

EXPLANATION CAPABILITIES
OF PRODUCTION - BASED CONSULTATION SYSTEMS

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Summary

A computer program that models an expert in a given domain is more likely to be accepted by experts in that domain, and by non-experts seeking its advice, if the system can explain its actions. An explanation capability not only adds to the system's credibility, but also enables the non-expert user to learn from it. Furthermore, clear explanations allow an expert to check the system's "reasoning", possibly discovering the need for refinements and additions to the system's knowledge base. In a developing system, an explanation capability can be used as a debugging aid to verify that additions to the system are working as they should.

This paper discusses the general characteristics of explanation systems. What types of explanations they should be able to give, what types of knowledge will be needed in order to give these explanations, and how this knowledge might be organized. The explanation facility in MYCIN [5,6,7] is discussed as an illustration of how the various problems might be approached.

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1 General Discussion

1.1 Consultative Production Systems

A consultation program plays the role of an expert consultant in some domain, giving advice or answers to non-experts with problems in the domain. Users will often want to know how the system arrived at its results during a particular consultation. This paper explains how the implementation of such a program as a production system can facilitate program-generated explanations.

A production system [2] consists of three basic components. a set of production rules, a data base which is both used and updated by these rules, and a rule interpreter. A production rule often is in the form of a situation-action rule. it describes a situation and a set of actions to be taken if this situation is found to exist. The rule interpreter determines the order in which rules will be tried, checks to see if the situations exist, and undertakes the required actions. It also determines how many of the potentially useful rules will be used. only the first (where ordering may be predetermined or computed dynamically), all possible rules, or enough rules to satisfy some criterion that the interpreter uses.

In some production systems, rules are always tried in a predetermined order. In others, the order in which rules are tried varies with different consultations, since a rule will be tried as soon as the rule interpreter determines that it may be useful. In such systems, the common alternatives are data-directed rule invocation, in which a rule is considered "useful" if its situation part matches the data base, and goal-

directed rule invocation, in which a rule is "useful" if its action part will help the system reach its current goal. Many systems use a combination of goal- and data-directed rule invocation.

A consultative production system need not be a psychological model, imitating a human's reasoning process. The important point is that the system and a human expert use the same (or similar) knowledge about the domain to arrive at the same answer to a given problem. The system's rules and data base can be viewed as a knowledge base containing the domain-specific knowledge of an expert as well as facts about a particular problem. When a rule is used, its actions make changes to the data base which are the system's decisions or deductions. Thus, a rule can be thought of as a piece of judgmental knowledge, using the judgment and knowledge of an expert to make deductions.

The process of trying rules and taking actions can be thought of as "reasoning", and explanations consist of showing how rules used information provided by the user to make various intermediate deductions and finally to arrive at the answer. If the information contained in these rules is sufficient to show why an action was taken (without getting into programming details), an explanation can consist of printing each rule that was used (or an English equivalent of what the rule means.)

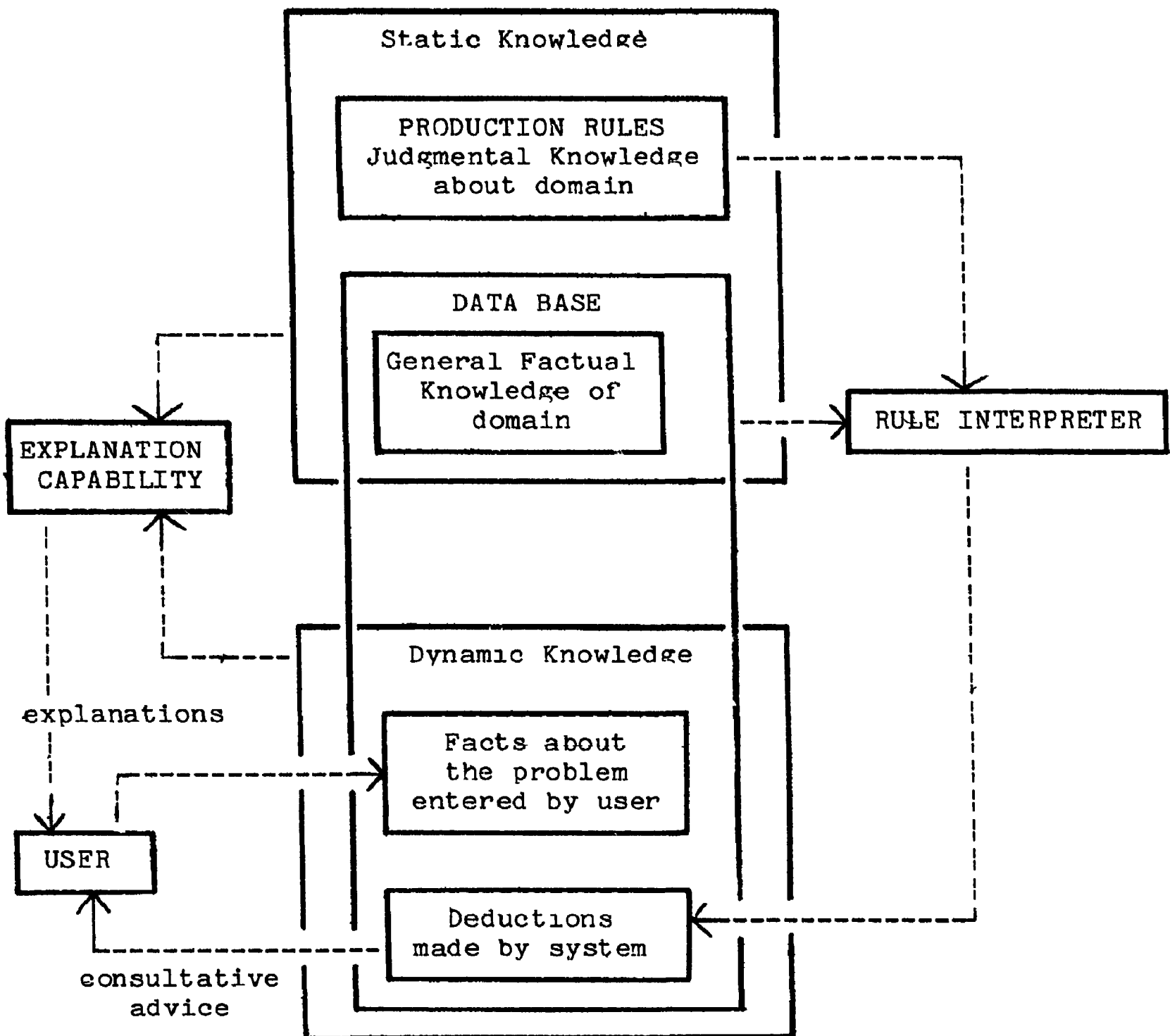


Figure 1. A Production-Based Consultation System with Explanation Capability

The three components of a production system (a RULE INTERPRETER, a set of PRODUCTION RULES, and a DATA BASE) are augmented by an EXPLANATION CAPABILITY. The data base is made up of general facts about the system's domain of expertise, facts that the user enters about a specific problem, and deductions made about the problem by the system's rules. These deductions form the basis of the system's consultative advice.

The explanation capability makes use of the system's knowledge base to give the user explanations. This knowledge base is made up of static domain-specific knowledge (both factual and judgmental) and dynamic knowledge specific to a particular problem.

1.2 Performance Characteristics of an Explanation Capability

The purpose of an explanation capability (EC) is to give the user access to as much of the system's knowledge as possible. Ideally, it should be easy for a user to get a complete, understandable answer to any sort of question about the system's knowledge and operation -- both in general, and with reference to a particular consultation. This implies three major goals in the development of an explanation capability.

1) To ensure that the EC can handle questions about all relevant aspects of the system's knowledge and actions. It should be capable of giving a few basic types of explanations, for example.

How it made a certain decision

How it used a piece of information

What decision it made about some subproblem

Why it didn't use a certain piece of information

Why it failed to make a certain decision

Why it required a certain piece of information

Why it didn't require a certain piece of information

How it will find out a certain piece of information

[while the consultation is in progress]

What the system is currently doing? [while the consultation is in progress]

The specific set of explanation types which are chosen as basics, however, will depend on the particular system.

2) To enable the user to get an explanation which answers the question completely and comprehensively.

3) To make the EC easy to use. A novice should be able to use the EC without first spending a large amount of time learning how to request explanations.

We will distinguish two slightly different functions for an EC and divide it into two components. the reasoning-status checker (RSC) to be used during the consultation, and the general question answerer (GQA) to be used during the consultation or after the system has printed its results.

A reasoning-status checker will answer questions asked during a consultation about the status of the system's reasoning process. A few

simple commands are often sufficient to handle the questions that the RSC is expected to answer

A general question-answer will answer questions about the current state of the system's knowledge base, including both static domain knowledge and facts accumulated during the consultation. A GQA will often need the ability to recognize a wide range of question types about many aspects of the system's knowledge. For this reason, it might be difficult to define a few simple commands which would be easy to learn and still cover all the possible questions that might be asked. Consequently, natural-language processing in this component may be important to an explanation system's acceptability.

In an interactive consultation, the system periodically requests information about the problem. This offers the user an opportunity to request explanations while the consultation is in progress. In non-interactive consultations, the user has no opportunity to interact with the system until after it has printed its conclusions. Unless there is some mechanism allowing a user to interrupt the reasoning process and ask questions, the explanation capability for such a system will be limited to questions about the system's final knowledge state. It will have no reasoning-status checker, and its general question-answerer will only be accessible at the termination of the consultation.

1.3 Knowledge Requirements of an Explanation Capability

An EC must know what is in the system's knowledge base, and how it is organized. In order to give explanations of the system's current (or previous) actions, an EC also needs to understand how the system's rule interpreter works. When rules will be tried how they can fail, what causes the interpreter to try one rule but not another etc. This general "schema" for how or why certain rules are used, together with a comprehensive record of the specific actions taken during a particular consultation, can be used as a basis for explaining the results of that consultation.

A reasoning-status checker will need a record of what the system has done so far in order to explain how it arrived at the current step. General knowledge of how the rule interpreter works is necessary in order to explain where the current step will lead. The ability to understand individual rules also may be necessary to the extent that the content of a rule may explain why it was necessary to use this rule, or may affect which future rules will be tried.

A general question-answerer will need more information about the system since the scope of its explanations is much broader. Its task is to answer general questions about the system's knowledge base. To do this, it must know how the system stores knowledge about its area of expertise (the static knowledge with which it starts each consultation) and how it stores facts gathered during a particular consultation (its dynamic knowledge). These two types of information will allow a GQA to answer questions about the substance and extent of the production system's current knowledge.

If an explanation capability also is to provide information about how the system arrived at the facts that are currently in its dynamic knowledge base, the GQA will need all the information that a reasoning-status checker uses. a detailed record of the consultation, an understanding of the rule interpreter, and the ability to understand rules.

These three types of knowledge could be supplemented with a limited amount of general information about such things as elementary logic, set theory, and arithmetic comparisons. This would allow the GQA to answer more complicated questions about why the system's knowledge base is in its current state, and to answer questions involving relationships between different facts in the knowledge base.

The nature of the consultation domain as well as what primary purpose the explanation capability is to serve will influence the range of questions that an EC should handle. In some systems, a simple retrieval of facts may suffice, while others may need to give detailed description of the production system's "decision" process and to make a number of deductions from facts that it has.

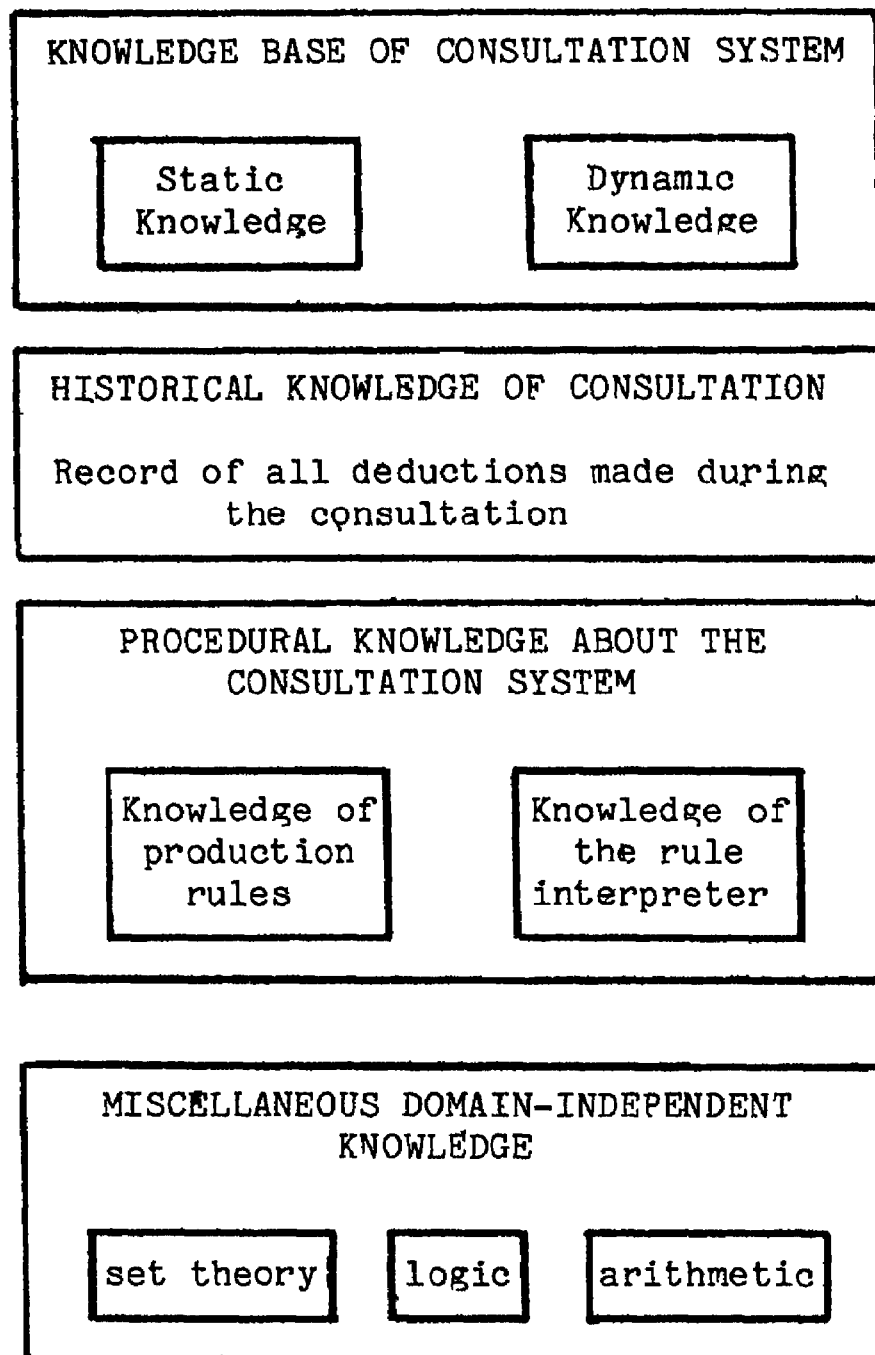


Figure 2. Knowledge Requirements of an Explanation Capability

Access to the consultation system's knowledge base is a prerequisite for performance of the explanation capability. Other types of knowledge may be added to the system to enable the EC to answer a wider range of questions.

