LANGUAGE RESEARCH and THE COMPUTER

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LANGUAGE RESEARCH AND THE COMPUTER:

A STUDY OF THE CONCEPT OF A NATIONAL CENTER OR NETWORK FOR COMPUTATIONAL RESEARCH ON LANGUAGE (Ce/NCoReL)

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PREFACE

This monograph is primarily the result of NSF Study Grant #GJ-28599: some of the ideas expressed in it are a development of earlier thinking and research, but even in those instances elaboration and publication here are owing to the support provided by the National Science Foundation.

In appendices we have sought to indicate something of the scope and extent of the assistance that was very generously provided us by conferees who journeyed to The University of Kansas at Lawrence, by commentators who responded by letter and in conversation to many issues raised in this study, and by other scientists, scholars, and administrators whom we met with during trips to their studies, offices, and laboratories in at least twenty states. The number and types of disciplines and research specialties represented by this sizeable set of professional, research people with whom we have been in communication are also considerable--including anthropology, archaeology, art history, biology, biophysics, communication science, computer science, engineering, the humanities (including a wide variety of languages and literatures: for example, Chinese, English, French, German, Greek, Latin and Russian), information science, library science, linguistics, mathematics, music, the neurosciences, psychology, psychiatry, social relations, and sociology.

The interest and support provided this study by various scientists within the National Science Foundation have been critically important and immensely helpful. In this connection we hope that it will not seem inappropriate if we explicitly mention Dr. D. D. Aufenkamp of the Office of Computing Activities, head of the Computer Applications in Research Section.

We wish also to express our thanks to two other federal agencies which have funded research by the principal investigators on computer-based language analysis and thereby have indirectly contributed to many aspects of this study: thus Dr. Sally Sedelow is indebted to the Office of Naval Research (Information Systems Branch) and Dr. Walter Sedelow, to NASA.

Assisting us in this effort at The University of Kansas were Mr. Herbert Harris (a graduate student in Linguistics), Mr. Frank Joyce (a graduate student in Computer Science), Mr. Thomas Kosakowski (a graduate student in Computer Science), Mr. Samuel Warfel (a graduate student in Linguistics), Miss Melanie Mitchell, and many others also associated with the University.

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TABLE OF CONTENTS

Preface i

Introduction 2

The Ce/NCoReL Concept 5

Research Implications and Emphases 26

Software 83

Hardware 101

Organization 112

Center and/or Network: Summary and Recommendations 144

Appendices:

I. The Computer and Symbolism 159

A. Knowledge Systemics 160

B. Humanities Applications 184

C. Arts Applications 199

II. Bibliography

A. Some References Relevant to Center or Network Computation for Research on Language 219

B. A Cybernetics and Systems Research Reading List 271

C. Selected Items from an Inventory of Measures of Language 319

D. Some Selected Background Items in the Literature on Computational Linguistics and Information Retrieval 353

E. Some Selected Background Items in the Contemporary Literature on the Sociology of Language 397

III. Conferring 459

A. Conference Participants 461

B. Scholars and Scientists Consulted 466

INTRODUCTION

In this monograph we endeavor to 'sum up' parts of our experience in studying the concept of a national Center or Network for Computational Research on Language (Ce/NCoReL).

The table of contents and, much more, the contents should speak for themselves. By way of introduction we do, however, wish to call attention to some properties of this report:

- it includes some recommendations for next steps to be taken toward creating, by means of the computer and attendant network technology, an exemplar for a new type of national research laboratory--i.e., a multi-institutional collaborative effort to articulate through a distributed center or network geographically separated research undertakings; and those recommendations are to be found both in the final chapter and also, as to the shorter-term, toward the end of the chapter on organization.
- it includes a considerable discussion (which, nonetheless, could well be further expanded) as to both the intellectual and the scientific importance as well as the social urgencies for assigning a high and immediate priority to establishing a Ce/NCoReL; and such discussion is to be found both in the chapter on research applications and in that on the Ce/NCoReL concept, as well as under the rubrics "Knowledge Systemics," "The Computer in the Humanities," and "The Computer in the Arts";
- it develops further than heretofore discussion of elements involved in computer support specifically adapted to research on language/types of languages/languages/language sub-sets (strings); and these observations are to be found in the "Software," "Hardware," and "Center and/or Network: Summary and Recommendations" chapters;

- it makes a beginning at pointing out the as yet largely unrealized role of a new science of knowledge with the computer as its critical instrumentation for achieving through a meta-disciplinary type of transformation education markedly more evidently useful and 'relevant'; "Knowledge Systemics," and more incidentally "The Computer in the Humanities" present most of that thesis;
- it includes an extensive bibliographic apparatus meant to pull together some of the disparate types of studies bearing on the present feasibility of using major computational capacity in network form for comparatively comprehensive symbol-system research;
- it includes, partly by implication and partly by explicit statement, evidence as to the high scientific desirability of greater interaction, such as a Ce/NCoReL could facilitate and provide, among various sorts of language researchers; the "Research Applications" and "Ce/NCoReL Concept" chapters throw light on this condition most directly;
- it makes manifest a variety of desiderata for a Ce/NCoReL expressed by members of the larger language research community, not only in "Hardware," "Software," and "Center and/or Network: Summary and Recommendations" but also, as to financing, fellowships, and training, staffing, and guidance and management, in the "Organization" chapter;
- it reflects a unique, and we think significant, 'pulling together' of the thinking of representatives of disciplinary sub-specializations which are in a sense generally kept from seeing some of the important unity, or at least complementarity, of their efforts by various (and in some cases comparatively outmoded, unfortunate, unexamined, and uncriticized) conven-

tions--conventions of disciplinarily-defined 'suitable' research projects and language for expressing research results, conventions of 'appropriate' publication outlets and audiences for them, conventions of departmental sanctions for professional and research compartmentalization and of departmentalized reward-structures, conventions as to research models and methodologies appropriate to classes of problems, conventions as to what is intellectually/academically/scientifically relevant and prestigeful, etc.;

- it shows in appendices indicating people, universities and other organizations, how numerous and diverse were the members of the variegated research community involved in one way or another in this study--although, of course, with greater time and other resources a more thoroughly comprehensive coverage could have been achieved;
- it includes, especially in the chapter on research applications, in addition to basic research and long term research implications some of the numerous direct benefits to current language research projects which could soon flow from an operational Ce/NCoReL;
- it includes brief mention (which might well be expanded) of concurrent and significant developments in both the U.S.S.R. and Japan, while parts of the bibliography suggest something of the level of activity in related research abroad.

THE Ce/NCoReL CONCEPT

There is no major problem faced by men for which the information available, the symbolic form in which that information is available, and currently applicable communication technology are not critically important conditions for any solution to it. Further, the very sense of there being a problem and the character of that problem are themselves each functions of properties of the language modellings of those parts of the environmental domains in which the problem is symbolically 'found.' And in some cases the mode and character of the symbolism which is thus problem-definitional may--when we more thoroughly understand the pragmatics and semantics of symbol systems--themselves prove to be at least as much a part of the problem as of its solution. We say, then, that symbol manipulation is a denominator common to all of man's social efforts to cope with his environment; and, further, that understanding symbol systems with the greater thoroughness needed to markedly improve our ability to utilize knowledge--and, in particular, scientific knowledge--in the solution of our increasingly numerous problems (as in research applied to national needs, e.g., RANN) is itself a matter of high urgency. (Certain implications of this thesis are discussed more fully further on in this monograph, in the chapter on "Knowledge Systemics.")

The computer and software and other hardware associated with computers will be, in various forms, central components in many future socially urgent uses of language. The computer's role as a receiver, processor, and transmitter of symbols has been only narrowly explored (even in special cases, such as statistics), and especially little attention has been devoted to how

it, and symbol systems presently or prospectively associated with it, might best be adapted to a range of language processing environments, including human language processing environments and, notably, the study of language processing environments themselves. Such research must be undertaken if we are to hope for a comprehensive science of symbol systems, upon the successful development of which so much else depends.

For representatives of a group of institutions already involved in significant symbol-system research to plan for the joint development and use of resources for a national Center/Network for Computational Research on Language with adequate, specialized computational capabilities is thus highly desirable. The national importance of learning how, with the aid of the computer, better to formulate and transform symbolic statements for use in practical action is so great that the earliest possible start toward planning for a Ce/NCoReL is clearly indicated.

Both pragmatic and theoretical considerations increasingly impress upon us the importance of comprehending more adequately the ways in which languages/symbol systems affect the direction and control of the numerous, variegated, and interactive systems (social, natural, technological, and mixed systems) of which we are a part. Cybernetic and general systems research, as well as many middle-range and applied studies, unite in forcefully demonstrating the heavy weighting due 'symbolic' communication as a variable-set in explaining the functioning of both the human and the non-human components of nature; it would be not excessive to assert that information-energy research is emerging as a central theme in contemporary science and, incidentally, as a possible source of success in efforts at the unifying of science itself.

