less receptive to questions, you may need to move the discussion to a different issue or take other action to reduce the stress.

Keeping the process visible. From time to time it is useful to make comments or ask questions about the interview itself, in addition to the questions about the software requirements. Questions such as these help ensure that the process is going well:

- "Are we doing all right?"
- "Have we ignored anything?"
- "Did we spend enough time on this issue?"

Make sure the interviewee understands the rationale for your questions. If asked, you should explain the purpose of a question.

You should take care, however, to remain in control of the interview. Don't accept too many questions, and if the discussion moves away from the subject of the interview, be prepared to point it out to the interviewee.

Types of questions. There are a few general types of questions that you will almost always use in interviews. Protocol questions address the context for the software system rather than the behavior of the system itself.

- "Why are we building this system?"
- "What do you expect from it?"
- "Who are other users of this system?"

Open-ended questions encourage unconstrained answers and can elicit a large amount of information. They can be very useful when you don't yet know enough about the system to ask more detailed questions.

- "Tell me what you do."
- "What aspects of your job are tedious?"

Closed-ended questions are useful when you need to educate the interviewee about a particular issue and force a precise or detailed answer.

You should be careful when asking some kinds of leading questions, depending on the personality and mind-set of the interviewee. For example, compare these two questions:

- "Should the sales report be produced weekly?"
- "How often should the sales report be produced?"

A "yes or no" question allows the interviewee to make a complete response without giving the question much thought. If you use too many such questions with a passive user, you may end up with your own view of the requirements instead of those of the user.

Avoid the tendency to anticipate an answer. When you have asked your question, stop talking. For example, if you ask, "How often should the sales report be produced?" don't follow immediately with "Daily? Weekly? Monthly?"

Software requirements are often complex, and the user may not have a fully developed understanding of his or her needs. This normally means that a single question about an issue may not elicit a complete or meaningful response. You should explore issues with questions that approach the issue from different directions, or that are at different levels of abstraction.

You should also ask questions to raise the level when the interview begins to get too detailed or too focused on a single solution to the problem. When the user says that a specific function is needed, you can ask a series of *laddering* questions to raise the level:

- "What is the goal of that?"
- "What is its purpose?"
- "By what means will that be accomplished?"

You may need to ask these questions two or three times, each time forcing the answer to be at a higher level.

Putting questions in context. During the course of the interview, you will switch topics or question contexts from time to time. Make sure the interviewee understands the context in which you are asking each question. You can often depend on the context of previous question, but after changing topics, you should explicitly state the new context. Otherwise you may get unreliable details.

For example, if you pose a question about the format of particular data items, the answer may depend on whether the context is a discussion of input data or output data.

Avoid switching context too often, because this prolongs the interview and increases confusion.

Checking for errors. During the interview, you must be sensitive to communication errors, check for them periodically, recognize when they occur, and correct them. Some of the most common kinds of errors are:

- Observational errors: when viewing a phenomenon, different people focus on different aspects and may "see" different things.
- Recall errors: the interviewee may be relying on recall of specific information, and human memory is fallible.
- Interpretation errors: you and the interviewee may have different interpretations of common words, such as "*small* amount of data" or "*special* characters."
- Focus errors: you may be thinking broadly, while the interviewee is thinking narrowly about an issue (or vice versa), which affects the level of abstraction in the discussion of that issue.
- Ambiguities: there are inherent ambiguities in most forms of communication, and especially in natural language.
- Conflicts: you and the interviewee may have conflicting opinions on an issue, resulting in a tendency to record your own view rather than what the interviewee is saying.
- Facts that are simply not true: the interviewee may give information as fact that is really judgment or opinion; you should check facts with other sources, especially those facts on which you will base significant decisions.

With experience, you can learn to recognize when errors like these might have occurred. You can then ask a question to confirm the error, and ask additional questions to correct the error.

Ending the interview. The interview can end when all the questions have been asked and answered, when the allotted time has been exhausted, or when you sense that the interviewee is becoming too fatigued or "drained" to continue.

Be sure to leave five to ten minutes for summarizing and consolidating the information you have received. Describe briefly the major issues that you believe you have adequately explored and those, if any, that you believe require additional information. Explain the follow-up actions that will be taken, including an opportunity for the interviewee to review a written summary of the interview. Solicit and answer questions about the interview, the follow-up actions, or what will happen to the information collected. Finally, thank the interviewee for the time and effort he or she has given.

Follow-up Activities

After conducting an interview, there are a few activities that you should perform. As a courtesy, it is usually appropriate to send the interviewee a written expression of thanks.

The most significant post-interview activity is to produce a written summary of the interview. The process of writing the summary provides an opportunity to reorganize or reorder the topics discussed and to consolidate related information. It may also help you uncover ambiguities, conflicting information, or missing information.

Give the interviewee a copy of the summary and request confirmation that the summary accurately reflects the information exchanged in the interview.

If the interview produced statistical or other factual information that depended solely on the memory of the interviewee, you should confirm that information with reliable sources.

Finally, you should review the procedures you used to prepare for and conduct the interview, with the goal of finding ways to improve the process in the future. You may want to pay particular attention to the kinds of questions that you found most or least successful in eliciting useful information. If you will conduct interviews with several potential users of a new software system, you can revise your prepared questions before the next interview.

Suggested Reading

This book contains a variety of information about interviewing, including an especially helpful section titled "General Suggestions for Beginners."

Bingham, W. V. D.; & Moore, B. V. *How To Interview, 4th Revised Edition*. New York: Harper & Brothers Publishers, 1959.

Requirements Elicitation Using the PIECES Framework

Often the main problems for an inexperienced requirements engineer is how to get started. It is not at all clear what questions you should ask to elicit requirements from the users. The PIECES framework helps solve this problem by providing a set of categories of issues that can help you structure the elicitation process.

PIECES is an acronym for the six issue categories: performance, information and data, economy, control, efficiency, and services. In each category there are several issues that you should explore with the users. The framework can be tailored to include initial or seed questions that are especially appropriate for the kinds of systems that an organization is likely to build.