1.4 Program Design Considerations

The last two sections described what an explanation capability is, outlining what tasks it should perform, and what it requires in order to perform these tasks. In this section, we discuss design considerations for the parent production system that will enable its EC to meet the requirements that were outlined in the previous section. This discussion is not meant to define the "correct" way of representing or organizing knowledge, but rather to mention certain factors which should be taken into account when deciding what representation or organization will be best for a given production system.

1.4.1 Question Types

The first step is to decide what basic types of questions the system should be able to answer. This will have a direct influence on how the EC is implemented. It is important, however to make the initial design flexible enough to accommodate possible future additions to the set of basics.

If the basic forms are diverse enough, some level of natural-language understanding may be necessary. The degree of sophistication of the natural-language processor will depend upon what kind of performance is expected of the EC

1.4.2 Organization of Knowledge

The format and organization of various components of the production system's knowledge base will affect the design of an EC. Individual pieces of static and dynamic knowledge presumably will be organized in some fashion

which makes them accessible during the consultation. A GOA facility could make use of such organization to help in finding the information needed to answer a question. The less organized the knowledge base the more difficult will be the task of the EC, as more complicated routines must be used in order to find the desired information.

During the course of the consultation, the system should keep a record of its actions for use by both components of the explanation capability. Where the ordering of events is important (e.g. when the action of one rule establishes the situation necessary for a subsequent rule to succeed), the record should be structured in a manner which reflects the ordering of events as well as the reasons why each event occurred.

1.4.3 Knowledge of What Rules Mean

The explanation capability will need to understand some of the semantics of individual production rules. This requirement could be met by having the system's knowledge base include a description of what each rule means, encoded in some form which would be of use to the EC. If the format of the system's rules is highly stylized and well-defined, however, it might be possible instead to implement a mechanism for "reading" the rules. The language in which the rules themselves are written could be defined. A high-level description of the individual components of this language, telling what each component means, could be used to enable the EC to read and understand rules. If the rule set consists of a large number of rules, and these rules are composed entirely of a relatively small number of primitive elements, this second approach has the advantage that less information needs to be stored -- a description of each of the primitive

components, as opposed to a description of each rule. When new rules are added to the system, the first approach requires that descriptions of these rules must be added. With the second approach, provided that the new rules are made up of the standard rule components, no additional descriptive information would be needed by the explanation capability.

1.4.4 Knowledge of the Rule Interpreter

Enabling an EC to understand how the rule interpreter works is analogous to enabling it to understand rules. It must be able to "read" the interpreter or else it must have access to some stored description of how the interpreter works. There is a third approach for understanding the rule interpreter, one which would not be feasible for understanding a large number of rules. Knowledge of how the interpreter works could be built into the EC -- the information would not be stated explicitly, but would be used implicitly by the programmer in writing the actual code for the explanation capability. The EC can be thought of as a number of "specialists", each capable of giving a single type of explanation. There could be one specialist for each of the basic question types that the system can answer. Each of the specialists needs only a small amount of information about the rule interpreter which could be built into its "explaining" program.

1.4.5 Other Domain-Independent Knowledge

The final type of knowledge that some general question-answering facilities will need is information allowing deductions to be made from facts in the knowledge base. The representation and extent of this knowledge will depend upon the types of questions that the system is to

answer. If logic is needed only to determine the answers to questions of a certain type, for example, the necessary deductions could be built into the specialist for answering that type of question. On the other hand, in some explanation capabilities, the GQA will be expanded to do more than simply give explanations of the system's actions or to query its data base -- it will be expected to answer a wide range of questions involving various kinds of inferences about the knowledge base. Such a GQA will need to check for equality or set membership, make arithmetic comparisons, or make logical deductions. In general, most information of this type can be embodied in a new kind of specialist which is an expert at some sort of logical deduction or comparison. Representation of this sort of general knowledge will become important as the GQA becomes not simply an explanation tool, but also a deductive one.

2 An Example -- MYCIN

2.1 Overview

MYCIN [5,6,7] is an example of a production-based consultation system with a well-developed explanation capability. A production run is an infectious disease therapy consultation in which MYCIN is the infectious disease expert, and the user is a doctor who wants advice about the treatment of a patient.

Knowledge that is gathered during the consultation is organized into attribute-object-value triples. In response to questions during the consultation, the user enters information about the existence of several objects, called contexts. the patient, infections that the patient has, organisms which may be causing these infections, cultures that were taken, and drugs that were given. The task of the consultation system is to determine the values of various attributes (called clinical parameters) of these contexts. For example, AGE is a clinical parameter of the patient; IDENTITY is a clinical parameter of an organism, with STREPTOCOCCUS as a possible value; SITE is a parameter of a culture, with BLOOD as a possible value.

A clinical parameter's value may be determined by asking the user, or by using decision rules. The parameter is said to be "traced" when the system has done all it can to find out the parameter's value. Tracing a parameter involves asking the user for a value (where applicable) and trying rules for determining the value of that parameter. Rules are tried until the value is known with certainty or there are no rules left to use.

Each decision rule has a situation part called its PREMISE. This consists of predicates, conditions that are tested to determine whether the indicated situation exists. If the conditions in a rule's PREMISE are true, its ACTION will be evaluated, giving new (or updated) values to some parameter(s). Before a condition in a rule's PREMISE can be tested, the parameters that it mentions must be traced. For example, before rule 209 (below) can succeed, the system must know the site of the culture, the portal of entry of the organism, and whether the patient is a compromised host. If any of the clauses in the PREMISE is false, or if the system is unable to find out the value of one of these parameters, the rule will fail.

RULE209

(PREMISE) If: 1) The site of the culture is blood, and
 2) The portal of entry of the organism is GI, and
 3) The patient is a compromised host
 (ACTION) Then: It is definite (1.0) that bacteroides is an organism
 for which therapy should cover

Associated with each attribute-object-value triple is a certainty factor -- a number between -1 and 1 inclusive which indicates how strongly the system believes that the attribute of the object has the indicated value. The user may modify the answer to any question with a certainty factor, and all rules make conclusions which specify a degree of certainty as well as attribute, object, and value.

Each context is named uniquely, allowing the system to refer to CULTURE-2, meaning the second culture, or ORGANISM-3, meaning the third organism. Moreover, the contexts are organized into a tree known as the context tree, which defines relationships among them. For example, an organism is the direct descendent of the culture from which it was isolated.

In the portion of a tree shown in Figure 3 ORGANISM-3 hangs under CULTURE-2 indicating that STREPTOCOCCUS was isolated from the BLOOD culture.

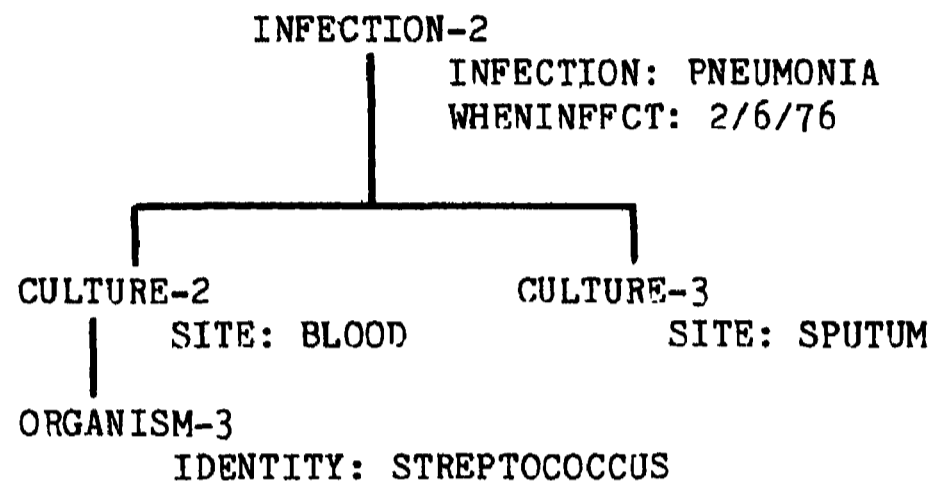


Figure 3. Portion of a Context Tree Showing Some Contexts, Clinical Parameters, and Values

The rule interpreter (MYCIN's control structure, described in detail in [7]) chooses the rules which should be used in the particular consultation, interprets these rules, and creates a record of its actions for use by the explanation system. Rules are invoked to find out values of parameters in a given context. A rule is applied to the lowest context in the context tree whose parameters are mentioned by the rule. The rule can use (or conclude about) parameters of this context, or of any context which is its ancestor in the tree. For example, if RULE209 were applied to ORGANISM-3 (see Figure 3) it would need the SITE of the culture from which the STREPTOCOCCUS was isolated. The tree indicates that this is CULTURE-2.

Rather than being a sequential cycle through the rule set, where each rule is tried in some predetermined order, the flow of control is goal-directed. This means that only rules which conclude about the current goal (to find out the value of a given parameter) are examined. The PREMISE of

one of these rules may need to use some parameter whose value is unknown. This sets up a subgoal, namely to determine the value of this parameter so that the rule can be used. MYCIN's goal-directed approach means that the system (and not the user) takes the initiative during a consultation. The user will be asked about only those parameters which may be relevant to the particular patient's case.

2.2 Organization of Knowledge in MYCIN

In order to give explanations of a consultation system's decisions, an explanation capability must have access to the system's knowledge base. More informative explanations can be given if the EC also has knowledge of how the system works, a record of the consultation, and possibly some domain-independent knowledge. This section discusses how MYCIN meets these requirements.

The system's knowledge base consists of static medical knowledge plus dynamic knowledge about a specific consultation. Static knowledge is further classified as factual and judgmental. Factual knowledge consists of facts which are medically valid independent of the particular case. Judgmental knowledge consists of production rules representing deductions which might be made, conditional on what is already known about the case. The format of production rules and of dynamic knowledge has already been described.

2.2.1 Organization of Factual Knowledge

As discussed in Section 2.1, all knowledge which is gathered during the consultation is organized into attribute-object-value triples. For consistency, many facts in the static knowledge base also have this format. This includes objects such as bacteria and antibiotics, and attributes such as the staining characteristics of a bacterium or the recommended dosage of an antibiotic:

ATTRIBUTE	OBJECT	VALUE
-----	-----	-----
GRAM	E.COLI	GRAMNEG
DOSE	GENTAMICIN	1.7 mg kg q8h IV (or IM)

The remainder of the factual knowledge consists of lists and tables: pieces of medical knowledge, organized in such a way that they can be used to augment the production rules. For example, one such piece of knowledge is the list of the possible culture sites which are normally nonsterile.

NONSTERILESITES: (CERVIX CUTANEOUS-ULCER LOCHIA NOSE SKIN
STOOL THROAT URETHRA VAGINA)

The likely pathogens associated with the different culture sites are organized in a table, with different entries for the different sites.

PATH-FLORA	

THROAT:	(STREPTOCOCCUS-PNEUMONIAE STREPTOCOCCUS- GROUP-A NEISSERIA-MENINGITIDIS)
URINE:	(E.COLI PSEUDOMONAS ENTEROCOCCUS PROTEUS KLEBSIELLA ENTEROBACTER)
SKIN:	(STAPHYLOCOCCUS-COAG-POS STREPTOCOCCUS- GROUP-A STAPHYLOCOCCUS-COAG-NEG)
CERVIX:	(STREPTOCOCCUS CLOSTRIDIUM-GANGRENE NEISSERIA-GONORRHEA STREPTOCOCCUS- GROUP-A)

Production rules can make use of this tabularized information:

RULE058

If: 1) The site of the culture is one of: those sites that are normally nonsterile, and
 2) This organism and at least one of the likely pathogens associated with the site of the culture agree with respect to the following properties:
 gram morph air

Then: There is strongly suggestive evidence (.9) that each of these pathogens is the identity of the organism

Note that the information in the table could have been organized as attribute-object-value triples (where the object would be a culture site). If this had been done, however, the above rule could not have been written. To accomplish the same purpose (without a change in the control structure), the system would have needed several rules -- a separate one for each entry in the table. Structuring certain facts into lists and tables enables individual production rules to express general theories which allow a number of specific deductions to be made.

2.2.2 Procedural Knowledge

Each of MYCIN's approximately 400 rules is composed of a small number of conceptual primitives. A total of 60 such primitives make up the language in which rules are written. This design facilitated the implementation of a mechanism for translating rules into English (described in detail in [7]). Each primitive functions has a translation template with blanks to be filled in with translations of the function's arguments. A large part of MYCIN's explanation capability depends on this ability to translate rules into a form that the user can understand.

Having a small number of rule components also facilitates the examination of rules to see which might be applicable to the explanation at hand. MYCIN's knowledge of production rules, therefore, takes the form of a general mechanism for "reading" rules. On the other hand, no attempt has been made to read the code of the rule interpreter. Procedural knowledge about the interpreter is embodied in "specialists", each capable of answering a single type of question. Each specialist knows how the relevant part of the control structure works and what pieces of knowledge it uses.