Man is most notably differentiable from the rest of the world with respect to his capacity to model efficiently both himself and his environment. The entire progress of science and such successes as we have had in effectively relating to environment and environmental resources are manifestations of that capability. Thus, tests of the importance and successful use of that modelling capacity are in no insignificant way imposed on men from outside themselves: our ability as individuals, as a nation, as mankind to survive as well as to achieve environments of high quality flows from the level of our facility in adequately using symbolic inputs to model accurately and efficiently ourselves in our interactivity with all the impinging phases of our ecologies (human; natural; artifactual; and mixed). Some of that modelling takes place within the C.N.S., and some of it--proportionately, an increasing amount--takes place in part externally, through such 'prosthetic' devices as alphabets, number systems, logics, languages, and computers. Whether with people or with 'the forces of nature' the extent of our success in survival will be heavily conditioned by the adequacy of the simulations of them we derive from the transformations of symbolism received as 'sensory' in-put. And yet, despite its overriding importance for the key human function of man-adequately-modelling-his-world, man qua scientist has not yet directly addressed the question of how to put together knowledge needed to so understand the properties of himself and his technology (especially, here, computing devices) as transferers/transformers of environmentally-relevant (symbolic) data into adequate models of that environment that, in turn, we can answer with precision questions as to how best to go about any given job of symbol manipulation.

One of the major necessary conditions for a scientific understanding of symbol systems--including the understanding of the computer hardware and software devices so important as themselves instrumentation for such understanding--is the precise measurement of languages: 'natural', formal, and graphic languages. At present, languages have not been even effectively parameterized. Further, as to the empirical phase of such research, we do not know in anything approaching a comprehensive way what dimensions of language have been discovered and measured; nor, in those instances where any given investigator is interested in normalizing with reference to some property of language, have we, generally, any compilation available for him of the corpuses of language which have been measured along the dimension of interest to him, nor the results of the measurings. In brief, we may say that our knowledge of language components of symbolic processes is both radically defective and unassembled, not to mention not readily accessed. And all this is true despite the major efforts in modern linguistics in recent decades--which have concentrated heavily on formalisms for syntactic characterizations. (For an earlier [c. 1957] discussion of ideas relating to a physical process model for unifying symbol behavior understanding, see W. A. Sedelow, "History as Language".)

Within a center/distributed-center/network such as is here being discussed many different types of research on language (generically defined) could be accommodated simultaneously. The complementarity and interdependency of these separate efforts would vary through time; certain broad indications of interaction among types of language research (e.g., semantics vis-a-vis 'speech understanding') are specifiable, but many of the details of future research trajectories are, of course, utterly unknown and probably

unimaginable at this time. Just as the network under consideration would provide capabilities for use by researchers on their own individual initiative, and as they individually see fit, so, too, it could simultaneously offer opportunities to collaborative efforts for pushing forward with particular vigor along certain sectors of the opening frontier of language knowledge.

In the Research Applications chapter of this monograph there is some discussion of this latter, collaborative possibility--some examples of major research undertakings which a Ce/NCoReL might foster through a network in a co-ordinated way. Here, en passant, we wish to stress that Ce/NCoReL could function purely in the utility/facility mode (i.e., without allocating resources to foster directly any particular use of its capabilities), and that (though a very unlikely possibility) while in principle it could function exclusively in a mission mode (with all resources directed to one or a few specified research objectives), much the greatest likelihood would be for its use in a mixed mode.

In further study and planning the mixed mode of operation would be explored as the preferred and expected option, but each of the others would be worked out to a lesser degree.

* * *

A very strong argument for assigning a high priority to planning for the establishment of a national Center/Network for Computational Research on Language could be built solely on the importance of understanding and improving the use of symbols in systems modelling applicable to man-in-environments, but there are other highly salient considerations which have

a similar import. Discussion of some of these additional considerations follows.

The sheer intellectual fascination in seeking to understand language, or symbol systems, could be readily advanced as sufficient reason for wanting the best there is in instrumentation for such research. Just as the breaking of the chemical code of the gene was one of those great intellectual challenges to which scientists responded in no small measure owing to its fascination--despite subsequent attention to 'practical' implications and to the mixture of motive and sociocultural context revealed by The Double Helix--so, here, with the scientific comprehension of language, we have a vivid challenge to human understanding. One is even tempted to say, to the ultimate problem in human understanding--since understanding itself is significantly a language phenomenon. Language appears to be a prerequisite to most significant understanding, and to all shared understanding; understanding is largely an artifact of symbolization, although the properties of relationships between types of symbolization and types of (non)understanding--an extension, in a new way, of issues earlier raised in the 'Whorf-Sapir hypothesis' literature--presumably will be among the highly interesting sets of questions a national 'laboratory' of the Ce/NCoReL type would be used to study. Previously this vivid challenge of a truly scientific understanding of symbols/symbolic behavior/symbol systems/language was not taken up with the vigor and resources we now might well give to it, presumably in part because lacking the instrumentation needed for any real hope of managing the problem, somehow it was by and large effectively repressed from our imagination--much as we might say that despite occasional earlier comment on getting to the moon the substantial mobilization of ideas and effort to do so awaited the availability of a necessary basic technology.

With all due regard for the magnificence of the world's greatest scientific achievements and with all due awareness that at present there is no prospect of finding any individual or group on a language research track that could be expected to lead to a many-orders-of-magnitude leap in understanding such as achieved by a Copernicus, a Newton, a Darwin, an Einstein, or a Bohr, nonetheless, one can only say that if in our day the code of language is 'cracked' it would be in its magnificence and implications an achievement worthy of the enhanced scientific and technological resources of the present. Further, if we truly understood how language works in its functional relations to both our inner worlds and to external reality, we would begin to see all previous great scientific achievements from a new perspective--since a thoroughly scientific understanding of the essential human functions of symbolization should ultimately enable us to generate rather on demand specific sets, strings, or systems of symbols highly appropriate to any particular sought-for knowledge/intervention in our environments. The making of great scientific discoveries or 'revolutions' would then fall out as special cases in a general process so well understood that, by definition, the hitherto comparatively incomprehensible acts of original genius could be, to some significant extent, routinized. But, to repeat, there is, of course, no immediate prospect for that sort of glorious break-out to new heights of understanding of human understanding, or, in an alternate locution, of accurate and powerful symbolization of symbolism. Nonetheless we are now in a position to, so to speak, build and equip the national laboratory within which such scientifically transcendent achievements could take place: a distributed center or network capability

for computational research on the nature of language itself, and in the fullness of its empirical realization in specific languages and types of 'language.'

One part of the more immediate appeal in developing such a distributed center or network is in its precedental significance. Now we can, in effect, for the first time put together a laboratory that is nationwide in scope; and a small number of carefully studied experiences of working out the communications technology and researcher interaction patterns for such a 'distributed' national laboratory could prove vastly useful in the future as we strive to co-ordinate scientific and technologic personnel in shifting combinations for research efforts applied to major national and international needs. Unlike other developing or proposed center/networks analogous to Ce/NCoReL (in chemistry or economics) this one would undertake to serve a particularly diverse research constituency. In that respect, among others, it represents a significant innovation.

That innovation is especially important since we may well expect that few major socially pressing scientific problems will fall within the domain of any one academic discipline. With the maturing of sectors of science so that it is increasingly realistic for scientists to work on solutions to socially-defined, 'real world' problems, we need experience in substituting communication for transportation--so that variegated and temporary constellations of dispersed talent can be brought into effective, collaborative interaction without relocation. In addition, then to its multiple and highly significant substantive implications, national networking capability for the disciplinarily diverse researchers on human symbolization could be

so studied as to provide guidance for the numerous prospective multi-disciplinary center/network arrangements that will be needed in the future.

Of the substantive implications to this Ce/NCoReL center/network one of the most immediately significant would be its bearing on another problem which will be common to many networks: the accessibility of scientific information. For the moment taking the problem in very restricted form, one might conceptualize an improvement in science information accessibility through a network as no more than providing channels to existing machine-readable files of bibliographical control information at such sites as Chemical Abstracts in Columbus, Ohio, or the University of Georgia's stock-pile of science bibliography tapes, or one of the NASA literature search facilities, or any repository of MARC tapes. Making these bibliographic resources markedly more readily available nationwide would be very desirable. And, no doubt, that will come to pass. And when it does, if costs can be held down, it could prove an immense boon even to scientists working on those campuses and other sites at some distance from the most extensive scientific literature collections. It is, of course, also very important to develop and implement programs for normalizing bibliographic entries so as to make searches effective across the different formats utilized by different journals.

Now with a somewhat more ample view of the science literature access problem, one sees that the scientific community also needs the benefits of more complete studies of the problems associated with relevant document retrieval which, for example, the BIRS efforts at Michigan State and the SMART efforts at Cornell, have made a start on. Content analysis and very

unconstrained question-answering programs are examples of what needs further study. Most such efforts have suffered from their 'experimental' character, and, more particularly, from the small size of the files utilized. A network capability for computational research on language would have at one or more of its nodes unusually extensive--and hence, as to scale, thoroughly realistic--collections of machine-readable verbal text which could be utilized in relevant document retrieval research.