The PIECES framework is best used for analyzing existing systems, whether manual or automated. It is especially appropriate for eliciting requirements for enhancing or improving information systems.

For example, the processing of customer orders at a company may involve filling out paper forms of various kinds and delivering copies to various departments. This a manual system whose components, the forms themselves and the flow of those forms, can be analyzed to elicit requirements for an automated system for order processing.

The framework can also be tailored to a specific application domain. With experience, you can develop a set of detailed questions and checklists to help ensure that you have done a thorough requirements elicitation for each system you want to build or enhance.

Six Categories of Issues

Performance. The performance of a system is usually measured in one of two ways. The *throughput* is the number of tasks completed in a unit of time, such as the number of orders processed in a day. The *response time* is the amount of time required to perform a single task. (Note that mathematically, these two measures are inverses of each other: tasks per time and time per task.)

To elicit performance requirements, you need to ask questions that will help identify the tasks that the system must perform, and then identify the throughput or response time

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for each type of task. When analyzing an existing system, you may find that experienced users already know where performance problems exist. These problems represent opportunities for improving the system.

Information and data. It is the nature of information systems to provide information or data that is useful in decision making. To be most effective, the system should provide access to the right kind of information, neither too much nor too little of it, at the right time, and in a usable form.

You should explore these issues with the users. If users tend not to use the system, it may be a symptom of the wrong kind of information being provided. If they use it but express frustration, it may mean that the system presents too much information or presents it in a form other than what the users need. The system may provide information in a daily report that is only needed monthly, or a monthly report that is really needed daily. Or the reports may have good information, but it is tedious to have to look for data several times a day in a 100-page report, suggesting that online access may be better than printed reports.

Economy. Issues related to the cost of using a process or system are always important. Generally speaking, there are two interrelated cost factors that must be considered in the design of the system: *service level* and *excess capacity*. The service level is a measure of the system's performance (throughput or response time or both). For some systems, the demand on the system varies considerably from minute to minute or hour to hour, but the users would like to have a relatively stable service level or performance. This can be accomplished by building into the system the excess capacity needed to handle the peak demands.

Unfortunately, excess capacity is usually expensive. In manufacturing processes, for example, seasonal demand for certain products might suggest having several extra factories that can be activated as demand increases and then shut down. This is clearly not an economical solution, both in terms of the buildings and machinery that would often be idle and in terms of the hiring and firing of workers for those factories.

In a software system, excess capacity may mean having additional processors, disk drives, or network connections that can be brought online as needed, or it could mean designing internal data structures to handle information of unexpected size or complexity from time to time. As in the manufacturing example, such excess capacity can be expensive.

You should explore these issues with the users. A thorough understanding of the expected load on the system and the appropriate service level will help the developers make appropriate tradeoffs to balance service level and excess capacity.

Control. Processes are normally designed to have predictable performance and outputs. When the process deviates from the expected performance, control is achieved by taking corrective action. Many information systems must provide the information to managers who control such processes. In real-time control systems, the control is exerted directly by the software through appropriate hardware interfaces.

Security is a type of control that is important in some software systems. Access to the system may have to be restricted to certain users or certain times of the day. Access to some of the information in the system may be restricted to certain users, or the kind of access (read-only vs. read-write) may be restricted.

Another type of control is auditing—the ability to see, monitor, or reconstruct system behavior during or after the fact. An example is the kind of auditing that is done in financial or accounting systems

Requirements elicitation should address control issues carefully; otherwise a system may be built that provides too little or too much control. Too little control can let a process get out of hand, while too much can impede getting the real work done.

Efficiency. It is not always the case that all the energy or resources devoted to a task actually go to doing useful work; sometimes there is waste. Efficiency is, in a sense, a measure of the waste. It is usually defined as the ratio of the resources resulting in useful work to the total of all resources expended.

Note that this differs from economy (discussed earlier). To improve the economy of a process, the total amount of resources devoted to it must be reduced. To improve efficiency, the waste in the use of those resources must be reduced.

Consider, for example, a company that is growing and has found that its accounting software is no longer able to provide an adequate service level. One potential solution is to purchase faster processors and larger storage devices, and then to continue to use the same software. Another potential solution is to revise the software to use faster algorithms or more compact data structures, and then use the revised software on the current hardware.

There are many opportunities for efficiency in software systems. During requirements elicitation, you must explore these opportunities with the users. Some inefficiencies can be characterized as unnecessary redundancy; examples are acquiring data more than once, storing it in multiple places, or computing a particular value more than once. Inefficiencies also result from the use of poor algorithms and poor data structures. A poor user interface to the software may waste the user's time.

Services. A software system normally provides services to the users, and the users may be in the business of providing services to customers. Thinking in terms of services can be very helpful during the requirements elicitation process. You normally ask the users what kinds of services they need from the software and how those services should be provided. But you should also ask what kinds of services are needed by the users' *customers* and how the software system can help provide *those* services. The new software system may also provide services to other software systems, and you musk ask about the needed interfaces between the systems. All of these kinds of questions will help elicit the major functional requirements of the software system.

There is one particularly difficult aspect of understanding how the services should be provided: should the software simply provide automated assistance to users who will continue to do essentially the same work in essentially the same way, or should the software provide an opportunity for users to do different work in different ways? However this question is answered, some changes in the behaviors of the users are likely to be required.

Consider, for example, a company that wants to automate its customer order processing. Currently, the company sends sales personnel to customer sites; the orders are recorded on paper forms and then carried back to the home office for processing. There are several parts of this process that could be automated, and each causes some kind of disruption in the work of the company's employees. One approach is to provide automatic scanning of the order forms, reducing the need for data entry clerks. Another approach is to give the sales personnel portable computers with modems, so that orders could be entered directly into the computer at a customer's site and then transmitted back to the home office via telephone lines. This approach requires the sales staff to change the way they work (and perhaps acquire keyboarding skills and computer literacy), and it may eliminate part of the jobs of the persons who design, print, stock, and deliver the paper order forms. Still another approach is to install an online terminal at each customer site, so that they can enter their own orders directly. Such a solution would vastly change the jobs of the sales personnel.