In order to understand rules, the system's various specialists use a small amount of knowledge about rules in general, together with descriptions or templates of each of the rule components. As an example, the following rule is composed of the units SAND, SAME, and CONCLUDE.

RULE009

PREMISE: (\$AND (SAME CNTXT GRAM GRAMNEG)
 (SAME CNTXT MORPH COCCUS))

ACTION: (CONCLUDE CNTXT IDENTITY NEISSERIA TALLY 800)

[Translation:

 If: 1) The gram stain of the organism is gramneg, and
 2) The morphology of the organism is coccus

 Then: There is strongly suggestive (.8) that the identity
 of the organism is Neisseria]

[When the rule is used, the LISP atom CNTXT is bound to some object, the context to which the rule is applied (see Section 2.1)]

The template for CONCLUDE is shown below. This describes each of the arguments to the function: first, an object (context); second, an attribute (clinical parameter); third, a value for this parameter; fourth, the tally or degree of certainty of the PREMISE; and last, the certainty factor -- a measure of how strong our belief in this conclusion would be, assuming that the PREMISE of the rule is definitely true.

CONCLUDE

TEMPLATE: (CNTXT PARM VALU TALLY CF)

To illustrate how this is used, consider an explanation that involves finding all rules which could conclude that the identity of an organism is Neisseria. The appropriate specialist would start with those rules which the system uses to conclude values for the parameter IDENTITY. Using templates of the various ACTION functions which appear in each of these rules, the specialist picks out only those (like RULE009) which have NEISSERIA in their VALU slot.

This also illustrates the sort of knowledge that can be built into a specialist. The specialist knew that the control structure uses stored lists telling which rules can be used to determine the value of each parameter. Furthermore, it knew that it was necessary to look only at the rules' ACTIONS because it is the ACTION that concludes facts, while the PREMISE uses facts.

2.2.3 The History Tree

Many of the explanation capability's specialists need a record of the consultation. This record is built during the consultation, and is organized into a tree structure called the **history tree** which reflects MYCIN's goal-directed approach. Each node in the tree represents a goal and contains information about how the system tried to accomplish this goal: by asking the user or by trying rules. Associated with each rule is a record of whether the rule succeeded, and if not, why it failed. If trying some rule causes the system to trace a new parameter, thereby setting up a

subgoal, the node for this subgoal is the offspring of the node containing the rule which caused the tracing. Figure 4 illustrates how part of a history tree might look. In this example, RULE003 caused tracing of the parameter CATEGORY which is used in the PREMISE of this rule.

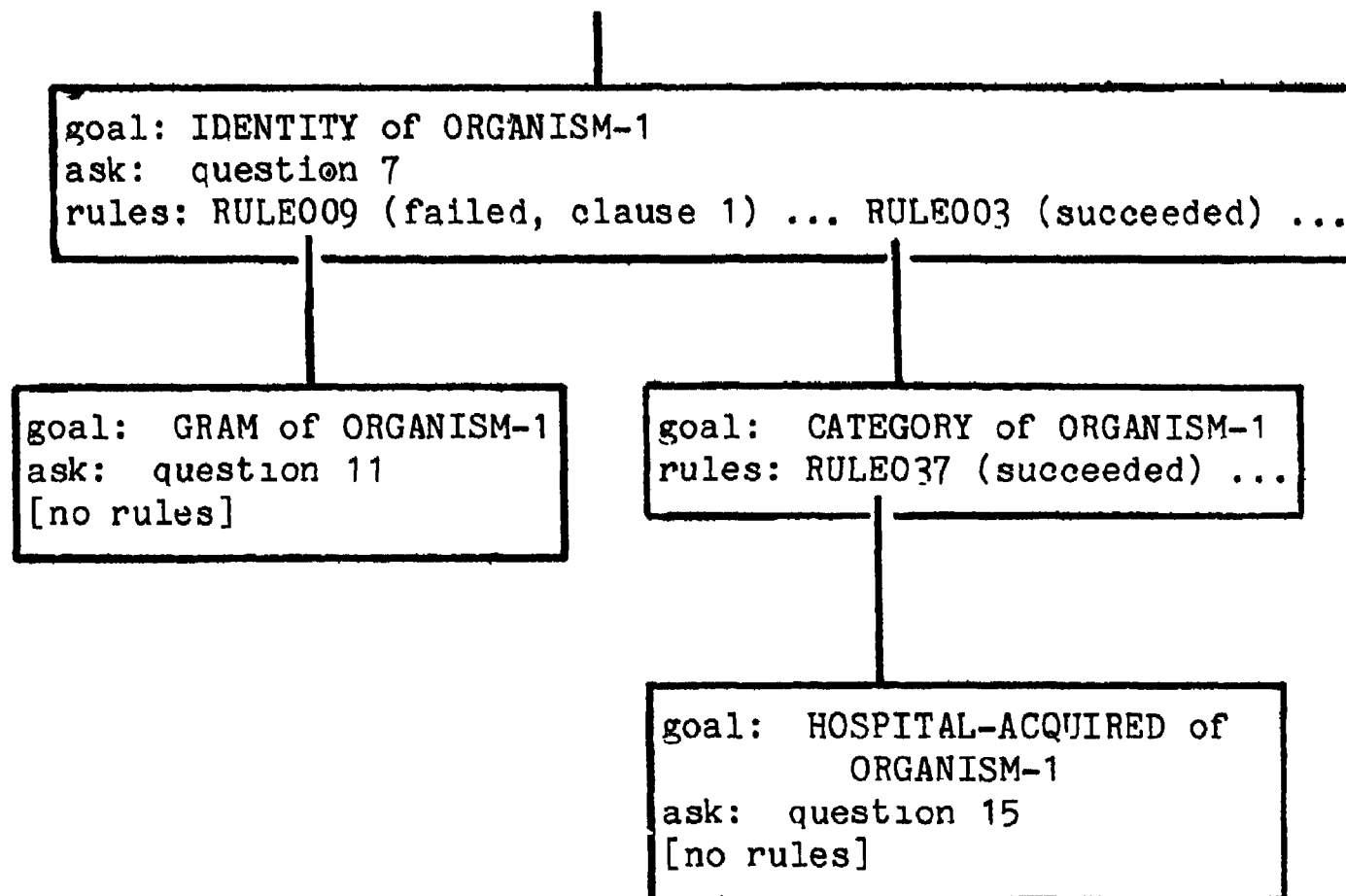


Figure 4. Portion of a History Tree
[RULE009 is shown above, see Figure 5 for RULE003 and RULE037]

2.2.4 Other Domain-Independent Knowledge

MYCIN's question-answering ability is limited to describing the system's actions, and explaining what facts the system knows. Some of the specialists for answering questions about the consultation make use of logic in arriving at their answers. In particular, to explain why a decision wasn't made, the appropriate specialist uses the logical conclusion that the answer consists of explaining what prevented the system from using each of the rules that would have made that decision.

If deductions or comparisons are needed to answer questions of a specific type, then the necessary logic is built into the appropriate specialist. There is no general representation of knowledge about logic, arithmetic, or set theory that the explanation capability can use to make inferences from different facts in its knowledge base. To find out whether ORGANISM-1 and ORGANISM-2 have the same identity, for example, it is necessary for the user to ask separately for the identity of each organism, then to compare the answers to these questions.

2.3 Scope of MYCIN's Explanation Capability

The purpose of the explanation system is to enable a user to see how MYCIN makes decisions, both in general and with reference to a particular consultation. To make this facility as useful as possible, we have tried to anticipate all types of questions which a user might ask, and to make every part of the system's knowledge base and reasoning process accessible through clear explanations.

The entire explanation facility consists of a number of components or "specialists" each capable of giving a single type of explanation. These components are grouped into three sets: one for explaining what the system is doing at a given time, one for answering questions about the system's static knowledge base, and one for answering questions about the dynamic knowledge base. The first set forms MYCIN's reasoning-status checker; the second and third together make up the system's general question-answer.

2.3.1 MYCIN's Reasoning-Status Checker

Whenever MYCIN asks a question, the user is allowed to interrogate the status of MYCIN's reasoning chain by asking WHY this piece of information is important. As explained in sections 2.1 and 2.2, the system asks a question in order to find out about its current goal. Consider the portion of a history tree shown in Figure 4. HOSPITAL-ACQUIRED is one subgoal, CATEGORY is another at the next level up, and RULE037 links them. The "reason" for asking whether the infection was hospital-acquired, then, is based on an attempt to use this rule to determine the higher subgoal. The answer to WHY at this point is simply a display of the goals and the rules linking them. We have given considerable attention to making this as lucid a display as possible. First, since "why" has several other interpretations, and no more extensive natural language processing is used in this component of MYCIN's EC, the question is expanded to indicate the sense in which it will be answered. The higher goal is then presented, followed by the rule. The clauses in the PREMISE of the rule are divided into those already established and those yet to be determined. Finally, since rules may have multiple conclusions about different clinical parameters, the relevant conclusion is presented first and all others follow.

As Figure 5 illustrates, further sections of the reasoning chain can be examined by repeating the WHY command. For any of the subgoals mentioned in answer to a WHY, the user may ask HOW this goal was (or will be) achieved.

MYCIN's reasoning-status checker is described in more detail in [3,4,6].

[preceded by the first 14 questions in the consultation]

15) Is the patient's illness with ORGANISM-1 a hospital-acquired infection?
**** WHY**
 [i.e. WHY is it important to determine whether or not the infection with ORGANISM-1 was acquired while the patient was hospitalized?]
 [1.0] This will aid in determining the category of ORGANISM-1.
 It has already been established that
 [1.1] the gram stain of ORGANISM-1 is gramneg, and
 [1.2] the morphology of ORGANISM-1 is rod, and
 [1.3] the aerobicity of ORGANISM-1 is facultative
 Therefore, if
 [1.4] the infection with ORGANISM-1 was not acquired while the patient was hospitalized
 then
 there is strongly suggestive evidence (.8) that the category of ORGANISM-1 is enterobacteriaceae
 ALSO: there is weakly suggestive evidence (.1) that the identity of ORGANISM-1 is pseudomonas-aeruginosa]
 [RULE037]

**** WHY**
 [i.e. WHY is it important to determine the category of ORGANISM-1?]
 [2.0]... in order to determine the identity of ORGANISM-1
 It has already been established that
 [2.1] this blood culture was taken from a sterile source
 Therefore, if
 [2.2] this current organism and at least one of the list of members associated with the category of the organism agree with respect to the following properties: air conformation
 then
 There is strongly suggestive evidence (.9) that each of them is the identity of ORGANISM-1
 [RULE003]

**** HOW 1.3**
 [i.e. HOW was it established that the aerobicity of ORGANISM-1 is facultative?]
 The following were used:
 [3.1] RULE027 indicated there is strongly suggestive evidence (.8) that the aerobicity of ORGANISM-1 is facultative
 [3.2] RULE027 indicated there is weakly suggestive evidence (.2) that the aerobicity of ORGANISM-1 is anaerobic
 Since this gave a cumulative CF of (.8) for facultative, and (.2) for anaerobic, it has been established that the aerobicity of ORGANISM-1 is facultative

**** HOW 1.1**
 [i.e. HOW was it established that the gram stain of ORGANISM-1 is gramneg?]
 You said so [question 11].

Figure 5. MYCIN's Reasoning-Status Checker
 [user entries follow the double asterisks]

2.3.2 MYCIN's General Question Answerer

The question-answering part of the system has natural-language routines for analyzing the user's input. The system recognizes questions phrased in a number of ways, thereby making the question-answering facility easier to use. Questions about the static knowledge base may deal with judgmental knowledge (e.g., which rules use or conclude a certain piece of information) or they may ask about factual knowledge -- entries in tables and lists. Some questions about static knowledge are shown in Figure 6.

IS BLOOD A STERILE SITE?
 WHAT ARE THE NONSTERILE SITES?
 WHAT ORGANISMS ARE LIKELY TO BE FOUND IN THE THROAT?
 IS BACTEROIDES AEROBIC?
 WHAT METHODS OF COLLECTING SPUTUM CULTURES DO YOU
 CONSIDER?
 WHAT DOSAGE OF STREPTOMYCIN DO YOU GENERALLY RECOMMEND?
 HOW DO YOU DECIDE THAT AN ORGANISM MIGHT BE STREPTOCOCCUS?
 WHY DO YOU ASK WHETHER THE PATIENT HAS A FEVER OF UNKNOWN
 ORIGIN?
 WHAT DRUGS WOULD YOU CONSIDER TO TREAT E.COLI?
 HOW DO YOU USE THE SITE OF THE CULTURE TO DECIDE AN
 ORGANISM'S IDENTITY?

Figure 6. Sample Questions about MYCIN's Static Knowledge

Perhaps the more important part of the question-answering system is its ability to answer questions about a particular consultation. While some users may be interested in checking the extent of MYCIN's static knowledge, most questions will ask for a justification of, or for the rationale behind, particular decisions which were made during the consultation. Outlined in Figure 7 are the types of questions about dynamic knowledge which can be handled at present. A few examples of each type are given. <Context> indicates some context which was discussed in the consultation; <parm> is some clinical parameter of this context; <rule> is one of the system's decision rules.

- 1) what is <parm> of <cntxt>
 TO WHAT CLASS DOES ORGANISM-1 BELONG?
 IS ORGANISM-1 CORYNEBACTERIUM-NON-DIPHtherIAE?
- 2) how do you know the value of <parm> of <cntxt>
 HOW DO YOU KNOW THAT CULTURE-1 WAS FROM A STERILE
 SOURCE?
 DID YOU CONSIDER THAT ORGANISM-1 MIGHT BE A
 BACTEROIDES?
 WHY DON'T YOU THINK THAT THE SITE OF CULTURE-1 IS
 URINE?
 WHY DID YOU RULE OUT STREPTOCOCCUS AS A POSSIBILITY
 FOR ORGANISM-1?
- 3) how did you use <parm> of <cntxt>
 DID YOU CONSIDER THE FACT THAT PATIENT-1 IS A
 COMPROMISED HOST?
 HOW DID YOU USE THE AEROBICITY OF ORGANISM-1?
- 4) why didn't you find out about <parm> of <cntxt>
 DID YOU FIND OUT ABOUT THE CBC ASSOCIATED WITH
 CULTURE-1?
 WHY DIDN'T YOU NEED TO KNOW WHETHER ORGANISM-1 IS A
 CONTAMINANT?
- 5) what did <rule> tell you about <cntxt>
 HOW WAS RULE 178 HELPFUL WHEN YOU WERE CONSIDERING
 ORGANISM-1?
 DID RULE 116 TELL YOU ANYTHING ABOUT INFECTION-1?
 WHY DIDN'T YOU USE RULE 189 FOR ORGANISM-2?