But of course one also wants to go beyond document retrieval to 'fact' retrieval; and, again, the large verbal data-bases available to researchers primarily for their own substantive purposes also could be used for fact retrieval research. Further, facets of the actual utilization of these data-bases might well serve as a subject of study in order to help cope with the persistent difficulty of information retrieval systems which don't mesh well with the established use habits and expectations of their putative users. And in the matter of fact-retrieval research we must bear in mind the need for a parallel to the single bibliographic search request which must be manageable across varied bibliographic formats--manageable if not by an antecedent normalization of the bibliographies, then by software which will call out from a general-form search program whichever specific format-accommodating programs are needed for scanning format-divergent segments of bibliographic text. That is, as to question-answering by means of <u>fact</u> retrieval, we need to carry out the research which will give us normalizing conversion routines for in-put text, as adumbrated in, say, the work of Quillian; or, much to be preferred, we need to apply such research to the alternative procedure of dynamically adjusting the search programs to cer-

tain of the varying characteristics (syntactic, stylistic, semantic) by discipline, etc., of the texts being studied. Among the many types of research which have a bearing here, and to which a network capability could handsomely contribute, are the new views of 'sustained discourse analysis' currently under exploration. The implications of extra-sentential parsing, as with paragraphs, chapters, tales, or treatises, are very important for self-adaptive search procedures scanning for subtleties greater than Boolean conjunctions of terms, or items in term categories within a thesaurus.

At a still higher level of subtlety we need to be able to use Ce/NCoReL facilities for helping with scientific knowledge dissemination through language research beyond that needed both for bibliographic data assembling and, even, for fact gathering. A thoroughly satisfying system for accessing scientific knowledge through a computer network also will contribute to the creative side of science by enabling a scientist to quickly feed his technical imagination through the very rapid locating and displaying of passages in the literature which bear upon new ideas, even when they are in a very amorphous, ill-formed condition. Through interacting within a literature store of the scale made possible and feasible by a network the scientist should be able to achieve to a degree usually not possible the kind of one-idea-quickly-leading-to-another experience which is often a crucial part of a creative moment, and which is now available only under fortunate and somewhat fortuitous circumstances of colleagueship. If we aspire to make available content from scientific literature on this sort of associative basis, we need to know far more than we do now about the extra-logical, extra-syntactic structure of term associations in extended discourse. To achieve

this goal we need large stores of written and transcribed discourse in a number of languages for careful study by means of such programs as the VIA (Verbally Indexed Associations) package which has been developed in conjunction with S. Y. Sedelow's language analysis project. Implementation of the Ce/NCoReL idea also would make possible greater progress in the thesaurus structure research which is another element in that project relevant for improved effectiveness in scientific knowledge dissemination.

In the effort to make science literature more readily available and more effectively used, as network technology makes possible in principle, we also need to know more about the characteristics of various specialized discourse domains, such as professional 'dialects.' Again, large stores of verbal data are required and extensive measurements need to be made on them, in order to understand how to use the computer to aid in mapping from one type of 'cognitive structure' onto another. As also with members of larger language communities, people with divergent professional socializations or enculturations have learned to use (technical) language in differing ways; and at present there is no good fashion for efficiently and effectively detecting and presenting differences in discourse properties relevant for enabling a person to get a useful conspectus of how to map, for example by type, one professional sub-specialty's symbol structure onto another's. The project begun by W. A. Sedelow at Chapel Hill on the computer-assisted reduction of interdisciplinary discourse barriers addressed that topic by initiating an examination of available modes of rigorously characterizing language strings. Again, a network capability for studying language would facilitate this research, which has strong implications for

all manner of major interdisciplinary efforts, such as those applying research to large-scale national needs.

But beyond improving the uses of symbology in reality modelling and beyond the facilitation of more effective interchange among the various sectors of science, and apart from the pure pleasure of a major intellectual and scientific challenge, there are other strong motivations for the development of a network arrangement which would produce synergism in language research. Among these additional incentives to recognizing the very high priority which needs to be assigned to a broadened national effort at basic computer-aided language research is the need for 'real-time' oral translation. Important as were the arguments of a decade and more ago concerning machine translation of texts, the present arguments for 'real-time' translation are even more potent. (We make these arguments in full awareness of both the restricted success, thus far, of machine translation efforts and of the additional difficulties posed by 'real-time' oral translation.)

'Space-ship Earth' would be a very different place if each person with access to a telephone could communicate with anyone else also within reach of a phone. It isn't practical either economically or to achieve conflict avoidance/conflict resolution to have a world which technologically has been so reduced in scale that in many social ways it is effectively 'one,' but where we do not talk each other's language. Difficult as would be the task of achieving negligible-delay translation of oral discourse from any major language to any other major language, the costs of not doing so are intolerably high--if we once assume that heightened interaction, both verbal and verbally-facilitated, would create a day-after-day condition such that more and more of the earth's people were bound by communication

experiences and attendant co-operative activities which built us all into a growing, complex network of actions and sentiment. The illusion of separateness and non-interdependence--social distance illusions in the midst of the real closeness technology has already effected--is another way of referring to a present dangerous human condition. If the major language barriers were drastically reduced through the availability of MOTS (Machine-aided Oral Translation Systems), then the rate of communication across national boundaries might be expected to skyrocket, producing in process a 'people-to-people diplomacy' whose commercial benefits alone should be truly extraordinary, without mentioning the overriding benefits to international, or inter-people, understanding.

Clearly, there is an intersection between the research implications of a Ce/NCoReL for, on the one side, the dissemination and utilization of scientific and technical literature and, on the other, international communication facilitation through 'real-time' oral translation. The significance of that overlap is highlighted by the recent agreement on cooperation in science and technology signed in Moscow on May 24, 1972, by President Nixon. Congruent with the earlier, more general agreement on exchanges for cooperation in scientific, technical, educational, cultural, and other fields signed on April 11, 1972, the new agreement on cooperation provides for a U.S.A.-U.S.S.R. joint commission on scientific and technical cooperation to participate in establishing on a closer and on a more regular basis cooperation between the scientific and technical organizations of both countries. Article II of that agreement, as distributed by Reuters, indicates that this new effort at cooperation is to provide for broad opportunities to combine the efforts of scientists and specialists in working on major problems whose solution would

promote the progress of science and technology for the benefit of both countries and of mankind. In a subsequent section of the agreement there is provision for the exchange of scientists and specialists and for the exchange of scientific and technical information and documentation, as well as for the joint development and implementation of programs and projects both in basic and applied science. These efforts are explicitly extended to include joint research, development and testing, and exchanges of research results and experience between scientific research institutions and organizations, as well as the organization of joint courses, joint conferences, and joint symposia. Attention is also given to establishing contacts between firms and enterprises in both countries, and to implementing agreements to further cooperative scientific and technological work in particular areas. This agreement is to remain in force until 1977 and is then subject to modification or extension by mutual agreement of the two governments. It is, then, clear from this development that we have another, more immediate incentive to attempt to perfect through the use of the computer in the study of language our capacity not only to make scientific literature more effectively utilizable by research workers using it in English, but, more to the immediate point, to perfect our capability of rapidly making available Russian scientific literature to English-reading researchers and making available our literature to the researchers with whom we would cooperate abroad. Given the significant strength of science and technology in the U.S.S.R., the inducement that agreement provides for further effective effort at the intersection of science information services with very high speed and even higher quality translation is very considerable. In addition

to other advantages which may be expected to flow from the implementation of this agreement, one may anticipate economies through greater utilization of the scientific and technological accomplishments efforts of scientists working in languages other than English, provided the necessary communication facilitation can be achieved. If, indeed, the scientists and specialists do collaboratively work on the major problems which this agreement calls for their addressing themselves to, then the resultant economies may be very significant indeed, as well as, even more, the resultant economic benefits.

Further to place in international perspective some of the significance of planning now for the possibility of a national center or network for computational research on language, it may be mentioned that overwhelmingly the most highly budgeted research and development project to be undertaken by the Japanese government through the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry is research and development on a "Pattern Information Processing System." During the period from 1966 to 1971, according to figures released by the Japanese government, more than $27 million--perhaps a very suspiciously low 'public' figure--was spent on the development of super-high performance, large electronic computer systems, under this national research and development program. That was once and a half again as costly an effort as any other of the projects announced for a nine year period covered by that research and development program. It is interesting to note, then, that even the publicly announced budget ($125,000,000) proposed for the development of pattern information processing technology is more than four times as great as that for the development of the super-high performance, large computers. The develop-

ment of this pattern information processing system has been described by the Japanese agency involved as one urgently needed for the development of their economy, and it is meant to make provision for the direct computer input of written characters, information in the form of pictorial patterns, and the human voice. The Agency of Industrial Science and Technology specifies various prospective applications for such a system, including medical, educational, and information gathering functions, looking to sophistication in overall information handling systems, partly through the direct input of characters, sentences, pictures, shapes of objects, and voices. The r. & d. effort would be directed to such goals as the direct input for memory and processing of diagrams of up to approximately 100 lines, the identification of various polyhedra against both simple and complex backgrounds, the recognition of various words and voices, as well as an understanding of the composition and meaning of simple sentences. Their timetable calls for the completion of a prototype of the integrated system by 1978. Among the anticipated effects of this system cited in the Japanese government prospectus is the development of a voice typewriter and the possibility of high-level CAI systems, the latter through the development of robotry. It is of interest to note that in conjunction with this research on pattern information processing a large scale research computer capability is to be provided, which has been given the acronym EPICS. Simultaneously, in the U.S.S.R., planning is underway for a large scale institute for computational linguistics (Vyčisliteelńaja lingvistiks). While both the Japanese effort and the U.S.S.R. effort may be regarded as in various ways challenges, it is also the case that we may need to achieve new levels of coordination and

capability in these research areas ourselves even in order to take full advantage of opportunities for international research cooperation which these computer-related efforts overseas at basic symbol system studies may make all the more desirable. More than a decade ago, the late Professor Léon Dostert of Georgetown University pointed out the extensive efforts which had gotten underway at that time in the U.S.S.R. in the area of applied linguistics, with specific implications for such fields as language teaching and scientific literature; his observations were made in the context of his proposal for a greater formal recognition here of the importance of language research. And this past spring David Hays raised the question of what the consequences would have been of devoting to language research beginning, say, a decade ago the scale of resources assigned to NASA.