Issues such as these often cannot be resolved by eliciting requirements only from the direct users of the system (in this example, the data entry clerks and sales staff). When the behavior of whole departments of a company will be affected, you must also talk to managers within and above those departments. Failure to do so can result in the development of a software system that technically meets its requirements, but that cannot be made to function within an organization.

Suggested Reading

This book contains a more detailed description of systems analysis using the PIECES framework.

Wetherbe, J. *Systems Analysis & Design: Traditional, Structured, and Advanced Concepts and Techniques*. St. Paul, Minn.: West Publishing, 1984.

Classroom Materials

Student Handouts for the Role-Playing Exercise

Requirements Elicitation Exercise: Joint Application Design

Requirements Elicitation Exercise: Brainstorming

Requirements Elicitation Exercise: Interviewing

Requirements Elicitation Exercise: the PIECES Framework

The Software Services Group

The Stealth Helicopter Avionics Project

The Customer Statement of Need

The Role of the Customer

The Role of User 1

The Role of User 2

The Role of the Requirements Analyst

The Role of the Software Engineer

Transparency Masters

GAO Survey of Software Contracts

Adaptive Loops Framework

Goal-Directed Elicitation Process

Requirements Elicitation Exercise: Joint Application Design

Participant Roles

Customer: ______________________________

User 1: ______________________________

User 2: ______________________________

Requirements Analyst: ______________________________

Software Engineer: ______________________________

Session Leader (optional): ______________________________

Preparation

Read chapters 3, 4, and 6 of [August91].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.
Read the description of your assigned role.

Description

Your group is to perform a requirements elicitation activity using the Joint Application Design (JAD) technique. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system. Due to time restrictions, an entire Multiterm JAD cannot actually take place. Therefore, the group should concern itself with performing a JAD/Plan session phase only.

You will be given 15 minutes to prepare. During this time, reread the description of your assigned role and start expanding on it. If you are the customer or a user, jot down your ideas about the requirements and expand upon the ideas in your role description. If you are the customer, plan what you will say during the JAD/Plan session phase orientation.

A JAD/Plan session phase normally consists of eight tasks through which the session leader guides the participants. Again, due to time restrictions, the group should concern itself with performing only five of them:

- conduct JAD orientation
- define requirements
- bound system scope

- document issues and considerations
- conclude session phase

If no student has been designated to play the role of session leader, that role should be played by the customer. The requirements analyst will document the agreed-upon detailed requirements, and the software engineer will document the issues and considerations.

Conduct JAD orientation: During this task, the session leader reiterates the main points of this description to familiarize the participants with the procedures and to define terms such as *issues* and *considerations*. [5 minutes]

Define requirements: For this task, follow the normal procedures for a JAD/Plan session, except change the category *Anticipated benefits* to *General requirements*. Don't concern yourself with anything outside the scope of the system itself, such as business and legal issues. Focus on the requirements for the software system, and make them as detailed as you can in the time allotted. Give all participants a chance to introduce new ideas. [40 minutes]

Bound system scope: For this task, the session leader leads the participants through a clarification of the scope of the system; the generated requirements are reevaluated with respect to that scope. Any requirements falling outside the scope are removed from the list of requirements and documented separately by the requirements analyst. [10 minutes]

Document issues and considerations: This activity is an ongoing one. The software engineer documents each of these as they are identified during the JAD/Plan session phase.

Conclude the JAD/Plan session: The session leader reviews the accomplishments of the JAD/Plan session with the participants. [5 minutes]

Reference

August, Judy H. *Joint Application Design: The Group Session Approach to Systems Design*. Englewood Cliffs, N. J.: Prentice-Hall, 1991.

Requirements Elicitation Exercise: Brainstorming

Participant Roles

Customer: ______________________________

User 1: ______________________________

User 2: ______________________________

Requirements Analyst: ______________________________

Software Engineer: ______________________________

Preparation

Read pages 69-85, 96-103, and 107-113 of [Clark58].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.
Read the description of your assigned role.

Description

Your group is to perform a requirements elicitation activity using the brainstorming technique. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system.

You will be given 15 minutes to prepare. During this time, reread the description of your assigned role and start expanding on it. If you are the customer or a user, jot down your ideas about the requirements and expand upon the ideas in your role description.

You will have one hour to perform the brainstorming activities. Spend 20 minutes in the idea generation phase and 40 minutes in the consolidation phase.

For the idea generation phase, be creative but phrase the ideas in terms of requirements for the Multiterm system. If your ideas describe features, capture them in terms of functional requirements. If your ideas describe responses, capture them as behavioral requirements. Designate one person in the group to write down each complete idea on a single list.

During the consolidation phase, the requirements analyst reads through the list of requirements (ideas) one at a time. The entire group then classifies each requirement in two ways: first by practicality (good ideas that can be investigated immediately, ideas that need long range or involved study, and unusable ideas) and then by priority (ideas that absolutely must be implemented, those that are desirable but not urgently needed, and those that should be added only if time and money permit). Any new ideas generated in this phase should be considered for addition to the final list.

Reference

Clark, C. H. *Brainstorming*. Garden City, N. Y.: Doubleday & Company, Inc., 1958.

Requirements Elicitation Exercise: Interviewing

Participant Roles

Customer: ______________________________

User 1: ______________________________

User 2: ______________________________

Requirements Analyst: ______________________________

Preparation

Read pages 64-78 of [Bingham41].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.

Description

Your group is to perform a requirements elicitation activity using the interviewing technique. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system.

You will be given 35 minutes to prepare. For the first 30 minutes, discuss and write down sample questions that an interviewer might ask a customer and a user. Develop two lists of questions, one for the customer and one for the user. Deliberate not only about the questions themselves, but also the sequencing of the questions.

During the last 5 minutes of the preparation time, decide which role each group member will take and then distribute the descriptions of the roles. Study your role for the remainder of the time, expanding on your role and on the requirements enumerated in the description.