Figure 7. Sample Questions about a Consultation

Before a question can be answered, it must be classified as belonging to one of these groups. As Figure 7 illustrates, each question type includes a variety of ways in which the question can be worded, some specifying the parameter's value, some phrased in the negative, and so forth. MYCIN's natural-language processor must classify the questions, then determine what clinical parameters, etc. the question references.

2.4 Understanding The Question

The main emphasis in the development of the MYCIN system has been the creation of a production system which can provide sound diagnostic and therapeutic advice in the field of infectious disease. The explanation system was included in the system's original design in order to make the consultation program's decisions acceptable, justifiable, and instructive. Since the question-answering facility was not the primary focus of the research, it is not designed to be a sophisticated natural-language understander. Rather, it uses crude techniques, relying strongly on the very specific vocabulary of the domain, to "understand" what information is being requested.

The analysis of a question is broken into three phases: the first creates a list of terminal or root words; the second determines what type of question is being asked (see the classification of questions in Section 2.3); and the last determines what particular parameters, lists, etc. are relevant to the question.

In the first and last steps, the system dictionary is important. The dictionary contains approximately 1400 words that are commonly used in the domain of infectious disease. It includes all words that are acceptable values for a parameter, common synonyms of these words, and words used elsewhere by the system in describing the parameter (e.g., when translating a rule into English or requesting the value of the parameter).

2.4.1 Reducing the Question to Terminal Words

Each word in the dictionary has a synonym pointer to its terminal word (terminal words point to themselves). For the purpose of analyzing the question, a non-terminal word is considered to be equivalent to its (terminal) synonym.

Terminal words may have properties indicating:

1) that this word is an acceptable value for some clinical parameter(s)

2) that this word always implicates a certain clinical parameter, system list, or table (e.g. the word "identity" always implicates the parameter IDENTITY, which means the identity of an organism)

3) that this word might implicate a certain parameter, system list, or table (e.g. the word "positive" might implicate the parameter NUMPOS, which means the number of positive cultures in a series)

4) that this word is part of a phrase which can be thought of as a single word (examples of such phrases are "transtracheal aspiration", "how long", and "not sterile".

Table 1. Properties of Terminal Words

The first three properties are actually inverse pointers which are generated automatically from properties of the clinical parameters. Specifically, a word receives the "acceptable value" pointer to a parameter (property (1) above) if it appears in the parameter's list of acceptable values -- a list which is used during the consultation to check the user's response to a request for the parameter's value. Also, each clinical parameter, list, and table has an associated list of key words that are commonly used when talking about this parameter, list, or table. These words are divided according to how sure we can be that a doctor is referring to this

parameter list, or table when the particular word is used in a question. It is from this list that terminal words "implication" pointers (properties 2 and 3 in Table 1) are generated.

During the first phase of parsing, each word in the original text is replaced by its terminal word. For words not found in the dictionary, the system uses Winograd's root-extraction algorithm [8] to see if the word's lexical root is in the dictionary (e.g., the root of "decision" is "decide"). If so, the word is replaced by the terminal word for its root. Words still unrecognized after root extraction are left unchanged.

The resulting list of terminal and unrecognized words is then passed to a function which recognizes phrases. Using property 4 (see Table 1) of the terminal words in this list, the function identifies a phrase and replaces it with a single synonymous terminal word (whose dictionary properties may be important in determining the meaning of the question).

2.4.2 Classifying the Question

The next step is to classify the question so that the program can tell which specialist should answer it. Since all questions about the consultation must be about some specific context, the system requires that the name of the context (e.g., ORGANISM-1) be stated explicitly. This gives an easy way to separate general questions about the knowledge base from questions about a particular consultation. Further classification is done through a pattern matching approach similar to that used by Colby [1].

The list of words created by the first phase is tested against a number of patterns (about 50 at present). Each pattern has a list of actions to be taken if the pattern is matched. These actions set flags

which indicate what type of question was asked. In the case of questions about judgmental knowledge (called rule-retrieval questions), pattern matching also divides the question into the part referring to the rule's PREMISE and the part referring to its ACTION. For example, in "How do you decide that an organism is streptococcus?", there is no PREMISE part, and the ACTION part is "an organism is streptococcus"; in "Do you ever use the site of the culture to determine an organism's identity?", the PREMISE part is "the site of the culture" and the ACTION part is "an organism's identity".

2.4.3 Determining What Pieces of Knowledge are Relevant

The classification of a question guides its further analysis. Each question type has an associated template with blanks to be filled in from the question. The different blanks and the techniques for filling them in are listed in Table 2. With the question correctly classified, the general question-answerer can tell which specialist should answer it. Filling in all blanks in the template gives the specialist all the information needed to find the answer.

1) <cntxt> - The context must be mentioned by name.
 2) <rule> - Either a rule's name (RULE047) will be mentioned, or the word "rule" will appear, together with the rule's number (47).

3) <value> - One of the terminal words in the question has a dictionary property indicating that it is a legal value for the parameter (property 1, Table 1 -- e.g. THROAT is a legal value for the parameter SITE).

4) <parm> - All of the words in the list are examined to see if they implicate any clinical parameters. Strong implications come from words with properties showing that the word is an acceptable value of the parameter, or that the word always implicates that parameter (properties 1 and 2, Table 1). Weak implications come from words with properties showing that they might implicate the parameter (property 3, Table 1). The system uses an empirical scoring mechanism for picking out only the most likely parameters.

Associated with certain parameters are words or patterns which must appear in the question in order for the parameter to be implicated. This scheme allows the system to distinguish related parameters which may be implicated by the same key words in the first pass. For example, the word "PMN" implicates parameters CSFPOLY (the percent of PMNs in the CSF) and PMN (the percent of PMNs in the complete blood count). These are distinguished by requiring that the word "CSF" be present in a question in order for CSFPOLY to be implicated.

5) <list> - System lists are indicated in a manner similar to parameters, except that scoring is not done. Lists, like parameters, may have associated patterns which must be present in the question. Furthermore, lists have properties telling which other system lists are their subsets. If a question implicates both a list and a subset of that list, the more general (larger) list is discarded. As an example, the question "Which drugs are aminoglycosides?" implicates two lists: The list of all drugs and the list of drugs which are aminoglycosides. The system only considers the more specific list of aminoglycosides when answering the question.

6) <table> - Tables are indicated in a manner similar to lists except that an entry in the table must also be present in the question. For example, the word "organism" may indicate two tables: one containing a classification of organisms, and the other containing normal flora of various portals. The question "What organisms are considered to be subtypes of Pseudomonas?" will correctly implicate the former table, and "What are the organisms likely to be found in the throat?" will implicate the latter, because PSEUDOMONAS is in the first table and THROAT is in the second.

Table 2. Mechanisms for Analyzing a Question

**** WHEN DO YOU DECIDE THAT AN ORGANISM IS A CONTAMINANT?**

[1] Terminal words: WHEN DO YOU CONCLUDE THAT A ORGANISM
IS A CONTAMINANT

[2] Question type: Rule retrieval
Premise part: (WHEN DO YOU CONCLUDE)
Action part: (THAT A ORGANISM IS A CONTAMINANT)

[3] vocab. clues: (WHENINFECT (ANY) 1) (WHENSTOP (ANY) 1)
(Premise) (WHENSTART (ANY) 1) (DURATION (ANY) 1)
vocab. clues: (CONTAMINANT (ANY) 4) (FORM (ANY) 1)
(Action) (SAMEBUG (ANY) 1) (COVERFOR (ANY) 1)

[4] Final translation:
Premise: ANY
Action: (CONTAMINANT ANY)

[5] The rules listed below conclude about:
whether the organism is a contaminant
6, 31, 351, 39, 41, 42, 44, 347, 49, 106
Which do you wish to see?
**** 6**

RULE006

If: 1) The culture was taken from a sterile source, and
2) It is definite that the identity of the organism
is one of: staphylococcus-coag-neg bacillus-
subtilis corynebacterium-non-diphtheriae
Then: There is strongly suggestive evidence (.8)
that the organism is a contaminant

Figure 8. Sample of MYCIN's Analysis of a Question

[User input follows the double asterisks.]

- [1] The question is reduced to a list of terminal words.
- [2] Pattern matching classifies the question as a rule-retrieval question, and divides it into a premise part and an action part.
- [3] Dictionary properties of the terminal words are used to determine which parameters (and their values) are relevant to each part of the question. These vocabulary clues are listed in the form (<parm> (<values>) weight) where weight is used by the scoring mechanism to determine which parameters should be eliminated from consideration.
- [4] After selecting only the most strongly indicated parameters, the final translation tells what rules can answer the question: there are no restrictions on the PREMISE, and the ACTION must contain the parameter CONTAMINANT (with any value).
- [5] The answer consists of finding all rules which meet these restrictions, and printing those that the user wants to see.

2.5 Answering the Question

Corresponding to each question type, there are a number of possible answer templates. For example, for questions of the form "How do you know the value of <parm> of <cntxt>?", two of the answer templates are:

I used <rule> to conclude that <parm> of <cntxt> is <value>.
 This gave a cumulative c.f. of <certainty factor>.
 The last question asked before the conclusion was made
 was <question number>.

In answer to question <question number> you said that <parm> of
 <cntxt> is <value>

The specialist for answering questions of a given type will need to check the history tree or the system's knowledge base in order to determine which of the answer templates is appropriate for a particular question. Some blanks in the answer template will be filled in by the same items that filled blanks in the question template. The remainder are filled by the specialist with information which will answer the question. In the above example, the slots <parm>, <cntxt>, and possibly <value> would be filled in from the question, and the other slots would be filled from the history tree.

2.5.1 Questions about MYCIN's Static Knowledge

General questions about MYCIN's factual knowledge are the easiest to answer. The specialist that provides answers to such questions must look up the desired information in the system's static knowledge base. Generally, an answer consists of simply displaying this information. As Figure 9 illustrates, the most processing that is ever done is to check the retrieved information against some item in the question (for equality of set membership).

**** IS BLOOD A STERILE SITE?**

Yes. Blood is one of those sites that are normally sterile.

**** WHAT ARE THE NONSTERILE SITES?**

Those sites that are normally nonsterile are: CERVIX,
CUTANEOUS-ULCER, LOCHIA, NOSE, SKIN, STOOL, THROAT, URETHRA,
VAGINA.

**** WHAT ORGANISMS ARE LIKELY TO BE FOUND IN THE THROAT?**

The likely pathogens associated with throat are: STREPTOCOCCUS-
PNEUMONIAE, STREPTOCOCCUS-GROUP-A, NEISSERIA-MENINGITIDIS.

**** IS BACTEROIDES AEROBIC?**

No, the aerobicity of bacteroides is anaerobic.

**** WHAT DOSAGE OF STREPTOMYCIN DO YOU GENERALLY RECOMMEND?**

The suggested dosage and route of streptomycin is 7.5 mg/kg
q12h IM (or IV).

**** HOW DO YOU TREAT MENINGOCOCCAL BACTEREMIA?**

For treatment of NEISSERIA-MENINGITIDIS in PRIMARY-BACTEREMIA
Select therapy from among the following drugs (ranked according
to relative efficacy, assuming uniform sensitivity):

PENICILLIN	(.91)	
AMPICILLIN	(.9)	dose: 30 mg/kg q6h
SULFISOXAZOLE	(.8)	dose: 60 mg/kg IV then 15 mg/kg q4h IV for 48 days then 15 mg/kg q4h PO
CHLORAMPHENICOL	(.7)	
ERYTHROMYCIN	(.5)	
TETRACYCLINE	(.4)	

Duration of therapy: 14 days

Figure 9. Questions about Factual Knowledge

The specialist that answers questions about judgmental knowledge is slightly more complicated. Answering these questions (Figure 10) involves built-in knowledge about the rule set, plus the ability to "read" the rules. By the time the question has been analyzed, the specialist knows exactly which parameters must appear in the PREMISE, and which must appear in the ACTION of any rule which answers the question. Values may be specified for any of the parameters. To answer the question, the rule-retrieval specialist must first find every rule whose PREMISE and ACTION satisfy these

constraints. To do this, it needs to know that there are two special lists associated with each parameter: one containing every rule that uses the parameter in its PREMISE, and the other containing every rule that concludes about the parameter in its ACTION. Using these lists for the various parameters mentioned in the question, the specialist can find those rules that might answer the question. If no values were specified, the job is done and the relevant rules can be displayed without further analysis; otherwise, it is necessary to read each of the rules in the list and to eliminate those which do not mention the correct values for the parameter.

The rule-retrieval specialist also makes use of a piece of MYCIN's knowledge which was not discussed earlier. The system contains models of its own knowledge (called rule models) which are used primarily during acquisition of new medical knowledge from an expert [4]. These models, however, can be put to many uses -- one is to explain general patterns in decision making. The rule models are abstract descriptions of a subsets of rules and are generated automatically by reading the rules. For example, the model for IDENT-IS-PSEUDOMONAS tells what features are common to the majority of rules which conclude that the identity of an organism is pseudomonas.

If a model exists describing the rules about which the question is asking, the rule-retrieval specialist incorporates this model's information into its answer (Figure 11). Thus the question-answering facility is able to give some information about strategies for achieving some of the system's goals, as well as the individual rules which use the strategies.