We are only beginning to realize the potentialities of the computer for cooperation between men and machines in the performance of complex functions. Artificial intelligence research and kindred work intimate the rich possibilities latent in the more imaginative use of computers. One of the most challenging aspects of man-machine cooperation is the utilization of the computer for assistance in the field of education. For the teaching of language and what it embodies in symbol systems, such as science for example, the computer has great promise. It could be used to facilitate the acquisition of additional social dialects to improve communication within any language community, as it might also be more effectively employed in the teaching of second and third languages. But to exploit anything like the capabilities which even present computers have for this purpose implies a better understanding of the nature of language itself. Hence we may argue

that one of the benefits of a coordinated effort at planning for the joint development of resources for using computers in the study of language would be better employment of such machines in the teaching of natural languages. Some aspects of these uses of computers in teaching language and literature are indicated in a recent article by S. Y. Sedelow in the Communications of the ACM, "Language Analysis in the Humanities," July, 1972. And very probably one of the best sources of a conspectual view of the prospective role of computers in higher education more generally is to be found in the most recent report of the Carnegie Commission on Higher Education, The Fourth Revolution: Instructional Technology in Higher Education. Without attempting to recapitulate the content of that report, it may well be noted here that it postulates a vast increase in the utilization of computers in college instruction. Their projections are that by the year 2000 ten to twenty percent of on-campus college instruction would be conducted by "informational technology," with up to four-fifths of "open university" instruction being handled by these new types of technology. The Commission proposes that the federal government spend from one hundred million dollars to three hundred million dollars per year for the next seven years to encourage the development and utilization of this new technology of instruction based on electronics. They argue that at present this utilization of electronic technology is being slowed down by, inter alia, the generally poor quality of "software" or materials available for use with such equipment. A deeper understanding of language, as might be achieved through the utilization of computers as research aids in language research, could be employed to improve the effectiveness of symbolic communication for educational purposes. It might be said also that

if, indeed, those Commission proposals are acted on which involve the establishment of seven regional centers to develop and disseminate materials and techniques for these new electronic media, then the experience of working out joint, multi-university computer resource sharing for language research might have great transfer value in facilitating the effective interaction over networks of personnel at those widely separated centers.

RESEARCH IMPLICATIONS AND EMPHASES

In order to provide context for the delineation of research emphases, a brief initial reminder of the major problems for which such research emphasis is relevant seems in order.

First, and most general, is the importance of man being able more effectively to model his environment in order to solve problems. Frequently, it is not economical, safe, nor humane to let events 'work themselves out.' Depending upon the nature of events, nations fall, lives are lost, businesses and other institutions collapse because--unchecked by modelling, understanding, and reflection--developments are allowed to 'take their course.' An understanding of the components of events, including the very important and often ignored linguistic symbol-system component, as well as an understanding of which languages or symbol systems are best suited to modelling interaction of all those components, are vital to efforts to model and effectively predict outcomes of those interactions. One of the major reasons that large classes of critical events taking their own course have not been sufficiently understood to allow for separating out components for model building and testing is that the languages and symbol systems involved in the events themselves are not understood sufficiently to permit the necessary macroscopic and microscopic analyses; in fact, it is far from clear that we have even roughly optimal symbologies for undertaking such analyses. In the past, a major obstacle to the development of such tools and analyses has been the sheer quantity of varied types of empirical data. The computer makes possible a concerted attack upon such masses of data, both in analysis and in modelling; and that is a reason major computation power for a Ce/NCoReL is now both important and timely.

Another major problem area--and as is the case for all problems to be mentioned here, a problem which is not separate from the general effort to model environment, when 'environment' is generically viewed--for which the research implications of a Ce/NCoReL are extremely important is comprehended under the heading 'international understanding and cooperation.' As the United States undertakes new cooperative efforts with Russia, China, and other nations in space research, medical research, trade, and presumably many other areas yet to be specified, it is vital that the obvious problems caused by natural language mistranslation and misunderstanding be minimized. It is also important that the more subtle sources of strain imposed by differing language structures be recognized, explicated, and thus, as far as possible, obviated. (Cf. various Language Analysis Project Technical Reports, S. Y. Sedelow, Principal Investigator.) Although social scientists do use the phrase "culture shock" and it is generally recognized that the effort to deal with an individual from another culture often inadvertently creates strains for both sides, the purely linguistic component of culture shock has received comparatively little attention except in the most obvious sense of learning words in the "foreign" language. For example, the possible strain between language use which is primarily nominal and language use which is primarily verbal has not been explored, although presumably it could bear at least a weak analogy to strains imposed by interaction between an introverted, passive individual and an extroverted, highly active individual. The obvious language barrier, i.e., not knowing a given "foreign" language is, of course, a major one. Research should move toward the ideal of making available to any individual wishing to deal with people whose language he does not know

'machine' versions of the kinds of interpretive facilities which, for example, now exist for a given set of languages at the United Nations. That is, one should be able to pick up the telephone and dial a party anywhere on the globe and be assured of an immediate and adequate translation for both sides of the conversation. The achievement of such a goal, even for a reduced set of languages, cannot even be contemplated as a wild dream without a massive research effort of the sort to which a Ce/NCoReL could be partly devoted.

Another major problem for which only partial, ad hoc solutions have been proposed is scientific information processing and dissemination. As it has become clear that the mass of science information now far exceeds the ability of traditional information specialists, e.g., librarians, to get it to the researcher who needs it, computers have increasingly been used to supply partial solutions. The solutions have been marginally satisfactory at best partly because scientific information is conveyed through symbol systems, and the symbol systems themselves are not adequately understood. As a result, full text processing, for example, has been very little used and computer programs have concentrated upon the much more constrained word matching implied by the examination of titles and, in more extensive systems, of abstracts. No new breakthroughs have been achieved in this field for a number of years precisely because aspects (notably semantics) of the symbol systems employed are not sufficiently understood to permit instruction of the computer as to how to handle them. Another very important type of science information processing and dissemination which has received very little attention is that of communication among scientists from different

disciplines who are working on a common problem. A few research efforts now take this factor into consideration. The effort in biological sciences at The California Institute of Technology is notable in this regard; and a recent conference sponsored by the National Genetics Foundation for geneticists, immunologists, and pathologists had as its aim not only reports of research involving genetic tests but also "to get researchers from these diverse scientific backgrounds to clarify subtle but critical semantic misunderstandings that result from different uses of the same word in different disciplines." (Lawrence K. Altman, New York Times, March 1, 1972) A NASA research project which began in 1968 at the University of North Carolina at Chapel Hill which was partly devoted to computer-aided reduction of interdisciplinary discourse barriers among scientists (W. Sedelow, Principal Investigator) was mentioned in the previous chapter.

The area of man-machine cooperation as it is and, even more, may be involved in education, in research, and in the communication of research methodology, insights and results to scientists and other research scholars, is another field to which Ce/NCoReL research is vital. At a recent meeting of the Advisory Committee on Computing for the National Science Foundation, one of the pioneering and continuingly effective users of the computer for education stated that for computer-assisted instruction to be effective for any advanced work (e.g., beyond straightforward drill and tests of recall) the natural language problem must be solved. That is, natural language as a whole must be susceptible to such precise understanding that the computer can be provided with rules for both analyzing and generating natural language. Other languages--notably kinesics and graphs--are of major importance

in education, but the nature of that importance is by no means clearly understood. It is not known--relative to significant and critical criteria--which symbol system is most appropriate for any given task, in part because the characteristics of the given symbol systems are not thoroughly enough understood; further, it is not known with precision what is lost and what is gained when moving from one language or symbol system to another.

This latter problem, mappings between and among symbol systems, is central to all the topics--education, research, communication of research methodologies among scientists, etc.,--cited as aspects of man-machine cooperation, as well as to the other major problems being listed as science applications context for research to be undertaken at a Ce/NCoReL. And again, it should be noted, prior to the advent of the computer the extensive data collecting and data descriptions and data reduction and theory testing implied for such research seemed all but impossible.

While facilitation of productive technical interaction, as indicated above when talking about cooperation among scientists, among teacher and pupils, and others, is one important implication of Ce/NCoReL research, it certainly is true that facilitation of the solving of social problems in general also would be an important research implication for a Ce/NCoReL. Almost all such problem solving entails a high percentage of symbolic exchange and the so-called factual content of that exchange is merely one factor of a totality making either for success or failure in the problem solving situation. Even speakers of the same language often in fact use differing 'dialects' which either obviously or subtly militate against effective communication and effective problem solving. Some of the dif-

ferences in the symbol systems of a resident of a city ghetto and of a resident of a suburban area are obvious and can be recognized and, to some extent, dealt with; others are more subtle and go unrecognized even though their impact on the symbolic exchanges may be so severe, even among scientists, as to jeopardize or destroy cooperative undertakings.