Next, the person playing the role of the requirements analyst conducts three ten-minute interviews, one with each of the other participant roles. The interviews can be done in any order, but each must be done in the absence of the other participants. Since the first interview will begin only five minutes after the descriptions of the roles are distributed, the first person interviewed will have to develop his or her role as the interview progresses. The others will have a chance to develop their roles before their interviews.

The interviewer starts with the questions developed during the preparation (in the interest of time), but he or she may generate new ones as the interviews progress. The interviewer writes down any elicited requirements on a separate sheet of paper, in complete sentences. After the interviews are complete, the interviewer should take ten minutes to finish writing down and organizing the elicited set of requirements.

Reference

Bingham, W. V. D.; & Moore, B. V. *How To Interview, 4th Revised Edition*. New York: Harper & Brothers Publishers, 1959.

Requirements Elicitation Exercise: the PIECES Framework

Participant Roles

Customer: ____

User 1: ____

User 2: ____

Requirements Analyst: ______________________________

Preparation

Read pages 114-124 of [Wetherbe84].
Read the description of the Software Services Group.
Read the description of the Stealth Helicopter Avionics Project.
Read the Customer Statement of Need.

Description

Your group is to perform a requirements elicitation activity using the PIECES framework. The goal is for the group to generate a set of requirements, written in English sentences, for the Multiterm software system.

You will be given 35 minutes to prepare. For the first 30 minutes, discuss and write down sample questions that an interviewer might ask a customer and a user, using the PIECES framework as a start. Develop two lists of questions, one for the customer and one for the user. Deliberate not only about the questions themselves, but also the sequencing of the questions.

During the last 5 minutes of the preparation time, decide which role each group member will take and then distribute the descriptions of the roles. Study your role for the remainder of the time, expanding on your role and on the requirements enumerated in the description.

Next, the person playing the role of the requirements analyst conducts three ten-minute interviews, one with each of the other participant roles. The interviews can be done in any order, but each must be done in the absence of the other participants. Since the first interview will begin only five minutes after the descriptions of the roles are distributed, the first person interviewed will have to develop his or her role as the interview progresses. The others will have a chance to develop their roles before their interviews.

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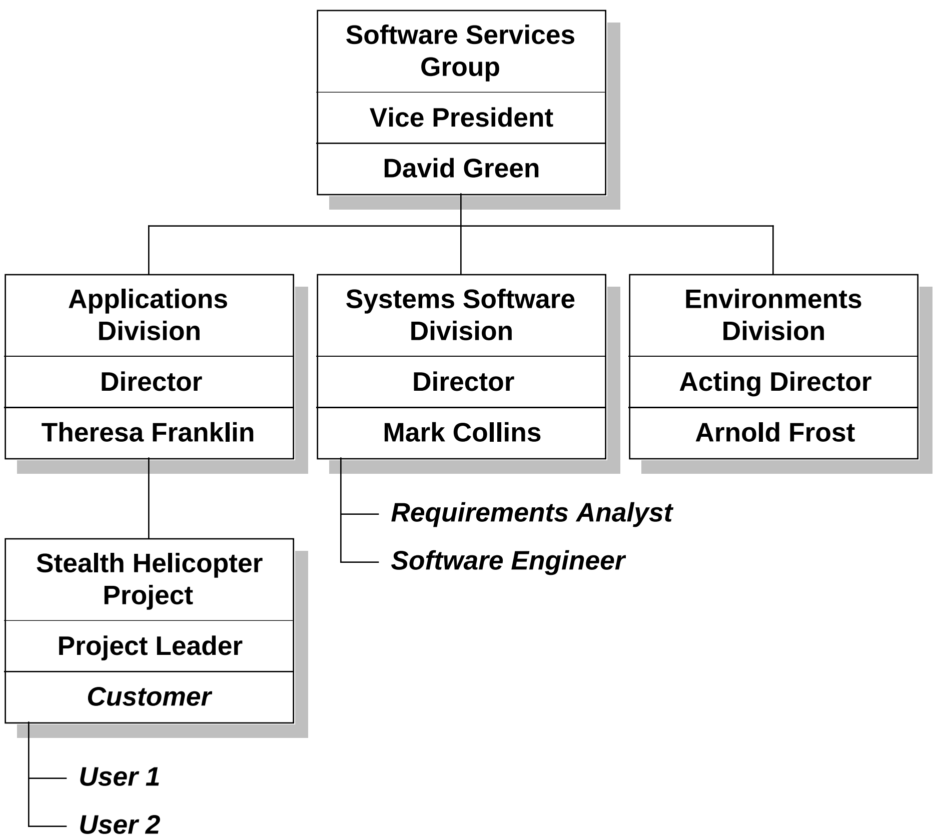
Reference

Wetherbe, J. *Systems Analysis & Design: Traditional, Structured, and Advanced Concepts and Techniques*. St. Paul, Minn.: West Publishing, 1984.

The Software Services Group

The Software Services Group within Zooming Airplane Company is responsible for the development of all new application, environment, and system-level support software for the entire company. The group has three divisions that operate autonomously, providing the software for various customers within the company (see the figure below). Each division is headed by a director, but right now one of the divisions is headed by a program manager who is really the deputy acting as director. The vice president in charge of the Software Services Group is David Greene, who has been at the site for five years and in charge of this particular group for one year. Rumor has it that he is looking forward to retirement in two years. Greene comes from a military background. He served in the Air Force for more than 20 years, attaining the rank of Captain. His background is in logistics, but he has worked in the computer field for the past eight years. He was previously director of the Environments Division within the group.



The Environments Division

This division is the smallest division in the Software Services Group and is headed by the program manager of the Case Tools program, Arnold Frost. He has been in his current position for about a year after being promoted into it when Greene was promoted to be the vice-president in charge of the group. He is acting as deputy director until a suitable replacement can be found. Frost spent his first ten years in the Army in a combat support role, and then he retired from the Army and switched over to the computer field for a total of six years of computer operations experience. He only understands the basics of operating a computer but is an excellent program manager. Arnold Frost has his sights set on becoming the permanent division director of the Environments Division. The Environments Division is responsible for maintaining a standard computing environment within the remaining divisions. It is largely composed of computer operations specialists, ranging from general computer operators to specialized experts such as telecommunications specialists. The division employs roughly 20 software engineers, whose responsibilities entail writing software to facilitate the integration of case tools, purchased from different vendors, into the standard computing environment.