**** WHY DO YOU ASK WHETHER THE PATIENT HAS A FEVER OF UNKNOWN ORIGIN?**

The rules listed below use:

whether the patient has a true fever of unknown origin

RULE180

- If: 1) The site of the culture is blood and
 2) The number of cultures in the series including the culture is greater than or equal to 1, and
 3) The number of cultures in this series which were positive for the organism is less than or equal to 1, and
 4) The patient has a true fever of unknown origin, and
 5) Cardiac-surgery is a relevant item from the history of the patient

Then: There is suggestive evidence (.6) that the infection is infective-endocarditis

**** WHAT DOES GU MANIPULATION TELL YOU ABOUT THE IDENTITY OF AN ORGANISM?**

The rules listed below use:

whether the patient has had a genito-urinary manipulative procedure

to conclude about:

the identity of the organism

156, 163, 190

Which do you wish to see?

** 156

RULE156

- If: 1) The site of the culture is blood, and
 2) The gram stain of the organism is gramneg, and
 3) The morphology of the organism is rod, and
 4) The portal of entry of the organism is urine, and
 5) The patient has not had a genito-urinary manipulative procedure, and
 6) Cystitis is not a problem for which the patient has been treated

Then: There is suggestive evidence (.6) that the identity of the organism is e.coli

Figure 10. Rule-Retrieval Questions

**** HOW DO YOU DECIDE THAT AN ORGANISM MIGHT BE
PSEUDOMONAS AERUGINOSA?**

Rules which conclude that the identity of the organism is pseudomonas-aeruginosa generally use one or more of the following pieces of information:

- the site of the culture
- the gram stain of the organism
- the morphology of the organism

Furthermore, the following relationships hold:

The gram stain of the organism, and the morphology of the organism tend to appear together in these rules.

RULE184, RULE116, RULE047, RULE085, RULE040 conclude that the identity of the organism is pseudomonas-aeruginosa. Which of these do you wish to see?

**** 184**

RULE184

- If: 1) The category of the organism is not known, and
2) The gram stain of the organism is gramneg, and
3) The morphology of the organism is rod, and
4) The aerobicity of the organism is facul

Then: There is weakly suggestive evidence (.1) that the identity of the organism is pseudomonas-aeruginosa

Figure 11. Question Which Uses Rule Models

2.5.2 Consultation-Specific Questions

One of the simplest questions about a specific consultation inquires about the value of a particular parameter (Figure 12). The specialist which answers these questions must know how to retrieve this information. In some cases it will also be necessary to make comparisons to see whether a value specified in the question is one of the values which was deduced for that parameter.

**** TO WHAT CLASS DOES ORGANISM-1 BELONG?**

The category of ORGANISM-1 is enterobacteriaceae (.9)

**** IS ORGANISM-1 A STREPTOCOCCUS?**

No.

The identity of ORGANISM-1 is e.coli (.74) bacteroides (.7)
klebsiella-pneumoniae (.4) pseudomonas-aeruginosa (.22)
enterobacter (.21) proteus-non-mirabilis (.19) serratia (.03)
salmonella (.02)

Figure 12. Questions about a Parameter's Value

Answering other types of consultation-specific questions involves the use of knowledge about the control structure, including:

- 1) how the system acquires information
- 2) why the system tries to find out about parameters
- 3) how information is used once it is acquired
- 4) what causes a rule to be tried
- 5) what causes a rule to fail.

The specialist for answering questions like "How do you know the value of <parm> of <cntxt>?", knows that the value of a parameter can come from two sources: it can be deduced by rules, or the user can tell us about it in response to a question. The history tree (see Section 2.2) will show which (possibly both) of these sources provided the particular information mentioned in the question (Figure 13).

**** HOW DO YOU KNOW THAT CULTURE-1 WAS FROM A STERILE SOURCE?**
 I used rule189 to conclude that this blood culture was taken from a sterile source. This gave a cumulative c.f. of (1.0). The last question asked before the conclusion was made was 7.

**** DID YOU CONSIDER BACTEROIDES AS A POSSIBILITY FOR ORGANISM-1?**
 Yes. I used rule095 to conclude that the identity of ORGANISM-1 is bacteroides. This gave a cumulative c.f. of (.7). The last question asked before the conclusion was made was 20.

**** HOW DO YOU KNOW THAT ORGANISM-1 IS E.COLI?**
 The following rules made conclusions about whether the identity of ORGANISM-1 is e.coli

RULE	cumulative certainty		last question asked before conclusion was made
	Yes	No	
RULE021	(.47)		20
RULE084	(.55)		22
RULE003	(.74)		24

In answer to question 9 you said that the identity of ORGANISM-1 is e.coli (.3)

Figure 13. Question Regarding How a Conclusion Was Made

If the question is phrased in the negative, it is necessary first to find all the ways the conclusion could have been made (this is a simple task of rule-retrieval), then to explain why it wasn't made in this consultation (Figure 14). The specialist for answering these questions must know what situations can prevent conclusions from being made. The second question in Figure 14 illustrates how the answer to one question might cause another question to be asked.

**** WHY DID YOU RULE OUT STREPTOCOCCUS AS A POSSIBILITY FOR ORGANISM-1?**

The following rules could have been used to determine that the identity of ORGANISM-1 is streptococcus: RULE033. However, none of these succeeded in the context of ORGANISM-1. If you would like an explanation for why any of these rules failed, please enter their numbers:

**** 33**

Clause 2 of rule033 ["the morphology of the organism is coccus"] was already known to be false for ORGANISM-1, so the rule was never tried.

**** WHY DON'T YOU THINK THAT THE MORPHOLOGY OF ORGANISM-1 IS COCCUS?**

It is definite that the morphology of ORGANISM-1 is rod. Knowing this with certainty rules out all other values for the the morphology of ORGANISM-1, including coccus.

Figure 14. Questions Regarding Why a Conclusion Wasn't Made

The specialist for answering questions of the form "How did you use <parm> of <cntxt>?", needs to know not only how to find the specific rules which might use a parameter, but also how a parameter can cause a rule to fail and how one parameter can prevent another from being used. The history tree can be checked to see which of the relevant rules used the parameter, which failed because of the parameter, and which failed for some other reason, preventing the parameter from being used (Figure 15).

**** HOW DID YOU USE THE AEROBICITY OF ORGANISM-1?**

The aerobicity of ORGANISM-1 was used in the following rules:
RULE003, RULE005, RULE084.

The aerobicity of ORGANISM-1 caused the following rules to fail:
RULE035, RULE051, RULE052, RULE053, RULE111.

The aerobicity of ORGANISM-1 also would have been used in:
RULE037, RULE050, RULE058, RULE086, RULE110, RULE184,
RULE203, RULE204, RULE205. However, none of these
succeeded in the context of ORGANISM-1. If you would
like an explanation for why any of these rules failed,
please enter their numbers:

**** 37**

Rule037 was tried in the context of ORGANISM-1, but it failed
due to clause 1 ["the category of the organism is not
known"].

**** DID YOU CONSIDER THE FACT THAT PATIENT-1 IS NOT A COMPROMISED
HOST?**

The fact that Fred Jones is not a compromised host caused the
following rules to fail: RULE085, RULE106.

The fact that Fred Jones is not a compromised host also would
have been used in: RULE109. However, none of these
succeeded in the context of PATIENT-1. If you would
like an explanation for why any of these rules failed,
please enter their numbers:

**** NONE**

Figure 15: Questions Regarding How Information Was Used

For questions of the form "Why didn't you find out about <parm> of <cntxt>?", general knowledge of MYCIN's control structure tells the conditions under which it would have been necessary to find out some piece of information. The record of the consultation can be used to determine why these conditions never arose for the particular parameter in question (Figure 16).

Figure 16 also illustrates that MYCIN's GQA allows a user to get as much information as is desired. The first answer given was not really complete in itself, but it led the user to ask another question to get more information. Then another question was asked to determine why clause 1 or

RULE159 was false. The answers to the first two questions both mentioned rules which could be printed if the user wanted to examine them. The special command PR (Print Rule) is for the user's convenience. It requires no natural-language processing and thus can be understood and answered immediately. ("What is rule 109?" or "Print rule 109." also would have been understood.)

**** DID YOU FIND OUT ABOUT THE CBC ASSOCIATED WITH CULTURE-1?**

During the preceding consultation, I never had reason to try to find out whether the results of the CBC from the time period of this blood culture are available. It would have been necessary to know this information in order to use any of the following: RULE109. However, none of these succeeded in the context of this blood culture. If you would like an explanation for why any of these rules failed, please enter their numbers:

**** 109**

Rule109 would be relevant to this blood culture when applied to: ORGANISM-1. I never had reason to try to apply rule109 to ORGANISM-1. I would have needed to use rule109 in order to find out whether ORGANISM-1 is a contaminant. However, during the preceding consultation, I never had reason to try to find out whether ORGANISM-1 is a contaminant.

**** WHY DIDN'T YOU NEED TO KNOW WHETHER ORGANISM-1 IS A CONTAMINANT?**

During the preceding consultation, I never had reason to try to find out whether ORGANISM-1 is a contaminant. It would have been necessary to know this information in order to use any of the following: RULE006, RULE007, RULE106, RULE108, RULE109, RULE159. However, none of these succeeded in the context of ORGANISM-1. If you would like an explanation for why any of these rules failed, please enter their numbers:

**** 159**

Rule159 was tried in the context of ORGANISM-1, but it failed due to clause 1 ["it is suspected that the identity of the organism is corynebacterium-non-diphtheriae"]

**** IS ORGANISM-1 CORYNEBACTERIUM-NON-DIPHThERIAE?**

No. The identity of ORGANISM-1 is e.coli (.74) bacteroides (.7) klebsiella-pneumoniae (.4) pseudomonas-aeruginosa (.22) enterobacter (.21) proteus-non-mirabilis (.19) serratia (.03) salmonella (.02)

**** PR 109**

RULE109

If: 1) The culture was taken from a sterile source, and
 2) It is not known whether the organism is a contaminant, and
 3) The patient is not a compromised host, and
 4) The patient was febrile due to the infection, and
 5) The results of the cbc from the time period of the culture are available, and
 6) A - The white count from the CBC is greater than 10.5, or
 B - The percent of pmn's in the cbc at the time the culture was obtained is greater than 78, or
 C - The percent of wbc's which were bands in the CBC at the time the culture was obtained is greater than 10
 Then: There is strongly suggestive evidence (.8) that the organism is not a contaminant

Figure 16. Questions Regarding Why a Parameter Wasn't Traced

In questions asking about the application of a rule to a context there are three possibilities: the rule told us something about the context; the rule failed when applied to that context; or the rule was never tried in that context. The history tree tells which of these is the case. Furthermore, if a rule succeeded, there is a record of all the conclusions it made, and if it failed, the reason for failure is recorded. As Figure 17 illustrates, rules are only applicable in certain contexts. If the rule could not apply to the context mentioned in the question, but might be relevant when applied to some other context [which is an ancestor or descendent in the context tree], then the question is answered as if it had mentioned the relevant context.

There are interactions among the different types of questions which weren't mentioned earlier for the sake of clarity. Sometimes a question may indicate an incorrect assumption about the state of MYCIN's knowledge. For example a question could ask "Why don't you think that ORGANISM-1 is E.coli?" when, in fact, the system has concluded that the organism is E.coli. To answer this question, the explanation system would explain how it did make such a decision, despite the phrasing of the question. Similarly, when asked how the system used (or concluded about) some parameter that was never traced, the system explains why it didn't need to find out about the parameter, regardless of how the question was phrased.

**** DID RULE 116 TELL YOU ANYTHING ABOUT INFECTION-1?**

Rule116 would be relevant to the primary-bacteremia when applied to: ORGANISM-1.

Clause 5 of rule116 ["the infection is meningitis"] was already known to be false for ORGANISM-1, so the rule was never tried.

**** HOW WAS RULE 178 HELPFUL WHEN YOU WERE CONSIDERING ORGANISM-1?**

Rule178 would be relevant to ORGANISM-1 when applied to:
CULTURE-1.

I never had reason to try to apply rule178 to this blood culture. I would have needed to use rule178 in order to find out whether this blood culture was taken from a sterile source. However, I was already certain that this blood culture was taken from a sterile source.

**** WHAT DID RULE 295 TELL YOU ABOUT ORGANISM-1?**

I used rule295 to conclude that the identity of ORGANISM-1 is hemophilus-influenzae. This gave a cumulative c.f. of (.25). The last question asked before the conclusion was made was 36.

**** WHY DIDN'T YOU USE RULE112 TO FIND OUT ABOUT ORGANISM-1?**

RULE112 was not executed because it would have caused circular reasoning when applied to ORGANISM-1. Would you like to see the chain of rules and parameters which makes up this circle?

**** YES**

I wanted to know about the identity of ORGANISM-1 because I try to find out the identity of the organism for all current organisms of the patient.

To find out about the identity of ORGANISM-1, I tried to use rule021. Before I could use rule021, I needed to know about a prior organism with possibly the same identity as ORGANISM-1.

To find out about a prior organism with possibly the same identity as ORGANISM-1, I tried to use rule005. Before I could use rule005, I needed to know about the aerobicity of ORGANISM-1.

To find out about the aerobicity of ORGANISM-1, I tried to use rule031. Before I could use rule031, I needed to know about the category of ORGANISM-1.

To find out about the category of ORGANISM-1, I tried to use rule112. Before I could use rule112, I needed to know about the identity of ORGANISM-1.

But this is the unknown parameter I sought originally.

Figure 17. Question Regarding the Application of a Rule

3 Conclusions

Consultation systems which give expert advice in some domain form one class of artificial intelligence programs which can provide useful solutions to real-world problems. The utility of such a system, however, depends on its acceptability to human users. One feature which can increase a system's acceptability is a mechanism whereby the system can explain or justify its advice.

The development of an explanation mechanism for a consultation system is very much related to the problems of representing knowledge and of making use of different sources of knowledge. Since the production system formalism provides a unified way to represent modular pieces of knowledge, the task of designing an explanation capability is simplified for production-based consultation systems. The example of MYCIN shows how this can be done and illustrates further that a system designed for a single domain with a small, technical vocabulary can give comprehensive answers to a wide range of questions without sophisticated natural-language processing.

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The U. S. Court of Appeals for the Eighth Circuit, in a separate case, last July upheld a district court ruling in Missouri that the First National Bank in St. Louis must remove CBCTs at two St. Louis County locations. The district court said that any one of the three major services provided by CBCTs constituted branch banking, which is limited in Missouri.