Other major problems for which Ce/NCoReL research has implications obviously could be cited. But surely those which have been noted are sufficient to suggest once more the social and scientific centrality of research on languages and symbol systems to the ordering and improving of our lives.

Research Emphases

Possible research emphases of a Ce/NCoReL have now been discussed with many more than two hundred scientists and research scholars. The scholars and scientists who have responded to letters, who have participated in conferences, or who engaged in discussion during visits by the principal investigators, range over a great many disciplines: computer science, electrical engineering, speech, communications research, linguistics, anthropological linguistics, sociolinguistics, psycholinguistics, music, art, 'foreign' languages, literature, mathematics, etc.--in short, across many of the disciplines comprehended under arts and sciences in a college or university. These researchers are almost all characterized not only by an interest in the use of symbol systems but also by an interest in the characterization of symbol systems being used. Not surprisingly, therefore, there was considerable agreement as to broad areas of research which might be comprehended by a Ce/NCoReL, although it should be noted that research on a given

symbol system would, of course, differ in specific detail from that on another. In general, it could be said that there are some problems which need to be solved for almost all researchers who might be connected with a Ce/NCoReL and there are other problems with which smaller subsets of researchers would be concerned; it is to be hoped that the interaction produced through the sharing and solution of common problems would prompt communication concerning details anent the more specialized problems, and that, in turn, would make for some positive synergistic effects.

The discussions of basic research to be undertaken by a Ce/NCoReL can be divided into the development of tools and methodologies for research and the areas of research themselves. It should be noted that this division is not as neat as it might sound, because in some cases the very development of the tools implies basic research.

Among the tools cited as necessary for a Ce/NCoReL are such methodological instruments as: statistical packages, data management systems, parsers, grammar testers, techniques for modelling and testing data; programming languages and special purpose hardware might also be listed among such tools; data banks, including documentation for the data banks; libraries of programs and documentation for the programs; methods for monitoring experiments and collecting data; communication links among researchers; collection and dissemination of bibliographical information concerning what is being published in areas relevant to a Ce/NCoReL.

The research, itself, can be described as concerned with the structure of languages and symbol systems: in other words, the specification of the units and the ways they combine in languages and symbol systems. Categories

used to specify the study of such units in some languages and symbol systems include some of those employed in phonology and/or acoustics, morphology, syntactics, symbolic logic and mathematical logic, semantics, music theory, and psychometrics.

Another area for basic research is what some researchers have labeled coding and notational communalities and what we have called the examination of mappings between and among languages and symbol systems.

And, finally, there is the basic research area of the central nervous system, itself, whose own encoding and processing of languages and symbol systems underlies all other research that might be described as basic.

Research Tools

To return now to the tools which either are in existence and could be used in a Ce/NCoReL, or need to be developed for basic research efforts, some comments about methodology might first be cited. As will become obvious, some of the areas listed under other categories above, e.g., program libraries and programming languages, are logically part of a Ce/NCoReL methodology and will be referenced within some of the passages cited here. They are listed separately above merely to give greater emphasis to their importance as tools for a Ce/NCoReL.

(We would like to insert a caveat here concerning our decision to list comments and remarks without specific attribution. A number of scholars provided written comments with permission to quote freely; a number of others provided qualified permissions; others provided no explicit permission to quote although permission may be construed as implicit in their comments.

We, in turn, would feel obligated to seek approval to attribute discussion and commentary from the scholars who were involved in conferences and with whom we met individually or in small groups. The implied logistics under all these constraints proved too complicated for available resources if we were to achieve a thorough uniformity for consistent explicit citation by name. Initially, we had planned to cite by name those scholars who had given permission; but then it seemed that to be utterly fair, they should be permitted to see the context of unattributed and attributed comments within which their attributed remarks would appear. Hence, our decision--not lightly constrained by considerations of timeliness in getting out this report. A list of all scholars and scientists who were consulted (and provided some response) as part of this study appears in an Appendix to this report. The length of that list should make obvious some of the logistics problems alluded to above.)

During the course of the conference (See Appendix III) on April 23rd, a computer-scientist/psychologist suggested that the development and use of research tools ought to be the first area of concentration for a Ce/NCoReL. That would, indeed, seem to be a logical way to get a Ce/NCoReL underway, but this comment had an additional, special slant which seems important. That is, that the development of research tools and methodologies by a Ce/NCoReL would facilitate replication of experiments. As we all know, one of the conditions of science is that experiments be replicable. But it seems to be the case in much research on languages and symbol systems that the conditions under which experiments are done vary so widely that replicability is difficult to achieve. Experiments for which the protocols and execution are administered by the computer or computer-driven devices to

which a user could have access through a network would seem to hold greater promise for replicability than those undertaken by researchers in isolation who attempt to duplicate both the methodology and the experimental data and environment.

In his discussion of research tools, another social scientist lists the following (with reference to the use of the computer for the analysis of English):

1. Local syntax analysis (i.e., local discourse) a la Winograd. This is especially for conversational messages, with the program having the option to ask questions.
2. A full syntax analyzer, primarily for well formed sentences as in printed text, where the analyzer is expected to proceed along largely without being conversational.
3. Pronoun reference analyzer for both of the above.
4. Homograph analyzer for both of the above.
5. Thematic analyzers and abstractors.
6. General development of knowing machines that learn about their environment with a maximum of bootstrapping and a minimum of pre-programming. (Letter)

A linguist says:

> I think linguists would like (or at least could come to like) to have available for use on their own local computer, written in languages with which their own local programmers can cope, programs for grammar testing, phonology testing and Proto-language reconstruction similar to those that have been developed by people like Joyce Friedman and Sheldon Klein. (Letter)

In his discussion of desirable research tools, a researcher/teacher lists

> Language processing systems such as those of Wood, Winograd, Sager, Kay that actually exist and can serve as a basis for experimental grammars, Q/A, conversation, and application systems. I think in general these are first priority items after the operating systems. (Letter)

A discussant of applications especially relevant to communication research, calls for both automated parsing programs and data management systems:

> In a variety of sociolinguistic projects, researchers are attempting to draw generalizations about variations in syntactic structure across social strata as well as in terms of how speech varies from situation to situation. If the lan-

guage samples are in a keypunched form, the further refinement of automated parsing programs would be a great advantage, particularly the programs which would provide a variety of part-of-speech ratios for subsequent analyses. A number of studies, for example, find that noun modification patterns and verb elaboration patterns are particularly sensitive indicators of social status differences. If an automated parsing program could not only identify such phrase structures, but could calculate modification indices, this would be most useful. Parsing to the level of interphrase modification patterns would be also very useful, although it is obviously a challenge for your analysis routines. I imagine that we are both well aware of the shortcomings of these types of descriptions, particularly in terms of the goal of linguistic analysis. However, for sociolinguistic studies, where we are dealing with large corpora of data and where we do want to incorporate statistics of individual differences, these types of programs are most useful.

Another need, I believe, is in the development of data management systems for use in language research. For example, we recently completed a large study of children's articulation substitutions, where the data were described in terms of distinctive feature variations as between target and realized articulations. The data base parameters for this study included distinctive features of English, the further identification of features in terms of certain aspects of markedness theory, phonemes, sequential environment of the phonemes, differentiation of the child's language sample, and characteristics of the child informants. A considerable amount of our time on the project was devoted to the adaptation of the Remote File Management System to the design of this data base. Our aim was to have a data base that we could interrogate in an on-line fashion, which would provide us with a variety of relative frequencies, contingency analyses, and would write out numeric data in a manner that would lend itself to statistical analyses. We were, for the most part, successful in this effort, however, we spent more time on the computational aspects of this project than desired. If a data management scheme of this type were available, it would have saved us considerable time, energy, and money. I might note that in Roger Shuy's Detroit dialect study, the computerized procedure for assessment of phonological data was never completed. It only remains partly described in the project report. If a data management scheme were available for phonologic data--particularly with the distinctive features approach--it would have facilitated that major study. (Letter)

Among the relevant research methodologies for a research/scientist in linguistics are:

strategies for storing, retrieving, and processing complex structures, for access to multi-dimensional data, for more comprehensive

> on-line display interaction, for eliciting and formalizing protocols of human behavior in the various domains that need to be modelled. (Letter)

The scientist quoted above lists modelling among the areas of research which might have priority in a Ce/NCoReL and a number of other researchers' comments are either directly or indirectly related to the development of modelling techniques. For example, when a conferee (Conference, February 13, 1972) spoke of the desirability of having a student interact with the computer in generating a sentence and then in building a grammar, he was implying that a student would provide a model according to which a computer program would generate a sentence and ultimately, a grammar. Interactivity means that as the computer generates a sentence, or longer or shorter string, in accordance with the rules specified in the model, he can see by inspecting the output of a program in what ways the model is succeeding and failing. This feedback, then, enables him to modify the model and test it anew.