The Applications Division

This is the largest division in the Software Services Group and is headed by Theresa Franklin, who has been at the site for three years. An engineer by training, she has been working in the computer field for about 15 of her 20 years of experience. She was promoted to the level of division director when the previous director retired, approximately two months ago. This division handles all the applications for the company. In particular, the division is responsible for the avionics applications for each of the airplanes manufactured by the company.

The Applications Division enjoys a very good reputation within the group. It is composed of approximately 90 software engineers of various levels of experience, and they have a reputation of developing applications that meet their specifications on time and with only minor cost overruns. Part of the success of the division can be attributed to the extensive use of case tools and system-level support software within the group's standard computing environment. The Applications Division either purchases commercial off-the-shelf (COTS) support software or has it custom made by the System Software Division if no COTS software can satisfy the particular need. The Applications Division then works with the Environments Division to integrate the support software into the standard computing environment for the group.

The System Software Division

Due to the complex nature of the software developed by the Applications Division, COTS software that can meet their special support software needs is not generally available. Therefore, the Applications Division subcontracts to the System Software Division to have much of their support software custom made. The System Software Division, the second largest division in the Software Services Group , is headed by Mark Collins, who has only recently become involved in the computer field. He spent most of his 20-year career as the Chief Liaison Officer at a Strategic Air Command (SAC) Air Force base. He retired from the Air Force three years ago and has been working in the computer field since. Collins was bitten by the computer bug while in college, and has always been interested in software systems; so after retiring from the Air Force he acquired a master's degree in software engineering.

This division is composed of approximately 45 computer scientists and software engineers of various levels of experience, although it is starting to attract a significant number of younger staff. The division is viewed as being composed of largely inexperienced software "hackers." They have a reputation of being difficult to work with and of not always delivering what was originally requested by the customer. In addition to this, they often miss delivery deadlines and run over budget.

The Stealth Helicopter Avionics Project

The avionics system of the new Stealth Helicopter is being developed by the Stealth Helicopter Project within the Helicopter Program of the Applications Division. It is being developed in Ada and is composed of multiple independent threads of execution (programs), each dedicated to a single microprocessor in the helicopter. The threads of execution run simultaneously, communicating with each other to complete their tasks.

Early in the design of the system, project management decided to develop the software on a VAX 8600 minicomputer and later port it to the target microprocessors within the helicopter. Their rationale was that, because Ada is a standard language, porting problems would be small in comparison to the problems and cost associated with testing and debugging the system on the target hardware. Project management, however, also knew that the members of the Stealth Helicopter Project did not have the appropriate computing equipment to perform adequate integration testing of the multiple threads of execution in the system.

To perform integration testing on the VAX 8600, an engineer would need the capability of running, monitoring, and debugging all of the independent threads of execution simultaneously on the minicomputer. This capability can easily be provided on a VAXStation II workstation running the same version of VMS operating system and using the same Ada compiler as those used on the VAX 8600. In this scenario, the engineer has access to multiple windows from the same keyboard. Each independent thread can be set up to execute in one of the windows, allowing the engineer to test and debug the entire application from a single computer. However, because of the prohibitive cost associated with giving every engineer a workstation, only one in ten Applications division staff members has one. The other nine staff members have VT220 *paging* terminals hooked to a VAX 8600 running VMS. Since Digital Equipment Corporation (DEC) does not supply VMS owners with even a primitive windowing capability for such terminals, the only way an engineer without a workstation can test the avionics system is to go to a place where there is more than one VT220 terminal and set the tests up from as many VT220 terminals as is necessary. Running such tests this way, however, is next to impossible with only one or even a few engineers.

To solve this problem, the Applications Division investigated the availability of software that might provide their staff with a primitive windowing capability for VT220 terminals. After having no success in the commercial market, the Applications Division decided to subcontract to the System Software Division to solve this problem. The System Software Division accepted the contract and set up a project called Multiterm within the Operating Systems Program. When the project was established and a sufficient number of staff was hired, the Applications Division presented the Multiterm Project with a statement of need. This officially signaled the start of the project.

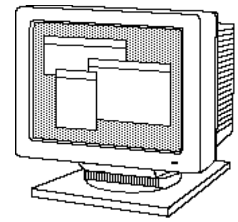
The Customer Statement of Need

The Stealth Helicopter Project of the Applications Division, hereafter referred to as the *contractor*, has the need to run, monitor, and debug multiple, autonomous, simultaneously executing, communicating Ada threads of execution (programs) from a single VT220 terminal on a VAX 8600 running VMS version 5.1.

The Multiterm Project of the System Software Division, hereafter referred to as the *subcontractor*, will provide a software system, hereafter referred to as the *software*, that enables the contractor to have this capability.

The software provided by the subcontractor must have a decidedly VMS-like look and feel; must have an unobtrusive user interface; must allow the customer to operate the VMS symbolic debugger, the VMS EDT and TPU editors, the VMS mail program, and other VMS applications while debugging application software; and must exhibit the same keystroke-to-display response time that VMS already provides typical user sessions on a VAX 8600 from a VT220 terminal. The software provided by the subcontractor must also allow the customer to supply input (from the keyboard) to and view the output from any application program currently being run, monitored, or debugged.

The Role of the Customer



Multiterm

You are the customer. The customer for the Multiterm system is the technical team leader for the Stealth Helicopter Project within the Applications Division. You have been with the Applications Division in the Zooming company for seven years and with the Stealth Helicopter Project since its beginning one year ago. You have 15 years of software development experience on large projects and were awarded the technical team leadership position on the current project as a result of displaying outstanding commitment, leadership, and design and development abilities on your past two projects.