In the cases of the two petitioning Chicago banks, decided by the Federal Court of Appeals in Illinois last May, all functions performed by CBCTs were deemed to constitute branch banking, which is forbidden in Illinois.

However, a Federal District Court in Oklahoma approved all three uses of CBCTs, finding terminals "only processors," and as such legal. An appeal of the case was mooted when the state legislature authorized legislation sanctioning the use of CBCTs.

GOVERNMENT OPERATIONS COMMITTEE CRITICIZES NONCOMPETITIVE PROCUREMENTS

Following hearings last June (*Washington Report*, 8/76), the House Committee on Government Operations stated in October that "the low level of fully competitive ADP procurements, coupled with the apparent lack of effective utilization of ADP resources will, if allowed to continue, ultimately result in seriously jeopardizing the effectiveness of the Brooks Act [P.L. 89-306], at a cost of millions of dollars annually to the taxpayers."

Reexamination of 'true impact of computers' suggested. In a report, titled *Administration of P.L. 89-306, Procurement of ADP Resources By the Federal Government* (#), the Committee said: "If the full benefits of the Act are to be achieved, GSA, OMB, NBS, and the user agencies must join together in a commitment to fully support and adhere to the provisions of the Act."

The report suggested a reexamination of "the true impact of computers on government operations." It raised the question of whether "acquisition of ADP resources is necessary to carry on an essential program, or whether such acquisition will foster non-essential activity because the computer is available."

ADP must . . . receive attention of top management. The Committee concluded that ADP "can no longer be viewed as a mere tool, but must now be treated in the same way as other major programs and, as such, receive top attention of top management." The report attributed the basic causes of noncompetitive procurements to a lack of: (1) adequate justifications for ADP acquisition; (2) long-range planning; (3) standards; (4) high level languages; (5) utilization reviews; and (6) use of functional specifications.

OMB directs GSA to use "functional ADP specifications." Responding directly to the Committee report and other criticisms, OMB Director James T. Lynn, in a letter last month to GSA Administrator Jack Eckerd, wrote that "[t]o preclude the adverse effects of unduly restrictive specifications, agencies shall, to the maximum practical extent, express their ADP requirements in terms of functional performance specifications rather than equipment specifications."

Lynn added: "GSA should strive for expeditious review of agency submission to avoid delays in the procurement process. Agencies should cooperate with GSA to expedite these reviews. An undue length of time for the normal ADP procurement process may be considered a disagreement by GSA with the request of the agency, and may be appealed to the Office of Management and Budget.

"Consistent with the policy expressed herein, any such appeal will be handled expeditiously, but the burden will be upon the agency to demonstrate the need to specify the particular make or model of equipment or its functional equivalent when such specification is at issue," he said. The GSA has 60 days from October 6, the date of the letter, to comply with the directive.

HOUSE COMMUNICATIONS SUBCOMMITTEE CHAIRMAN RECOMMENDS OVERHAUL OF 1934 COMMUNICATIONS ACT

A "basement-to-attic" overhaul of the *1934 Federal Communications Act*, the statute which provides the basis for regulation of the nation's telecommunications systems, was proposed to the next Congress last month by Rep. Lionel Van Deerlin (D-Calif.), chairman of the House Communications Subcommittee. The Subcommittee has just completed three days of hearings on the proposed *Consumer Communications Reform Act of 1976* (*Washington Report*, 10/76). Joined by Rep. Lou Frey (R-Fla.), Van Deerlin said the original Act is outdated.

According to the trade press, issues to be considered by the Subcommittee include: whether the FCC has established fair competitive ground rules; whether business telephone services really subsidize residential services; and what the implications of changing FCC policies are toward competition.

NEW TAX ACT REPEALS PART OF 1974 PRIVACY ACT ON STATE USE OF SOCIAL SECURITY NUMBER

President Ford last month signed into law the *Tax Reform Act of 1976*, recently passed by Congress (*Washington Report*, 9/76), which includes an amendment permitting state governments to demand and retain an individual's Social Security Number (SSN) to aid in searches for parents not supporting their children. The amendment repeals part of the *Privacy Act of 1974*.

In addition, state and local governments can now use the SSN as an identifier for tax administrative programs, for drivers' licenses, and for motor vehicle registration. However, government officials who disclose the number without authorization are subject to a fine of up to \$1,000 or imprisonment of up to one year.

NEWS BRIEFS

Rep. Tim Wirth (D-Colo.) last month wrote Office of Telecommunications Policy (OTP) Director Thomas Houser (who had reportedly contacted Assistant Attorney General Donald Baker to discuss the "economic rationale" for the Government's antitrust action against AT&T) that "any further contacts between OTP and the Department of Justice, concerning the [suit]. . . would be most inappropriate."

The FCC last month set new dates for providing comments on the second "Computer Inquiry" and rulemaking regarding the use of computers by common carriers in providing communications or data processing services; comments are now due by January 10, 1977; replies, by February 24, 1977.

Responding to protests by AT&T, the FCC last month revised registration specifications for modems to facilitate direct interconnection of modems to the telephone network.

The House Government Operations Committee last month failed to report to the House floor a bill that would have authorized the Federal Assistance Program Retrieval System (FAPRS).

The Institute for Computer Sciences and Technology (ICST) of the National Bureau of Standards (NBS) last month issued Disk Drive Interface Characteristics (#--enclose \$5.50); the report was prepared by Auerbach Associates under NBS contract, and deals with characteristics of the interfaces between high performance disk drives and their controllers.

The National Communications System (NCS) last month announced proposed Federal standards for data communications interfaces; the proposed standards specify the general purpose electrical characteristics to be applied to data communications interfaces.

The National Science Foundation (NSF) last month said several of its staff members have been appointed to provide initial support for the Office of Science and Technology Policy (OSTP).

The first Federal Software Exchange Catalog, designed to promote the exchange and sharing of software among Federal ADP units, is scheduled to be released this January by the Agency Services Division of the General Services Administration (GSA).

The Bureau of the Census last month announced the availability of a 584-page report, titled Computer Programs for Demographic Analysis (#--enclose \$5.50), first published last June.

The National Bureau of Standards (NBS) is holding a Bicentennial Conference on Mathematical Programming November 29 through December 1 in Gaithersburg, Md.; the conference is being co-sponsored by NBS and the ACM Special Interest Group on Mathematical Programming (SIGMP).

AFIPS IN WASHINGTONFCC/AFIPS PLANNING CONFERENCE ON COMPUTER COMMUNICATIONS CONVENED IN WASHINGTON

A Planning Conference to provide technological background for the second FCC "Computer Inquiry," organized by AFIPS in conjunction with the FCC (Washington Report, 10/76), was convened in Washington November 8-9. The conference focused on computer communications, especially as it relates to regulatory policy. Detailed coverage will appear in the December AFIPS Washington Report.

WASHINGTON OFFICE ACTIVITIES DESCRIBED AT DPMA INFO/EXPO '76 IN LAS VEGAS

AFIPS Washington Office Director Philip S. Nyborg last month chaired a panel session on major activities of the Washington Office at the DPMA INFO/EXPO '76, in Las Vegas October 26. The session covered the Office's activities in such areas as privacy, EFTS, legal protection for software, computer security, data communications, and technology transfer.

The panel opened with a discussion of the historical perspective of the office and its outlook for the future by Mr. Keith Uncapher, chairman of the AFIPS Washington Activities Committee. Nyborg followed with a description of the daily operations of the Office, outlining the manner in which comment has been organized by AFIPS on specific issues.

Mr. William Moser, DPMA International Vice President for Industry and Government Liaison, described his role as DPMA liaison to the Washington Office. Moser emphasized his interaction with DPMA members in developing comment on testimony, and he encouraged their continued participation.

Dr. A. Michael Noll, formerly the staff member for computers in the White House Office of Science and Technology (OST), described past and present Presidential science advisory mechanisms. Noll's presentation also covered the new Office of Science and Technology Policy, and its potential relationship to the field of information processing.

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appeals court in Cincinnati, the Federal Home Loan Bank Board could appeal to the Supreme Court.

A spokeswoman for the FHLBB in Washington told AFIPS that the FHLBB had no comment on the case since it is in litigation. She stated that the New York Federal Home Loan Bank ceased providing data processing services prior to the district court ruling, not after the injunction, as Marks contended.

NEW CBCT REGULATIONS MAY SANCTION OPERATION OF NON-FEDERALLY REGULATED EFTS TERMINALS

Acting Comptroller of the Currency Robert Bloom last month announced new customer-bank communications terminal (CBCT) regulations for national banks. The new regulations allow national banks to apply for permission to establish CBCTs as branches in states where state-chartered banks are permitted to establish branches. Bloom's action follows the Supreme Court's refusal to consider consolidated petitions from two Chicago banks and the Comptroller of the Currency seeking review of Federal Appeals Court decisions which equate CBCTs with bank branches and forbid CBCTs in non-branching states (*Washington Report*, 11/76).

The Comptroller has unsuccessfully argued in the courts that CBCTs are not branches, and are not forbidden in states which limit or disallow branching. The trade press suggests that the new regulations may sanction the operation of non-federally regulated EFTS terminals by retailers, shopping mall operators, owners of apartment complexes, or operators of transportation terminals. Thus, the effect of these regulations may be to extend the present list of EFTS "providers" beyond financial institutions, i.e., to include what were formerly only EFTS users.

The Comptroller's new regulations state that capitalization required for a CBCT branch may now be shared among the participants, thus lowering the cost of operating a CBCT, and presumably making CBCTs available to smaller banks with less capital (see *Washington Report*, 11/76). Also, in contrast to the \$500 application fee for a traditional branch, the application fee for a CBCT branch is \$200.

In the section of the Acting Comptroller's statement, said to sanction operation of non-federally regulated EFTS terminals, Bloom held that "any CBCT which is not established by a national bank . . . is not a branch of a national bank, and not subject to the provisions of" the applicable section of the federal bank regulation, the McFadden Act, which the courts have held forbids CBCTs in non-branching states.

WHITE HOUSE ANNOUNCES APPOINTMENTS TO PRESIDENT'S COMMITTEE ON SCIENCE AND TECHNOLOGY

The White House has announced appointments to the President's Committee on Science and Technology (PCST), which will conduct a two-year review of science and technology as it relates to the Federal government.

The Committee was created by the same legislation (*Washington Report*, 5/76) which established the new White House Office of Science and Technology Policy (OSTP). As previously announced, the chairman of the committee is Dr. Simon Ramo, co-founder of TRW. Inc. Vice chairman is Dr. William O. Baker, president

of Bell Labs. Both Ramo and Baker were chairmen of committees organized last year by President Ford to plan for OSTP.

Other members of the PCST are: Otis R. Bowen, governor of Indiana; W. Glenn Campbell, director of the Hoover Institute on War, Revolution and Peace, Stanford University; Edward E. David Jr., vice president of Gould, Inc., and former science adviser to President Nixon; Elizabeth H. Leduc, professor of biology, Brown University; Fritz J. Russ, president, Systems Research Laboratories, Dayton, Ohio; Charles P. Slichter, professor of physics, University of Illinois; Charles H. Townes, professor of physics, University of California at Berkeley; and W. Bradford Wiley, chairman of John Wiley and Sons.

FEDERAL ENERGY ADMINISTRATION ASSISTS WITH COMPUTERIZED CONSTRUCTION FORECASTING SYSTEM

The Federal Energy Administration (FEA) is assisting in developing a computer-based system to permit national and regional projections of construction labor needs in relation to energy development. The system will also provide long and short-range forecasts in local areas, FEA Administrator Frank G. Zarb said last month. It will be implemented late next year, Zarb added.

NATIONAL SCIENCE FOUNDATION RELEASES GUIDE TO PROGRAMS REFLECTING APPROPRIATIONS

The National Science Foundation (NSF) last month released its *Guide to Programs* (#-- enclose \$1.35) reflecting NSF's appropriations for FY 1977. Programs in theoretical computer science, software systems science, software engineering, intelligent systems, computer systems design, and special projects are described. Proposals for support are ordinarily assigned to the appropriate NSF division or office for review and evaluation.

The theoretical computer science program encompasses the theory of computation, numerical analysis and computational mathematics, theory of formal languages, and analysis of algorithms. The software systems science program covers "fundamental" questions of communicating with and controlling computer systems.

The software engineering program includes the methods, tools, and techniques for specifying, designing, and implementing "quality" software. The intelligent systems program covers computer-based systems which have such characteristics as pattern recognition, pattern generation and knowledge representation.

The computer systems design program includes the principles of computer systems design such as: computer system architecture, performance, graphics, man-machine interaction and logic design. The special projects program encompasses research projects, studies, workshops, and other activities which "might encourage the development of new fields of computer science research."

Should future legislation result in some modification to the FY 1977 program, changes will be announced in the monthly *NSF Bulletin*. Program schedules, deadlines, updates, and availability of brochures describing individual programs are also published in the *Bulletin*. It may be obtained free-of-charge by writing: Editor, *NSF Bulletin*, Public Information Branch, NSF, Washington, D.C. 20550.