When another linguist speaks of building and testing a grammar he, too, is speaking within a domain of modelling:

> I tend to think of the grammar in two parts: a prose part, and a set of rules that the parser can get at sprinkled through the prose. I would think of a phonology as a special kind of limited grammar. We would want to drive a simulator from underlying expressions that we run through the grammar to test it (with the possibility of specifying part of them randomly). We would also want the grammar to control a parsing program. There are quite a few parsing models around, so that I would hope to offer alternate strategies in order to arrive at the best possible grammar.
>
> In addition there are a number of useful but not terribly sophisticated routines that I think most linguists would like to have access to. One looks for empty spots in paradigms and asks how to fill them. Another probes for analogies in semantic rule sets, using Fillmore's approach to grammar. Another works on sequencing: affix systems, rule systems, or teaching sequences. (Letter)

During a working conference (April 23, 1972), the above linguist emphasized the role of modelling as a "bug finding mechanism" for theories. He argued

that the simulation, or modelling, of theories would reduce the time between the initial formulation and testing of a theory and the point at which "it boomerangs on you."

In somewhat the same vein, another linguist urges

> that at this stage massive analysis and synthesis of natural languages be started and vigorously sustained for the next five years. Its results would be used for testing the theoretical research that might be developed at the same time. Language modelling would be improved if theoretical researchers would pay more attention to the real data, and not force the data into their preconceived frames of reference. (Letter)

One of the major functions of a Ce/NCoReL would be to bring together theory and data. At present, theorists who would like access to data for testing purposes often find it difficult to come by more than a few samples, and some scientists would say that much 'empirical' research is insufficiently enriched and guided by appropriate theory.

A psycholinguist who is studying the language-learning capacities of chimpanzees, says that "someday I would like to compare my animal experimental approach to conceptual structure with that of computer simulation." (Letter) Again, there is the emphasis upon comparing experimental design and results, with a computer model or simulation incorporating the theory and its computer-based realization.

A communications scientist would seem to be talking in part about modelling when he notes that

> much basic research has to be funded in order to get a center as proposed off the ground. In other words, I am asking, parallel to the development of computer programs and the data storage devices, for a systematic attempt to validate the underlying assumptions of those computer programs by testing their results against hard evidence, and for considering in a rigorous way what a particular form of storing linguistic information fails to maintain. (Letter)

Underlying assumptions would seem to refer to theory embodied in computer programs which would generate results to be tested against hard data.

On the general subject of the use of formal languages for modelling natural languages, an automata theorist sees value in the effort but suspects that none of the present formal models is "remotely sufficient to even start." He stresses the need for "very facile communication" among researchers interested in this area stating that he "would like to use resources and accomplishments in just about any place that is interested in such research." (Conference, February 13, 1972)

Statistics represents another area of methodological development and implementation which is of interest to a number of prospective Ce/NCoReL users. A psycholinguist notes that he would like "a statistical analysis cum data management package." (Letter) During the February 13, 1972, working conference, another psychologist noted that if

> you want to do some simple standard stuff, e.g., analysis of variance, it is awfully nice to be able to get at sophisticated packages that have been written for unsophisticated users. You probably don't want to spend a lot of time putting up an analysis of variance package for your computer. It would be nice to get to someplace where somebody who worries about those things every day has done something good for you.

Another scholar states that

> I wouldn't want to start listing what should be developed regarding statistical packages for language analysis. Once natural language can be mapped into a form suitable for traditional statistical packages, many of the problems will disappear. On the other hand, there are a few language-centered statistical analyses needed. But most of these are not yet fully enough developed for implementation in a computer and, for those that are, the underlying theory (of syntax and of semantics) is often naive if not unfounded. (Letter)

Another researcher has found that the mapping of natural language into a form suitable for traditional statistical analysis, as suggested above,

poses serious problems even for book-length text samples. Thus, although a prominent statistician believes that word frequency over very large (million words or more) samples is log-normally distributed, appropriate statistical procedures for shorter samples still need to be verified and, possibly, developed. In addition, the development of data structures, programming procedures, and possibly hardware to make possible the construction and analysis of, for example, 400 x 400 x 400 x 400 contingency table matrices would constitute relevant methodological research for a Ce/NCoReL. It may also be the case that even if natural language symbol systems do turn out to be mappable into parametric statistics, other symbol systems for which a Ce/NCoReL is intended would turn out to be nonparametric. Statistical analysis of such systems would seem to be in order and it seems quite likely that a great deal of research on statistical methodology, itself, would be implied by such efforts.

In a comment that is relevant for this discussion of research methodology, a psycholinguist says:

> I see such a center as a basic educational and communicational device for an interdisciplinary area of science. As systems are developed, they become accessible for experimental use by many users without delay now entailed by programming one's own version for one's own computer. I personally had many occasions when I could profitably have used systems for retrieval, content analysis, syntactic analysis, etc., that had previously been developed but which could not easily be gotten on the system I was using. (Letter)

The quotations above reflect views held by many researchers concerning the desirability of methodologies not only for work on natural languages but for other symbol systems as well. Data management systems, statistical analytical systems, parsers, grammar testers, and modelling and testing are methodologies relevant to all symbol systems, whether they be acoustic,

graphic, pictorial, two-dimensional, three-dimensional, or n-dimensional. To be sure, the parser for one natural language will differ from that for another and the parser for a programming language will differ from that for a natural language, a formal language, or a graphic language. However, it is clearly already the case that categories used in parsing for certain formal languages and abstract machines, such as automata, can fruitfully be applied to natural languages. There is no apparent reason why such cross-fertilization cannot occur between and among researches into many different symbol systems. A Ce/NCoReL would have as one of its major goals the bringing about of such cross-fertilization, e.g., general models of parsing that were interlingually appropriate even with a very extended definition of language and symbol systems, such as we have used in this study.

Although programming languages and packages, as well as program documentation, are discussed separately in this study it seems important to stress the desirability of doing the necessary research and development for tools in this area by citing comments from prospective users. (It is also the case that such programs and packages already have been either specifically mentioned or alluded to in earlier remarks placed beneath the methodology rubric.) Under the heading of important research problems for a Ce/NCoReL, a researcher in artificial intelligence stresses, among other things, the importance of programming languages:

> good languages are needed for the researcher, in particular extending the development of LISP, COMIT, and SNOBOL-like languages, to make them easier for the nonprogrammer to use, and to make them nice interactive languages. This almost certainly means expensive computing so that good funding of large computers is also needed. (Letter)

A classicist indicates the desirability of indexing and concordance routines and a professor in Romance language would like to see scanning and

parsing programs available through a Ce/NCoReL. A psycholinguist would like programs available for reformatting texts for performing word counts as well as counts of other units, for translating real words to nonsense syllables, and for retrieving specified information. An English professor uses programs which take both literary and nonliterary texts, expand each symbol in the text into its set of distinctive features, and then provide a "spectrum" analysis giving data concerning each specific feature. These programs permit this scholar to describe any natural language strings in terms of these distinctive acoustic features and thus might permit him to discriminate between and among various types of language strings. Programs of this type, as is the case for parsers and other programs for linguistic analysis, are only as good as the theory to which they relate. Just as is the case with replication of experiments, a Ce/NCoReL would make possible rather extensive testing of such programs and more particularly of models of the theory upon which they are based, which could then be tested against the data used by the program.

A linguist is interested in programs for grammar analysis, for dictionary analysis and stylistic analysis, and a Slavic language professor, in programs for the morphological analysis of Slavic.

A scholar interested in content analysis notes that

> a large number of analytical routines for linguistic information are pretty common to most languages and instrumental to most research objectives. These include adequate parsing of sentences, and content sensitive kernelization of longer utterances, simplifications according to dictionaries of synonyms (thesaurus) and according to patterns of syllogistic reasoning. (Letter)

In a long statement basically concerned with statistical packages, a linguist notes that

In addition, a number of software packages for statistical research of speech and automatic analysis of texts should be developed immediately. De Saussurian's antinomy of language vs speech could be statistically evaluated. The results of statistical studies would shed additional light on the concept of language 'norm.' Distributional patterns on various levels should be studied with the newly developed software. The software serving the statistical observation should be geared to various statistical models. Software packages should be developed for automatic recognition of the subject fields and subfields in various scientific disciplines. The software should also include statistical models applicable to studies of literary works, including poetry. (Letter)

In his discussion of desirable software, the above scholar says that

> The software serving the statistical observation should be geared to various statistical models. Software packages should be developed for automatic recognition of the subject fields and subfields in various scientific disciplines. The software should also include statistical models applicable to studies of literary works, including poetry. Among its components there should be software facilities for analysis of a poem in terms of rhythm, rhymes, sentence kernels, stylistic uses of various expansions of kernel sentences. The synthesis of poetry should also be facilitated by the new software. Special software for generating subfield glossaries should be prepared. In regard to the automatic analysis of the written text, the software should be capable of automatically analyzing the punctuation system and use it as a set of signals for unit boundaries and their suprasegmental characteristics. . .
>
> Since quite often a written text contains quotations from other languages, software should be developed to recognize bilingual and multilingual texts, and their mixtures to various degrees. For automatic printers of the generated language, software should be developed for list-, data-, and edit-oriented printing softwares. In any automatic processing a classification system is necessary. The classification systems of language data due to their non-terminal and varying nature (including ambiguities) could be built around a set of criteria, satisfactory for the specific purpose. Whatever the number of criteria, the software should provide for two rather well known situations when classification is tested: overshooting ("unwanted acceptance") and undershooting ("unwanted failure"). We feel that the statistical norm should be applied for limiting over-shooting and increasing undershooting. The determination of the optimum level should be made by the individual user, geared to his special needs. This is one example of the beneficial symbioses of machine and man, with the relatively commanding position of the man. In addition, any classificatory software should satisfy the general requirements for simplicity, and exhaustiveness.