You are a very intelligent, experienced, capable software designer and developer who consistently produces software that meets or exceeds the quality, performance, and functional requirements of the customer. Because of this, you are extremely confident in your judgment and can rarely be persuaded to look at alternatives unless an extremely sound argument is presented. You have the uncanny ability to abstract away from the details of a problem and design a system that not only solves the problem but incorporates cutting-edge technology and innovative features into the solution. However, you evolve a design over time and rarely write it down until you must. Not all ideas come at once, therefore, and sometimes the ideas can even be general and conflicting. The following paragraphs describe your general requirements for the delivered software system.

The capability of the software system must *at the very least* mirror the capabilities provided on the DECStation running DECWindows under VMS version 5.1. This means that the software must support multiple windows on the VT200 or VT300 terminal simultaneously. It must provide the capability of running the DEC symbolic debugger, TPU and EDT editors, and the DEC electronic mail software in any window. This, however, is the minimum requirement. It would be nice to be able to run *all* VMS software and utilities in any window.

The software system must be able to allow creation and deletion of windows. It must be able to allow input to be directed to any desired window. It must be able to connect a desired window to the terminal display so that the user can see output from the process running in that window (i.e., it must support switching among windows).

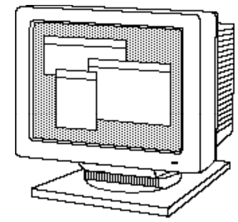
The user interface should be unobtrusive, and it should present the user with the look and feel of VMS wherever possible. Performance should not be noticeably different from the performance on the DECStation (with respect to keystroke response times).

The software system must be developed in Ada.

You have not thought about these requirements to any lower level of detail. For any question or discussion, your responses should be consistent with your own personal concepts regarding windowing systems, operating systems, dumb terminals, etc.

Note: You are to use this role to guide your actions during the role-playing exercise. The description provides only high-level guidance, however, and you are encouraged to embellish the role using your own experience and the background materials provided to you in this exercise.

The Role of User 1



You are a user for the Multiterm software system. You are one of the software developers on the Stealth Helicopter Project within the Applications Division. You have been with the Applications Division of the Zooming company for three years and with the Stealth Helicopter Project for about six months. You have five years of software development experience on large projects and were given a software development position on the current project as a result of demonstrating tremendous productivity and superior problem-solving skills on your last project.

You are a very intelligent, capable software developer who consistently produces software solutions that are creative, innovative, and elegant. You have a genius intelligence quotient (IQ), are highly productive, and prefer to work alone because you often get impatient with others who do not understand your solutions. Because of this, you are extremely confident in your abilities and are never afraid to experiment with new data structure designs and new algorithms. You utilize every available language construct at your disposal in each of the languages you use to develop software, namely C and Ada. You are often labeled a “hacker,” but your skills are those of a software engineer; your code adheres to strict software engineering principles. You have much respect among your peers and your ideas carry much weight.

With respect to the Multiterm software system, you are not as concerned about basic windowing functionality as you are about using the software to perform integration testing of the Stealth Helicopter avionics software. You are more interested in acquiring functionality that will make the testing not only possible, but also easier. The paragraphs below describe your general requirements for the delivered software system.

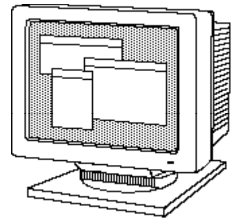
You agree with the customer that the capability of the software system must *at the very least* mirror the capabilities provided on the DECStation running DECWindows under VMS version 5.1. However, you desire some more interesting functionality and features. When creating a window under Multiterm, the software system should support starting either the DEC Command Language (DCL) interpreter or a VMS executable image. You do not know if it is possible, but you would like to be able to send keystrokes from the keyboard to more than one window simultaneously. You wish to be able to record input to and output from any and all windows under Multiterm control to keep as logs for debugging purposes. It would also be nice to have the ability to have input scripts to bring a Multiterm session to a predetermined, desired state. Output from windows not attached to the terminal display must not be lost.

You agree with the customer with respect to user interface and performance requirements.

You have not thought about these requirements to any lower level of detail. For any question or discussion, your responses should be consistent with your own personal concepts regarding windowing systems, operating systems, dumb terminals, etc.

Note: You are to use this role to guide your actions during the role-playing exercise. The description provides only high-level guidance, however, and you are encouraged to embellish the role using your own experience and the background materials provided to you in this exercise.

The Role of User 2



Multiterm

You are a user for the Multiterm software system. You are one of the software developers on the Stealth Helicopter Project within the Applications Division. You have been with the Applications Division of the Zooming company for six months, and you have just joined the Stealth Helicopter Project. You have two years of software development experience, all within the Zooming company, and were given a software development position on the current project as a result of your experience with VMS. You acquired all of your software development skills in college on DEC VAX systems using VMS, and you have worked on VMS systems since you joined the company.

You are a budding young software developer who shows much promise. You gained high marks in school in all of your software engineering classes. You were hired onto the Stealth Helicopter project because of your high marks in school and because your two years of software development experience were with Ada, on DEC workstations running VMS. The software that you produced on your last project adhered to the principles of software engineering you were taught in school, and the result was well-structured, well-documented code.

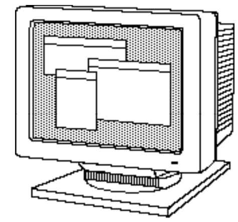
Because you lack software development experience in general, though, your code was not easily integrated with the rest of the system. However, your project manager has every confidence that your skills will improve as you gain experience. The project manager felt that you best represent the typical, intended user of the Multiterm software system and asked that you participate in the requirements definition activities.