NEWS BRIEFS

- The FCC at press time late last month reversed the Chief of the Common Carrier Bureau's rejection of AT&T's Dataspeed 40/4 filings (*Washington Report*, 4/76); the Commission concluded that the 40/4 service is "not inconsistent" with its existing computer rule; detailed coverage will appear next month.
- FCC Chairman Richard E. Wiley early last month said the FCC is considering whether it has authority to ask the courts to modify the 1956 AT&T anti-trust consent decree; the Justice Department has held that the consent decree bars AT&T from interstate marketing of the telephone company's Dataspeed 40/4 as "incidental" to regulated communications.
- The director of the White House Office of Telecommunications Policy (OTP), Thomas J. Houser, last month criticized the Federal Reserve System for expanding "its operational role in interbank EFT with pilot projects" linking automated clearing houses (ACHs) with telecommunications (*Washington Report*, 9/76); however, H.L. Baynes, president, National Automated Clearing House Association (NACHA), which is operating the project with the Federal Reserve, told this writer last August that the Fed has "the right to develop an ACH processing capability [and to go] interregional without involving the private sector."
- The General Services Administration (GSA) last month amended its Privacy Guidelines adding privacy and security considerations for use in ADP or telecommunications systems solicitations and contracts; the amendments also require that agencies provide an inspection program in system specifications and contracts that will "ensure continuous, efficacious and efficient safeguards, and provide for the discovery and the countering of any new threats or hazards."
- The National Science Foundation (NSF) last month said industrial spending for research and development reached \$23.5 billion in 1975, up five per cent from the 1974 level of \$22.4 billion.
- A study which lists "factors important to success" in the mainframe computer industry, titled *The American Computer Industry in Its International Competitive Environment* (#--enclose \$1.70) was released last month by the Domestic and International Business Administration of the Department of Commerce.
- Information which may be needed by managers considering data base implementations is featured in *Data Base Directions--The Next Steps* (#--enclose \$2.40), a 158-page special publication of the National Bureau of Standards (NBS), first announced last October; the document incorporates the proceedings of a 1975 workshop co-sponsored by NBS and the ACM.
- The National Civil Service League Career Service Award for 1976 was presented last month to Dr. Ruth M. Davis, Director of the Department of Commerce's National Bureau of Standards (NBS) Institute for Computer Sciences and Technology (ICST)

AFIPS IN WASHINGTONFCC COMPUTER COMMUNICATIONS PLANNING CONFERENCE: 'NO LOGICAL TECHNICAL BOUNDARY' BETWEEN COMPUTING AND COMMUNICATIONS

Summarizing the technical presentations at the *FCC Planning Conference on Computer Communications* November 8-9 in Washington, organized by the AFIPS Washington Office, Dr. Vinton G. Cerf of the Information Processing Techniques Office, Defense Advanced Research Projects Agency (ARPA), noted: (1) There is no "logical technical boundary" between computing and communications; (2) Packet switching is having an "important effect" on computer communications today, and will have a "profound effect" on frequency allocation in the future; (3) High

local access costs, international link costs, and user learning costs are "limiting" the growth of computer communications services; (4) The prime opportunities for network costs and tariff improvement lie in the development of new facilities for local access and for intercontinental links; and (5) A regulatory climate is needed "which encourages innovation, ensures reliable interconnection of primary services, and promotes the acquisition of capital for growth."

Wiley says FCC policy decisions must be based on understanding of technology. Opening the conference, FCC Chairman Richard E. Wiley stated his view that a computer is a communications device, not a data processing device, when it is used in a traditional communications service. However, Wiley also noted that the use of computer technology may result in an enhanced service, offering more than traditional communications.

He predicted that similar technological forces will develop in several areas of communications service. Wiley said: "I firmly believe that, in this great free enterprise society of ours, government regulations must not be permitted to stand in the way of technological development. If the new technology creates administrative difficulties for the government, it is the regulations that must be conformed and not the technology."

According to the FCC chairman, "We will see more instances in the future where, as here, the technology is developing in a manner that blurs traditional interfaces. In cases of this sort, the policymakers *must* have direct access to technical experts and decisions *must* be based upon an understanding of the technology."

Wiley also said, "It is our belief that AFIPS is a particularly appropriate entity to present this conference for the Commission, in view of the Federation's sponsorship of the National Computer Conference, and the Joint Computer Conferences prior to that. Moreover, it is also our view that AFIPS is a basically impartial organization in relation to our policy concerns, bringing to us the objective views of a group of highly qualified experts."

Computer communications accounts for 20 per cent of all expenditures in computer field. In the conference's first presentation on "Computer Communications: An Introduction and Overview," Lynn Hopewell (chairman, IEEE Computer Society Technical Committee on Computer Communications; and senior member, executive staff, Computer Sciences Corp.) said that computer communications systems had first been used in controlling "complex" operations of industry and government. Hopewell added that the most common use of computer communications is in data base applications.

The speaker suggested that the computer communications industry accounts for 20 per cent of all expenditures in the computer field. Examples of industrial areas affected by computer communications technology were listed as law enforcement, securities brokerage, insurance, reservations systems and banking. Hopewell said that 75 per cent of the top 500 industry corporations are now using computer communications.

Distributing samples of a microcomputer-on-a-chip, he noted technological changes that have produced a 1976 microcomputer CPU costing \$20 in contrast to a 1960 IBM CPU costing \$30,000. Hopewell added that microprocessors which cost \$20 today cost \$100 only a year ago. He indicated that such differentials represent only the beginning of extremely low cost computing.

Hopewell said that the proposed definitions employed in the new "Computer Inquiry"

aid in "clarifying the permitted uses of computers by common carriers, but in no way allow the proposed abandonment of the 'hybrid' service concept." He noted that the hybrid concept should be retained "because some service offerings have mixes of both computing and communications functions," not because of unclear definitions.

Since "hybrid services will become even more common in the future," Hopewell continued, elimination of the hybrid concept will "inevitably suppress innovation because any services that have communication functions inextricably bound into them will be defined as subject to regulation." The speaker concluded that he saw no "technological or economic reason for the regulation of the resale industry."

Technology is 'moving towards integrated wideband services.' In his presentation on "Research Topics in Computer Communication," Vinton G. Cerf summarized technological factors influencing the development of computer communications: the availability of wideband transmission media; the use of computers to control the switching and allocation of transmission bandwidth; the trend towards all-digital telephone networks; and interconnection of computer communications networks.

Cerf said the "technology is leading away from separate, distinct narrowband services . . . towards integrated wideband services. The potential social impact is pervasive; the possibilities for new wealth-creating activity, almost incalculable; and the need for regulatory adjustment, inevitable."

With the juxtaposition of computing and communication, he suggested the FCC could: reallocate the radio spectrum using computer-controlled demand access; mandate computer communication network interconnection through the enforcement of interconnection standards; and consider proposals by regulated carriers as well as others "to provide previously impossible combinations of information processing and traditional communication services."

'Boundary between communicating and computing will become more blurred.' In his presentation on the "Dimensions of the Need for Computer Communications," Alex Curran, president, BNR, Inc., suggested that domestic users must seek to reduce the cost of network access for smaller users, especially in the "smaller urban centers." FCC Interconnection Chief Louis Felder, in a question-and-answer period following Curran's presentation, stressed the "need for computer power" in rural areas.

In his formal presentation, Curran continued that the cost of intercontinental transmission must also be reduced. According to the speaker, these measures would help to insure that "the common carrier networks can cope with the data communications traffic of commercial users."

Curran stated that some of the office and home services associated with computer communications could require reintegration of voice and data capabilities. He provided several current examples of personal computing including: *Viewdata*, the embryonic electronic newspaper in the United Kingdom; *Incasting*, instantaneous voting and data collection in Canada; *Mailgram*, a precursor of electronic mail in the U. S.; and *CAI*, computer-assisted instruction.

Curran also said that other services will require switching machines "capable of recognizing information [interest] specifications as valid addresses." For example, switching machines could recognize selective information dissemination interest profiles as valid addresses, he noted. Curran concluded: "Thus, the boundary

between communicating and computing will become more blurred. There are economic arguments for suggesting that the boundary definitions be relaxed to encourage a new cycle of innovation."

FCC decisions may limit the growth of carriers, not necessarily the growth of unregulated suppliers in data processing. In his presentation, titled "Limitations on the Growth of Computer-Communication Services," Prof. Donald A. Dunn, Engineering Economic Systems Department, Stanford University, indicated that user learning costs will limit the rate at which new computer communication services can be introduced to markets serving non-computer professionals. Dunn suggested that, in future regulatory decisions, integrated service packages (designed to minimize user learning and operation costs) might be used in lieu of individual component services as the unit of service that is judged communications or data processing. He added that regulatory limitations on the rate of return and regulatory policies on depreciation allowances can restrict technological change as well as limit the rate of introduction of new equipment by carriers.

According to the speaker, the earlier "Computer Inquiry" rule, requiring data processing services to be provided by carriers through a separate affiliate, may limit the growth of carriers. But he added that the rule does not affect the growth of the data processing industry since unregulated suppliers can respond to this market. Dunn also noted that the resale and sharing decision, imposing regulation on resale carriers, would not necessarily inhibit the growth of the industry "since separate data processing affiliates will not be required of resale carriers that do not provide monopoly services."

He stated that the resale and sharing decision "removed some of the most serious limits to the growth of this industry by opening the market for network services to essentially any firm willing to operate as a resale carrier." Dunn concluded: "Pressures are likely to develop soon to regulate providers of information service packages that may offer computer message services to users that obtain network service from resale carriers. Such regulation would inhibit the growth of the industry, and is not needed to protect the interests of users."

"There is no natural boundary' between communications and computing. In their presentation on "The Future of Computer Communications." Vinton G. Cerf and Alex Curran said that "we cannot offer a solution to the definition of a boundary between communicating and computing--in fact, technical considerations convince us that there is no natural boundary."

Cerf and Curran urged the FCC to support the development of "competitive services"; to insure that a "sufficient set" of standards is created to facilitate interconnection of "prime services"; create a climate in which both computing and carrier interests profit from the installation of "reliable" facilities; and broaden the base for the acquisition of capital so as to eliminate a possible constraint on growth.

Conference presentations will become part of formal record of Computer Inquiry. The conference, open to the public, was attended by over two hundred people, including those who watched the proceedings via closed circuit television in an adjoining room. As previously announced, the presentations will become part of the formal record in the FCC's "Computer Inquiry." A Proceedings containing all the papers is available at \$10 per set from AFIPS Headquarters, 210 Summit Avenue, Montvale, New Jersey 07645. Headquarters telephone number is (201) 391-9810.

AFIPS PANEL MEMBERS COMMENT ON USE OF SOCIAL SECURITY NUMBER AT REQUEST OF
PRIVACY COMMISSION

Members of the AFIPS panel on private sector usage of the Social Security Number (SSN), organized at the request of the Privacy Protection Study Commission (*Washington Report*, 2/76), last October responded individually to a staff memo concerning the use of the SSN, submitted to them by Privacy Commission Executive Director Carole W. Parsons.

Daniel D. McCracken, independent consultant, said he favors legislation "to prohibit unauthorized matching of records" through use of the SSN as a universal identifier. McCracken wrote Parsons, saying that lacking such legislation, "I would argue for restrictions on the use of the SSN as a partial substitute, and as a way to keep the more basic issue alive and visible." McCracken, who is ACM vice-president, is responsible for passage of an ACM resolution opposing the use of the SSN as a universal identifier.

Herbert S. Bright, president, Computation Planning Inc., who also filed a response to the memo, said use of the SSN in licensing drivers opens SSN files to insurance companies as well as list compilers and other vendors. Bright added: "Continuing progress in cross-linking practice between insurance companies is increasing the justification for vigorous efforts by the Commission to examine such attacks on privacy and to place the facts before the public and the Congress." Bright is also a member of ACM.

Willard E. Hick, auditor, Massachusetts Mutual Life Insurance Co., Springfield, Massachusetts, responding to the memo, wrote that the Commission's statement supporting continued use of the personal identifier "should emphasize need and not concentrate on counteracting suggestions that have been made." Hick questioned why the Commission does not "address in more detail the reason universal identifiers are necessary on a positive rather than negative note." He told *AFIPS Washington Report* that, to the best of his knowledge, there is no "cross-linking" between insurance companies. Hick is a member of the Institute of Internal Auditors.

Also responding to the memo, with letters not available at press time, were: Jeffrey V. White, president, The Credit Bureau, Inc., Atlanta, Georgia; John J. Stiglemeier, director, Information Center on Education; Roger E. Creel, assistant vice president-Systems & Processing, Employers Insurance Co. of Wasau, Wausau, Wisconsin; Alden R. Dalzell, director of Data Processing, Ohio University, Athens, Ohio; J. M. Moore, section head, Exxon Corp., Florham Park, New Jersey; and William E. Perry, director of EDP and Research, the Institute of Internal Auditors, Orlando, Florida.

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IBM's algorithm chosen; companies to manufacture devices incorporating standard without paying royalties. ICST began soliciting encryption algorithms in 1973 and 1974. IBM's proposed algorithm was chosen in 1975. While IBM has patent rights in the standard, the company has agreed to grant royalty-free licenses to other companies which wish to manufacture devices incorporating the algorithm. The trade press notes that Motorola and Rockwell International are planning to manufacture integrated circuit chips which incorporate the encryption algorithm.

Standard to be published 2/15/77; conference scheduled. FIPS PUB 46 is expected to be published February 15, 1977, and to become effective August 15, 1977. Copies of the standard will be available after February 15 from the National Technical Information Service (NTIS), DOC, 5285 Port Royal Road, Springfield, Virginia 22161, or through the AFIPS Washington Office. NBS will hold a conference on February 15, 1977, at its Gaithersburg, Maryland, facilities to discuss FIPS PUB 46 in relation to other security measures.

TERMINAL MANUFACTURERS, INDUSTRY ASSOCIATIONS CRITICIZE FCC APPROVAL OF DATASPEED 40/4

Independent terminal manufacturers and industry associations last month criticized the Federal Communications Commission (FCC) for its approval of tariff filings on AT&T's Dataspeed 40/4 terminal device (*Washington Report*, 12/76). The FCC's approval, announced in November, reverses a previous proposed decision by the Commission's Common Carrier Bureau which rejected the Dataspeed 40/4 tariff (*Washington Report*, 4/76). Under the new FCC ruling, AT&T will be permitted to provide the Dataspeed 40/4 service.

Primary Issue. The debate centers on whether the terminal offering constitutes a data communications service or a data processing service. If it is a data communications service, as held in the present Commission ruling, AT&T can provide the service. However, if it is a data processing service, as the Chief of the Common Carrier Bureau stated last March, AT&T cannot provide the service.

The FCC had held earlier in its original "Computer Inquiry" that common carriers may provide data processing services, but only through unregulated subsidiaries. However, AT&T is even precluded from this option by its agreement in a 1956 consent decree (with the U.S. Department of Justice) not to participate in unregulated industries.

Specific industry criticism. The independent terminal manufacturers and computer industry groups charged that the development of the Dataspeed 40/4 terminal is subsidized by profits from AT&T's regulated communications service offerings. Thus, they contend that the device represents "unfair" competition by AT&T against unregulated industries.