> The priority of the software development should be based on the consecutive inclusion of the output of the preceding stage as an input for the next stage. For example, the analysis of punctuation marks should be done prior to determining the boundaries of the subject function within the kernel sentence. (Letter)

Comments on hardware, including indications of desired directions for research and development, appear in the section on hardware in this report.

Research Tools: Data Banking

Some of the comments already quoted allude to the desirability and necessity of various types of data banks. The discussions concerning data for a Ce/NCoReL have focused upon the types of data which might be made available through a Ce/NCoReL, possible formatting rules for such data, and problems related to the security of the data. A separate but clearly related question is the desirability of documentation describing available data; see for example W. A. Sedelow's VMI (Verbal Measures Inventory) Project, as discussed by M. Dillon in Language Analysis Project report.

Some of the types of data recommended for banking by a Ce/NCoReL might be classified either as reference information appropriate to many different applications or as data from a particular symbol system which would serve as grist for the mills of many different research efforts. Other data types recommended by prospective users are more restricted as to scope and application.

Data which might be characterized as fulfilling a reference function would include dictionaries, thesauri, and various types of bibliographical information. The latter will be discussed a little later in this section in connection with communication among scientists.

Many scholars and scientists have pointed to the desirability of dictionary data bases for a Ce/NCoReL.

One scholar speaks of the desirability of reference dictionaries within the context of computational aids for the preparation of language teaching materials. He notes that

> every teaching effort depends on a good reference grammar. Constructing a reference grammar for teaching is just like writing a grammar in the field as far as the computational side is concerned. Several of the languages for which we are writing teaching systems. . .right now could undoubtedly profit from more detailed reference grammars: Burmese, several dialects of Chinese, Japanese, Thai, Sinhalese, Javanese, Indonesian, and Romanian. The accompanying reference dictionaries and the glossaries that are extracted from them are also the kind of thing for which computational aids ought to be exploited. Eventually we might even plug into the connectivity structure of the grammar and the dictionary in order to form individualized review sequences for computer-assisted instruction, though we are not concerned with that yet.
>
> My own interests, as you know, center more in the area of getting as full information as we can on the little known vernaculars spoken around the world. Field work in this is usually thought of as collecting texts, compiling a dictionary, and writing a grammar. (Letter)

In connection with the study of student-tutor interaction, a psychologist cites his need for the capability of building miniature dictionaries. Again in his case computer-aided compilation of reference works could be used in an environment for computer-assisted instruction.

In a discussion of research methodology which really touches more upon data banking, another psychologist says that

> some capabilities. . .may be of considerable use to more than one research effort; I am thinking of items such as John Olney's computer-accessible conflated English dictionary and Harry Josselson's dictionary of Russian. (Letter)

In a discussion of the data base question in general, a research scientist in artificial intelligence notes that among desirable data bases

> are obviously ones like the Brown University corpus, the Merriam-Webster Dictionary and collected digitized works of just about everybody. (Letter)

Also on the subject of desirable data banks, another scholar lists "dictionaries, grammars, thesauri, formalized lexicons, etc., as well as a significant body of text are all desirable for such a center." (Letter)

A scientist who is responsible for the machine-readable transcripts of several dictionaries, takes one of the stronger positions on the desirability of the possible data-banking functions of a Ce/NCoReL:

> I assume that Ce/NCoReL is conceived as the central node (with respect to natural language processing and research) in a multiple-computer network like the one funded by ARPA, which has recently become operational. On this assumption it seems to me that the function of Ce/NCoReL which would have the most favorable cost-benefit ratio would be that of serving as an active archive of machine-usable data. For example, 97 tape copies of the million-word Brown corpus have been distributed (Computers and the Humanities, Sept. '71, p. 30), and more than 30 institutions have obtained tape copies of one or more of the data sets derived from the machine-readable transcripts of Webster's Seventh Collegiate and its pocket abridgement (two of these data sets contain more than 100 million bytes). I should think that most of the money and energy devoted to distributing all of these lexicological data sets could have been saved if they had been accessible to their users at Ce/NCoReL via computer networking. Moreover, this sort of centralization would make it possible to provide modes of access which are not economically feasible for most researchers working with their own copies of large lexicological data sets. Many of these data sets can be processed much more efficiently if they are stored on a random-access device, but how many researchers can afford to pay disc rental charges for large data sets these days?
>
> It seems to me that Ce/NCoReL would also be the right sort of organization to undertake certain large-scale data-providing projects. Suppose that its research into unmet needs were to indicate that a massive file of machine-readable lexicographic citations of word usage should be prepared for English, as is now being done for French under Prof. Imbs' direction. An individual researcher would doubtless find it difficult to handle all the coordination among institutions which such a project would require and still continue to do research, whereas Ce/NCoReL should be able to fit it in with its other coordination activities without undue strain. (Letter)

Thesauri are, of course, reference works which attempt to link together words which are semantically related. Thus, thesauri are of major importance

to any computer-based effort directed toward some form of content analysis--the content may be defined in terms of ideas, subjects, literary themes, political ideology, aspects of a psychological syndrome, or whatever. Many special-purpose thesauri (really just lists of words grouped together by topic) have been compiled for information retrieval in such areas as law, chemistry, medicine, etc. Mindful of the need for general-purpose thesauri for the wide range of content analysis tasks only hinted at by the list provided earlier in this paragraph, at least one research project (S. Y. Sedelow, W. A. Sedelow, et al.) has undertaken computer-based studies of Roget's International Thesaurus. For the study of structural bias, among other things, it will be desirable and indeed necessary to compare descriptive data re this thesaurus with that for other thesauri, dictionaries, and word lists such as the Brown million-word corpus. A Ce/NCoReL could facilitate making available such of these reference works as are already in computer-accessible form and putting into computer-accessible form those which are not.

The desirability of texts in machine-readable form has already been mentioned in some of the quotations cited above. A linguist summarizes the need for such data when he says

> Ce/NCoReL should encourage in a balanced manner both descriptive/taxonomic as well as theoretically-oriented and defined methodological procedures. However, in terms of computability, one should emphasize large data collections as a necessary step in both description of data (inductive methodology) and theoretic testing (deductive methodology). (Letter)

The data referred to above is, of course, not limited to texts; it would include texts, but also field linguistic data of the sort to which reference was made in an earlier quotation, as well as data collections specific to given research projects.

To gain some sense of the latter types of data, there follow some relevant remarks from other prospective Ce/NCoReL users:

> A lot of normative data is needed on people's utterances, especially children's at early years. We need the equivalent of the old single word data for syntactically and semantically interesting phrases, and longer utterances. A computer is needed to store, content analyze, access, and analyze these data. It might also be used to collect some. Well-controlled language learning experiments in very young children are needed. Chimp language learning may well be computer controlled. (Letter)

> A central data bank could offer a standard parser and a conceptually highly organized world-knowledge data base. It would take years to input the world-model but once there everyone could use it rather than trying the hopeless task of building one of his own. (Letter)

> All natural language, both transcripts of more-or-less spontaneous speech and carefully elicited data from syntactically and semantically oriented questionnaires (not phonology and not lexicon, not association stuff nor semantic differential data). (Letter)

> Text files and phonetic notation for many different languages. (Conference, February 18, 1972)

> Ce/NCoReL should contain a data base on language surface structures (and deep structures where possible) comparable to the Human Area Relations Files used by anthropologists. Such a data base would list, say, all known VSO [verb, subject, object] languages, along with other properties of such languages. It would contain cross-referenced information on such matters as surface realization of case relations, position of adverbial elements within sentences, etc. To be useful, such a file would have to be constructed by researchers with knowledge of current problems in theoretical linguistics. The data access system should be sufficiently flexible to allow retrieval for many varied purposes. (Letter)

During a Ce/NCoReL conference, an acoustician noted that acoustic data-banking poses problems because of the quantity of information. For work on speech in real-time, he would like a sixty to eighty kilobit sampling rate per second; a magnetic tape will hold 5 to 10 minutes of digitized speech. Other specialists in speech research and specialists in music also indicated an interest in acoustic data. Their needs are representative of those research scientists and teachers who are concerned with the auditory and

acoustic aspects of any symbol system. Concentration on the acoustic aspects for natural languages has, of course, been strongest (especially for scholars in speech, communication sciences, and linguistics) but it is also relevant for nonverbal symbol systems such as music. Thus far, however, most music in computer-accessible form consists of musical scores translated into a form suitable for keypunching. At a working conference on February 13th, a conferee pointed out that it would be desirable for a Ce/NCoReL to make available the body of musical scores which have already been so encoded. Several scholars (Conference on April 23, 1972) expressed an interest in using the computer for analysis of video data. Such analysis opens up the possibility for research on kinesics, an extremely complicated symbol system which is acknowledged to be an important form of communication, but--largely because of the difficulties--it has been relatively little studied and it is relatively little understood.