With respect to the Multiterm software system, you are concerned about maintaining a VMS look and feel and supporting VMS functionality within the windows under Multiterm control. You would like to see VMS command recall within each window preserved. In fact, if it is possible, you would like to see any VMS command, entered in any window, be recallable and executed in any other window under Multiterm control. You would not like to see borders on the windows; it takes up too much space. You want each window to have full control of the terminal display (each window uses the entire terminal display, overlapping every other window completely). You want to see Multiterm support VMS top-level DCL processes as well as DCL subprocesses in a window. You want the Multiterm commands to be simple sequences of keystrokes, not echoed back to the terminal screen. You want a quick help screen to refresh your memory about these keystroke sequences. You want VMS messages (such as “You have new mail.”) to come through Multiterm to processes running under it.

You have many more thoughts about user interface requirements at lower levels of detail. For any question or discussion, your responses should be consistent with your own personal concepts regarding the VMS operating systems, dumb terminals, etc.

Note: You are to use this role to guide your actions during the role-playing exercise. The description provides only high-level guidance, however, and you are encouraged to embellish the role using your own experience and the background materials provided to you in this exercise.

The Role of the Requirements Analyst



Multiterm

You are a requirements analyst for the Multiterm Project in the System Software division. You have been with the Zooming company for seven years and with the Multiterm Project since it began three months ago. You have ten years of software development experience on large projects and two additional years of experience as a requirements analyst. You were given your current position on the Multiterm Project as a result of demonstrating superior communication and problem-solving skills on your last project, where you were the principle requirements analyst.

Your undergraduate degree is in mathematics, and you initially gained experience in programming by writing statistical analysis programs in FORTRAN for your assignments in college. When you graduated from school, the job market was tight for mathematicians, but there were plenty of jobs for programmers. Your first job was as a FORTRAN programmer in a telephone company. While you were there, you picked up some limited experience with C. After three years of working with the telephone company, your project delivered its software system and you were laid off because of a lack of available work. At that time, the Zooming company was entering full-scale development on three of its projects and hired you because of your C experience.

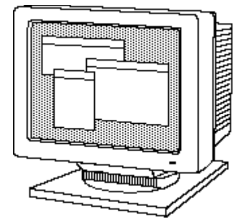
Over the next seven years, you were proficient and productive enough to continue to find work within Zooming. You learned Ada and gained much experience in both C and Ada. Over the years, however, you became more interested in the human aspects of software development and less interested in developing code. As a result, you enrolled in a program at the local university to obtain a master's degree in behavioral psychology, and you are about to graduate. Two years ago you applied for and obtained a position as a systems analyst on a management information systems project within the Applications Division. You knew immediately that you had found a home. You became extremely productive because communicating with people was easy and fun, and you did it well. Your first project as a systems analyst was extremely successful in that the delivered software met or exceeded every expectation of the customer and users. You were instrumental in the project's success because you were able to get the customer and users to communicate their needs, and you captured an accurate understanding of them.

Your success inspired you to pursue more requirements-related work within Zooming; you, therefore, learned some requirements elicitation techniques on your own.

With respect to the Multiterm software system, all you know is what you have read from the customer's statement of need; you are, nevertheless, excited to get started on this project. You plan to use one of the requirements elicitation techniques you know to get started with gathering the requirements for Multiterm. You are also confident that your previous development experience will help you resolve technical conflicts that might arise.

Note: You are to use this role to guide your actions during the role-playing exercise. The description provides only high-level guidance, however, and you are encouraged to embellish the role using your own experience and the background materials provided to you in this exercise.

The Role of the Software Engineer



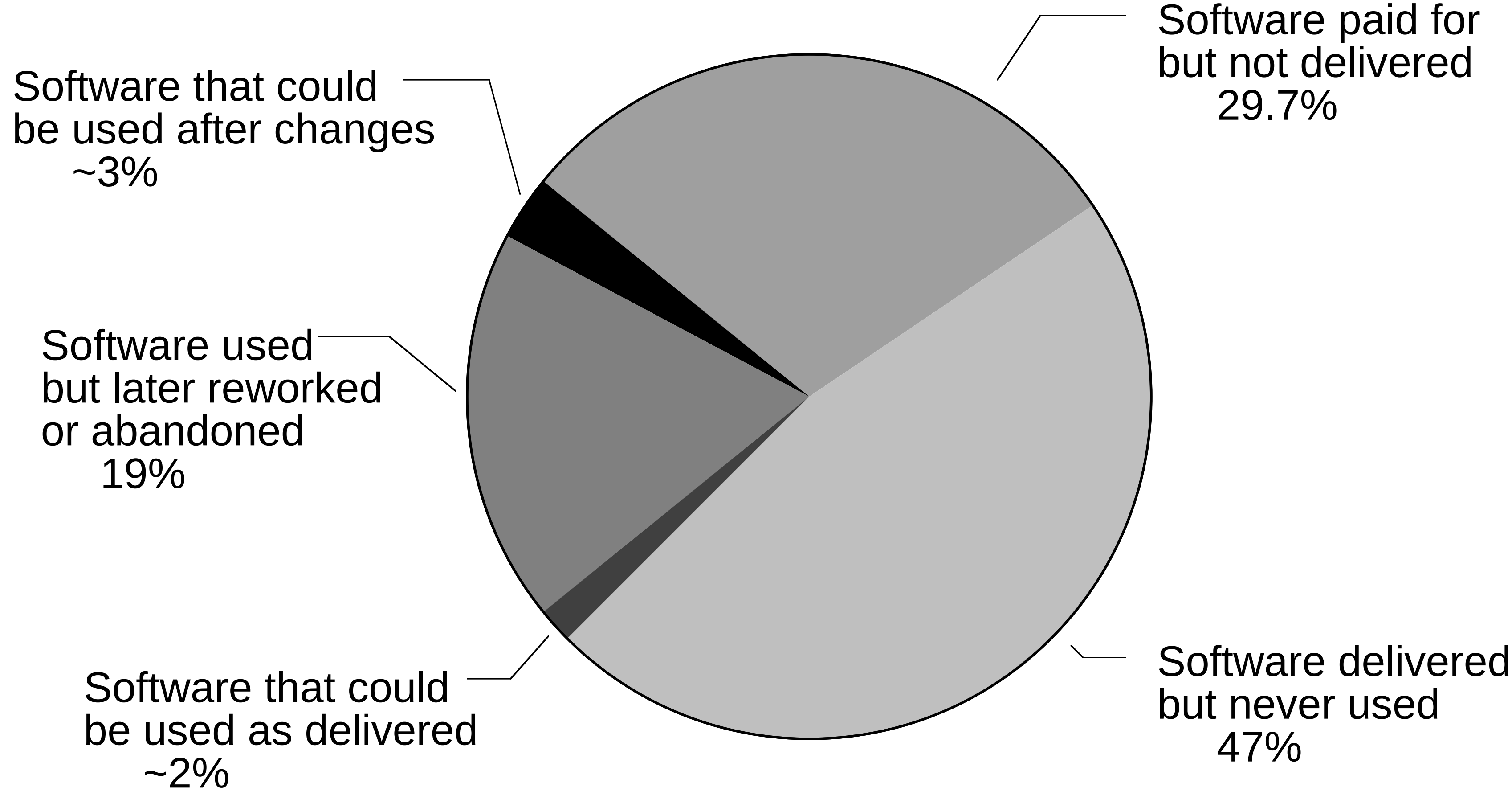
You are a software engineer on the Multiterm Project, hired to perform high-level design of the system. You have been with the System Software Division in the Zooming company for four years and were just brought on board the Multiterm Project last week. You have six years of software development experience in all; your first two years were spent writing application programs in the Applications Division at Zooming, which hired you directly from college. You were given a software design and development position on the current project as a result of your knowledge of VMS and the software design skills that you demonstrated on your last project, a software simulator for the embedded computer aboard the Stealth Fighter.