Possible further action. The FCC has stated that its latest ruling is contingent on the outcome of the Commission's new "Computer Inquiry" (see *Washington Report*, 8/76). (Comments in this proceeding are now due April 11, 1977; replies are due May 25, 1977.) However, the trade press speculates that it is unlikely that the Dataspeed 40/4 offering, once tariffed, will be "detariffed."

The Computer and Communications Industry Association (CCIA) has indicated its intention to file suit against the Commission in the U.S. Court of Appeals in the District of Columbia. CCIA seeks to enjoin implementation of the FCC's ruling, pending a full court review on the merits.

CCPA APPROVES PATENT FOR SOFTWARE PROGRAM SECOND TIME

Some software programs are eligible for patents, according to the U.S. Court of Customs and Patent Appeals (CCPA), which last November reversed the U.S. Patent Office for the second time on the issue of software patentability. The CCPA decision involves the "Regulator" program (developed by Glen F. Chatfield, president of Duquesne Systems, Inc.), which adjusts the priorities on computer programs.

In two previous cases, the Supreme Court (prior to the latest *Chatfield* decision) has reversed the CCPA, deciding in favor of the Patent Office on limited grounds and not addressing the question of software patentability. In *Gottschalk v. Benson*, the Court ruled four years ago that a program to convert binary-coded decimal was not a patentable "process" as defined in the U.S. Code. In *Dann, Commissioner of Patents and Trademarks v. Johnston*, the Court held last April (*Washington Report*, 5/76) that a computerized record-keeping system, developed for banks by Thomas R. Johnston, is "obvious to one 'reasonably skilled in [the applicable] art,'" and is therefore not patentable.

CCPA Chief Judge Harold T. Markey ruled in the *Chatfield* case that "no prior art was cited [by the Patent Office] against the appealed claims, and, accordingly, [the] invention must be considered to have been new and unobvious." The judge also held that Chatfield's invention meets the U.S. Code requirement for "process" claims.

TELEPROCESSING SERVICE PROGRAM INITIATED BY GSA, TO HELP REDUCE \$10 BILLION FEDERAL DATA PROCESSING BUDGET

The General Services Administration (GSA) in November signed its first two teleprocessing services schedule contracts, permitting agencies to order services at government-wide volume discounts, rather than make separate procurements at greater cost. The contracts, effective December 1, provide for interactive and remote batch processing services estimated at between \$50 to \$80 million over the next year. Computer Network Corp. and First Data Corp. received the first two contracts.

The trade press suggests that the teleprocessing services program is the first of several steps the Government is implementing to reduce its \$10 billion in yearly expenditures on data processing. For example, the Office of Management and Budget (OMB), Executive Office of the President, is encouraging greater use of outside service bureaus as well as third-party leasing firms. In addition, each Federal agency has been directed by OMB to determine five operations now being performed on its own computers that could be performed on service bureau computers.

OMB is expected to continue its moves to cut DP expenses through the transition to the Carter Administration.

CONSUMER BENEFITS IF EFT TERMINALS ARE NOT CONSIDERED BRANCHES: NCEFT TELLS SENATE

Members of the National Commission on Electronic Fund Transfers (NCEFT) last month told a Senate Subcommittee that the American consumer "may suffer unnecessary inconveniences and may pay higher prices for payment services" if EFT terminals are governed by the same laws and regulations that apply to bank branches. Such Federal laws equate EFT terminals with branches thus forbidding EFT terminals in non-branching states. (See *Washington Report*, 12/76.)

In testimony presented to the Subcommittee on Financial Institutions, chaired by Sen. Thomas J. McIntyre (D-N.H.), NCEFT Chairman William B. Widnall and Executive Director John B. Benton agreed that "[t]he greatest current impediment to putting into place the technology which can provide the benefits of EFT to the consumer is the uncertainty which exists about the legal environment within which EFT systems will operate in the future." The chairman and executive director, joined by three NCEFT commissioners, said that a competitive imbalance is created when federally-chartered savings institutions have greater freedom in deploying EFT terminals than national banks, which are governed by more restrictive legislation. The NCEFT representatives added that business enterprises, such as retail chains, "should not be considered . . . regulated institutions or branches thereof," when they employ electronic terminals to communicate with depository institutions.

Last month, the NCEFT convened hearings on competition and sharing. The Commission's interim report is due February 23.

R&D HAMPERED BY LACK OF COOPERATION BETWEEN GOVERNMENT, PRIVATE ENTERPRISE: RAMO

"Lack of teamwork between the Government and private enterprise is the number one bottleneck in the nation's pursuit of research and development," said Dr. Simon Ramo, vice chairman of the board and chairman of TRW, Inc. Speaking last November in Washington at the annual fall meeting of the National Academy of Engineering, Dr. Ramo added, "Even the nation's most capable researchers spend much of their time defending their selection of projects and describing potential results, rather than in carrying on research. We are persisting in this tendency even with growing indications that the U.S. is losing its leadership position as to the fraction of gross national product being devoted to basic research." The TRW Executive, who is also chairman of the President's Science and Technology Committee, expressed the hope that the new Office of Science and Technology Policy, Executive Office of the President, will contribute to the formation of "sound" national policy.

ASST. COMMERCE SECRETARY RECOMMENDS USPS COMPROMISE ON PAGE CHARGES FOR NON-PROFIT SCIENTIFIC, ENGINEERING, AND TECHNICAL JOURNALS AND PERIODICALS

The U.S. Postal Service (USPS) is "willing to modify" the USPS regulation requiring reading matter in all non-profit, second class publications to be marked "advertisement" when contributors are required to pay page charges on their submissions. Dr. Betsy Ancker-Johnson, the Department of Commerce's Assistant Secretary for Science and Technology, last month said the USPS is "willing to modify the regulation so long as contributions to publishing costs aren't mandatory but voluntary."

Convening a meeting last month of the Committee on Intellectual Property and Information, Federal Coordinating Council for Science, Engineering and Technology, Dr. Ancker-Johnson, committee chairman, indicated that this voluntary arrangement should be clarified in the publication's masthead. The regulation could affect the policy of AFIPS constituent societies which must publish a non-profit journal as one qualification for membership.

Page charges, paid by researchers, are viewed by journal publishers as one method of defraying the cost of reporting research. In many cases, page charges are paid by funds obtained through research grants. Charges may be voluntary, for example, with researchers who are not supported by grants.

Dr. Bernard Forscher, managing editor of the National Academy of Sciences' *Proceedings*, suggested in an interview with *AFIPS Washington Report*, that page charges should be considered in research budgets. Dr. Forscher compared publication of research findings with "staking a claim to a discovery," or "obtaining a deed." Forty per cent of the production costs of the *Proceedings* are defrayed through page charges; the remaining 60 per cent is covered by sales of subscriptions as well as reprints and back issues, he said.

The meeting of the Committee on Intellectual Property and Information was attended by representatives of IEEE, the National Science Foundation, the American Astronomical Society, as well as AFIPS and others. A representative of the Federation of American Societies in Experimental Biology said that the scientific community will not accept the compromise solution. He indicated that unless page charges are mandatory, they "won't work." The biology society's representative recommended a special exemption from the regulation for scientific journals.

The counsel for the National Academy of Sciences agreed that page charges cannot be voluntary. He said "those who now pay must continue [to pay] or serious problems [will arise]." He stated that scientific journal articles are "as deserving of second-class [mailing privileges] as anything that goes through the mail."

There was, however, some support for the USPS compromise. One society representative suggested that attendance at the meeting, reflecting opposition to the voluntary page charges, was not representative of most professional societies views.

Ancker-Johnson stated that her committee could "monitor" cases brought to its attention and act as "brokers" in situations in which voluntary payments, once agreed to, were not made. She confirmed that the compromise is about to be put in writing (#) by USPS counsel.

Ancker-Johnson suggested that further comments concerning the regulation and the proposed compromise be directed to her in Room 3862, DOC, 14th Street between Constitution Avenue and E Street, N.W. Washington, D.C. 20230; telephone is (202) 377-3111.

NEWS BRIEFS

\$42.9 billion in total funding is predicted for U.S. R&D in calendar year 1977, according to the annual R&D forecast of Battelle's Columbus Laboratories. Federal Judge Joseph C. Waddy last month ruled that antitrust laws apply to the Bell System; AT&T has argued, since a suit was filed in Washington two years ago by the U.S., that antitrust laws do not apply to the monopoly because it is already regulated by the states and the FCC.

Lionel Van Deerlin, chairman of the House Communications Subcommittee, last November asked the FCC to expand its new "Computer Inquiry" to include an examination of the 1956 consent decree with AT&T; the decree prevents the Bell System from offering unregulated products or services.

Sen. Abraham Ribicoff (D-Conn.), chairman of the Senate Committee on Government Operations, is expected to hold "computer abuse" hearings this spring (see Washington Report, 7/76); Donn B. Parker of the Stanford Research Institute, Menlo Park, California, will testify.

The Office of Management and Budget (OMB) last month proposed an OMB Circular establishing a uniform policy for all executive branch agencies in working with commercial (*i.e.*, non-Federal) standards-setting bodies; the proposed Circular No. A (#) appeared in the Federal Register on December 8, 1976, p. 53724.

A proposed standard for Optical Character Recognition (OCR) Paper (#) is being recommended for Federal use by the National Bureau of Standards; the standard, which adopts American National Standard X 3.62-197___, now in the final approval process, provides the requirements and test procedures for paper to be used in OCR Systems; it appears in the Federal Register, December 9, 1976, pp. 53836-53839.

The newly established Office of Science and Technology Policy (OSTP) has reportedly negotiated contracts with the Futures Group, Inc. and Harbridge House for studies on how OSTP should fill its legislative mandate; the Office is charged with issuing an annual report and five-year forecasts on national R&D activities; in addition, two of the three assistant director positions have been filled by former National Science Foundation personnel: Phillip Smith is the assistant director for natural resources and commercial services, and Dr. Russell C. Drew is the assistant director for national security.

The FBI has reportedly asked the Department of Justice for permission to abandon a nationwide criminal records computer system; Attorney General Edward H. Levi has also asked Congress to consider the major policy implications of such a system.

The Federal Advisory Committee on False Identification has recommended against a national ID card, according to an 800-page report on criminal use of false identification (#) issued by the Department of Justice.

Copies of the October 8, 1976, Preliminary Report to Congress and the President of the National Commission on New Technological Uses of Copyrighted Works (CONTU) are now available (#); the report summarizes CONTU's first-year activities.

A report, titled Operating Structures to Support Security and Reliable Software, written by Theodore A. Linden, has been issued by the National Bureau of Standards (#--enclose \$1.25).

Establishment of a Washington Office for DPMA has been approved by the association's international board of directors; the new Office is being designed to coordinate with, as well as supplement the activities of the AFIPS Washington Office; DPMA's new facility is scheduled to open mid-year.

The major annual conference of AIAA is being held here January 10-14, 1977. INFO/EXPO '77 is being scheduled by DPMA October 9-12 in Washington.

AFIPS IN WASHINGTON

WASHINGTON OFFICE GATHERING DATA TO UPDATE STATE OF THE COMPUTER INDUSTRY REPORT

The Washington Office last month began data gathering to update AFIPS' *The State of the Computer Industry*, edited in 1973 by Dr. Bruce Gilchrist and Dr. Richard E. Weber. The updated research, which may later be incorporated into a report, is focusing on major trends in information processing to reflect the breadth, growth, and pervasiveness of the information processing field.

It covers: suppliers, users, and costs; usage and applications; sales; and education and employment. Representatives from several market research firms have indicated a willingness to participate in the study. A part-time research assistant, William Erickson, has been hired on a temporary basis to work on the update with Pender M. McCarter, research associate.

AFIPS PANEL MEMBERS COMMENT ON USE OF SOCIAL SECURITY NUMBER AT REQUEST OF PRIVACY COMMISSION: ADDITIONAL RESPONSES DESCRIBED

Last month, *AFIPS Washington Report* described responses of some members of an AFIPS panel on private sector usage of the Social Security Number (SSN) to a position paper on this subject issued by the Privacy Protection Study Commission. We now report several additional responses which have since been received from: Jeffrey V. White, president, The Credit Bureau, Inc. (CBI), Atlanta, Georgia; John J. Stiglemeier, director, Information Center on Education, New York State Education Department; Alden R. Dalzell, director of Data Processing, Ohio University, Athens, Ohio; J.M. Moore, section head, Exxon Corp., Florham Park, New Jersey; and William E. Perry, director of EDP and Research, the Institute of Internal Auditors (IIA), Orlando, Florida.

Credit Bureau President White wrote: "Since one of CBI's primary obligations is to maintain the confidentiality of the information in its data base, we would be opposed to any general prohibitions against the use of the Social Security Number in the private sector. While CBI does not use this number as a universal identifier or as a sole factor in the identification or authentication process, it is an aid in maintaining confidentiality in a small number of cases. Therefore, eliminating the use of the Social Security Number would have an adverse impact on our ability to serve the consumer and the credit granting community."

Exxon Section Head Moore wrote: "[T]he presence of the SSN in the record constitutes unique identification and restricting its use as a formal record identifier would serve no useful purpose." Ohio University Data Processing Director Dalzell said: "I would question whether the individual's knowledge and consent should be a complete qualifier. An individual may be informed that he need not supply information if he does not wish, and he may be informed of how it will be used, but that does not completely answer the question of whether the information should be gathered and used, even with his permission."

New York State Education Department Director Stiglemeier wrote that the Commission's position paper constituted an "excellent" outline of the project boundaries and issues, but the paper's introduction omitted discussion of "goals, information needs, and interrelationships with other projects." He called these omissions "critical" to the success of the project.

IIA EDP/Research Director Perry cited examples of what he called "some preconceived findings and conclusions" of the position paper, described by the Commission as a "problem and issue statement." He mentioned such Commission "findings" as "the use of the SSN for personal authentication does not appear in itself to constitute an unfair information practice," and "the exchange of information without the knowledge or consent of an individual may constitute an unfair information practice." Perry also wrote that individuals who feel that divulging the SSN for personal authentication is dehumanizing "would probably object to the alternatives even more."

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