You are a very methodical software designer and developer with a reputation for producing software systems that meet their specifications. You are very thorough, investigating every alternative design and weighing the benefits and risks associated with each. This gives you a reputation for working slightly slower than other engineers, but this is acceptable because you produce systems that work and that contain few errors.

You have read the statement of need supplied by the customer and have done some initial investigation, experimentation, and prototyping in VMS to answer questions that came to mind while reading it. You know that using Ada increases the risk that keystroke-to-display response times will be longer than is acceptable. You know that there are VMS library routines, accessible from Ada programs, that will allow a program to create multiple, dependent subprocesses in VMS. You know that it is possible to open I/O channels to each of these subprocesses via pseudo-terminal device drivers. In short, you know that VMS will support your creation of a windowing system for dumb terminals. The risks are with the performance that Ada will provide.

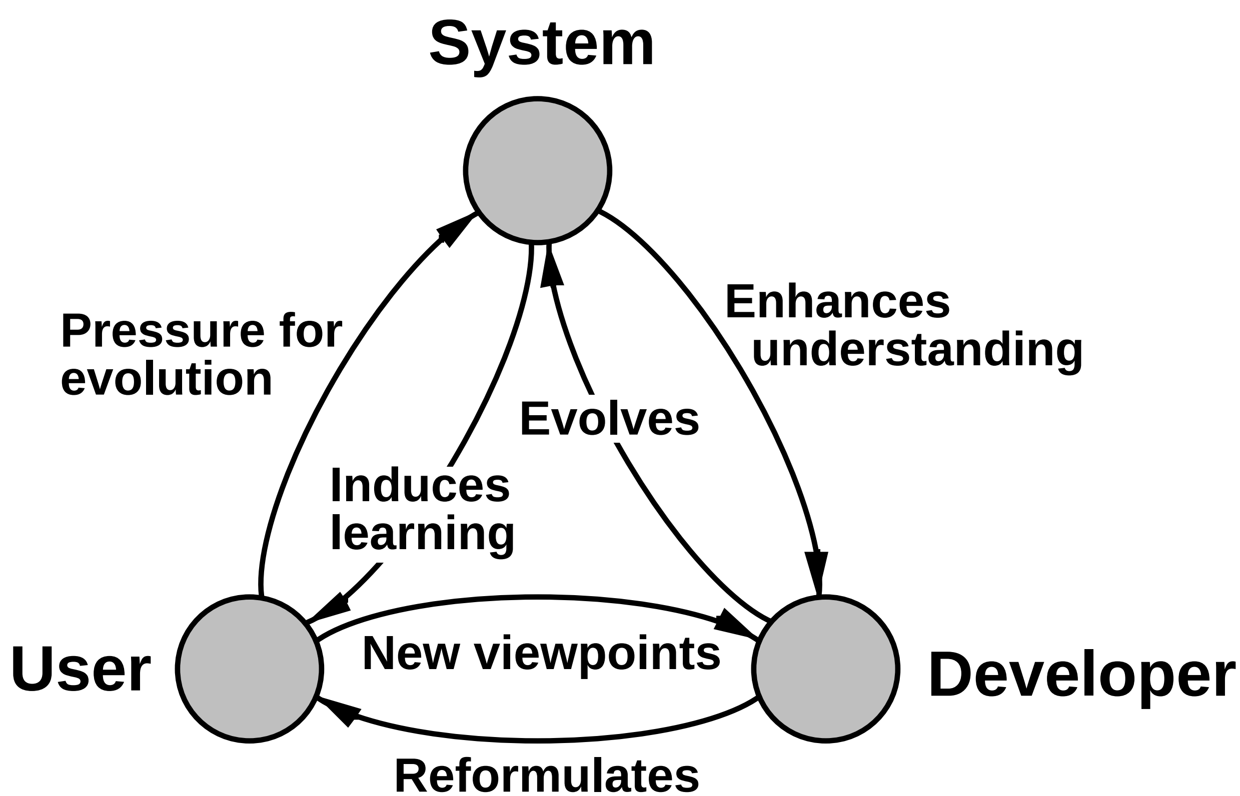
Note: You are to use this role to guide your actions during the role-playing exercise. The description provides only high-level guidance, however, and you are encouraged to embellish the role using your own experience and the background materials provided to you in this exercise.

GAO Survey of Software Contracts



Year 1982: Nine Contracts Totalling $6.8 Million

Adaptive Loops Framework



Goal-Directed Elicitation Process