Video data is, of course, nonverbal visual data. Scholars interested in iconics are also interested in such data. An electrical engineer makes a strong case for their point of view:

> The only general observation that I would like to make is that I fear we are apt to regard language almost exclusively as strings of symbols which obey some kind of syntax. In face, I believe that human beings use signs in a much broader and more flexible way and that with the advent of new computer graphic techniques, we need to explore the development of other kinds of forms (that is, two-dimensional rather than one-dimensional strings). . . The interesting aspect of much of the work that has been done on pictorial or visual thinking is that the subject is still expected to respond verbally or symbolically, thus in my opinion negating much of the studies that have been made. The issue of syntax and the lack of it in human communications has been emphasized in some of the recent studies by Professor Alphonse Chapanis on how people would like to communicate with computers if they could do so naturally without any constraint at all. Unfortunately, only one article of Chapanis' has thus far appeared in print (American Physiologist, Vol. 26, No. 11, November, 1971, "Prelude to 2001;--Expirations in Human Communication"). . .

> For almost ten years, I and a number of other people have felt there should be a national center to aid in the development of computer animation for educational and other purposes. However, I have recently concluded that even if there were such facilities it is likely that few would use it because the real limitation is not a technical one of facilities but rather that people are not used to, or perhaps able to, think visually once they have developed a highly abstract symbol system. I think a similar comment may very well apply to the development of computer-aided instruction materials. The format and instructional method is so different from the usual method which we are all familiar with, that this too will likely receive little attention until ways and means are found to help teachers reformulate their methods of organizing and presenting concepts in materials. (Letter)

One of the "fallouts" from a Ce/NCoReL might well be the research on iconic symbol systems which would enable them to be characterized clearly enough so that teachers would understand how such systems might most effectively be used in a classroom situation. A recurring theme in this study which we do not apologize for stating again and again is that studies of mappings between and among symbol systems are needed so that gains and losses involved in the transmission from one to another can be understood and utilized, in formal and informal education both.

The range of types of data implied by the above comments which, it should be remembered, are only a few among the many that have been offered during the course of this study, inevitably raises the question of whether a Ce/NCoReL or any other entity can possibly cope with so much and such varied data. One respondent raises the issue in his letter:

> The data base question is a tricky one to handle. There are obviously ones like the Brown University corpus, the Merriam-Webster Dictionary, and collected digitized works of just about everybody. However, in the speech understanding work--which I do not believe is unique--there are serious questions about the utility of data out of the context of the specific research enterprise. Perhaps my biases toward more complex processing of language show here, but I do not feel comfortable about using the kind of facility envisioned for concordances or word counts.

> More complex data bases tend to respond to and to be constructed in the image of the research enterprise that prompts them. What generality they have remains to be seen. Data bases should be selected on the basis of problems, and you have thrown your proposed center/network open to an incredible proliferation of them. (Letter)

The problem was raised in another way during the conference on April 23rd when a conferee suggested that a Ce/NCoReL might have to decide on priorities between a repository and a brokerage function; another scholar raises the issue in his letter when discussing development priorities:

> Here each scholar will have his own set of priorities. I see only one overriding consideration: a national effort must be directed at genuine scholarly research, i.e., at the discovery of new knowledge, and not at elaborate clerical-type projects. Experience shows that computer-based research tends to become preoccupied with mechanics (getting more and more material onto tape, with too little time for real analysis). (Letter)

A different, but related, aspect of the problem was touched upon during a conference on April 9th, when it was suggested that a Ce/NCoReL should be set up but that private companies should prepare information data bases and sell them either to a Ce/NCoReL or to other interested research scientists and scholars.

At the April 23rd meeting, there was considerable discussion of the data banking problem. One possible course for a Ce/NCoReL to take that seemed to meet with rather general approval at the meeting would be for a given node within a Ce/NCoReL to try to make available and maintain in computer-accessible form general reference works such as dictionaries and thesauri. Such reference works likely would be obtained directly from the publisher or prepared with the publisher's permission. Arrangements for purchase or fee payment on the basis of usage presumably would have to be made. Data banks specific to research projects would be prepared and maintained at the nodes which are the home sites for such projects. It is to be hoped that

the network would function in such fashion that data from any node would be easily available to users at any other node. If such data exchange posed either short-term or long-term problems, then a given node (presumably the node already dedicated to making reference works available) should undertake to make available those data bases for which demand exceeds some yet-to-be-determined threshold. Selection of data to be banked as well as determination of thresholds and any other factors having to do with the distribution of data for purposes of experimentation and research would be a matter for the Ce/NCoReL advisory committee and representatives from participating institutions to determine.

The question of data security was also raised at the meeting on February 13, 1972. It was noted that there might be types of data that would be somewhat sensitive and a Ce/NCoReL would have to determine how to handle such data. One suggestion was that a scholar might be allowed access to such data with the understanding that it was not to be generally available. Security in another sense--that is protecting data from being wiped out inadvertently--was also raised as an issue. One conferee noted that a network might alleviate the latter problem somewhat by providing the possibility of having the same data set stored at various locations; thus, the scratching of a disk pack at one location would not mean that a data set had been destroyed. In general, it would always seem desirable to have backup data sets, so that if the version being operated upon were destroyed another version of the data set would be available. The problem of security in terms of privacy would have to be dealt with through the use of "keys," as is the case for highly sensitive data at laboratories such as the Livermore Radiation Laboratory. It is probably worth observing that this latter type of

security was not raised as an issue by anyone else either by letter or during conversations with the principal investigators for this study. This latter fact may reflect, first, a greater sense of urgency to get data into computer-accessible form than to prevent other people from getting at it and, secondly, a feeling that much of the data to be made available through a Ce/NCoReL would probably not require any protected status. Nonetheless, once a Ce/NCoReL began to be widely used, there would inevitably be a desire to protect certain research results until they appeared in some form of publication. Several scholars have suggested that a network might help provide almost instantaneous publication (see below) so this requirement might not pose serious problems either.

The other major topic connected with data banks which received extended discussion at the conferences on April 9th and April 23rd is whether there should be formatting rules to which all data placed in a Ce/NCoReL should adhere. One conferee urged that there be cooperation among various data banking efforts and the prospective Ce/NCoReL. He suggested that some attention should be paid to delineating the kinds of descriptors that might be used to record data for a Ce/NCoReL. He stressed the desirability of making any such scheme of descriptors open-ended and he was supported in this view by another conferee, who cited the open-endedness of the SELGEM system at the Smithsonian. The open-endedness of SELGEM means that the individual describing data is not blocked into a minimal, limited number of data fields.

A computer scientist noted that computer scientists are beginning to give up the idea of a standard data base, moving instead in the direction of devising descriptions such that each person's data base can be included in the form most useful to him. The conferee made the point which most people

who have tried to settle on a standard have discovered, that is, "as soon as you try to force a person to put his data in a certain form, he doesn't want to do it." He then went on to argue for a general, open-ended tagging scheme of the sort mentioned above.

A dialectologist suggested that the differing levels of abstraction that a field like linguistics works with would determine the nature of the categories. He went on to argue that given the range of theories in linguistic science today, trying to agree on standard categories "would be bloodshed."

Another conferee suggested that it might be desirable to let the categories, or tags, emerge from the data base, making sure that they were consistent within the data base, and then design translating programs for reformatting data bases into whatever structure a particular researcher desired. Several people supported this suggestion; one noted that he had found it useful to include with any data base he puts into computer-accessible form a record of where the particular tags for that data base came from.

Another proposal was for an approach somewhat intermediate between the first two--that the center build in alternative standardizations for data with translating programs to cope with data in one form which was then needed in some other "standard" form.

A psychologist noted that very often the desired output from a computer-based procedure affects the format of the data input to that procedure; therefore, a standard tagging system might cause difficulty.

Somewhat in the same vein, another participant pointed out that there are often difficulties in storing data in a form which is model independent.

In response to this remark, another conferee noted that the linguistic atlas designed to delineate the dialects of American English is not terribly useful today because the theory providing the principles for the construction of the atlas is no longer popular today. This remark led to the suggestion that perhaps one desirable research thrust of a Ce/NCoReL would be to put research scholars to work on data already in existence which ranges across many different fields in order to try to work out more universal categories.

Yet another conferee emphasized the point made earlier--that is, that descriptors which are satisfactory today may not be appropriate for future users. On the other hand, he noted that diversity in data description does pose problems, citing as an example, the twenty different ERIC centers each making up categories for a particular discipline; because categories are used in different ways in different disciplines, the potential user of a given ERIC's categories has to know where those tags came from in order to use them efficiently. Another participant suggested that one of the functions a Ce/NCoReL might well serve would be to enforce by example a certain standardization on the way data is organized and described. He went on to suggest that a function of a Ce/NCoReL should be to gather not only data but opinions on how data might be formatted.

We have reported on these discussions at some length in order to indicate the range of problems and some attitudes toward how they might be solved. It is probably fair to say that no one now advocates setting up one standard according to which all data must be formatted. Rather the pressure is toward setting up a system which is open-ended enough to accommodate a wide range of

users or toward setting up a number of systems whose differences will be mediated by translating programs. This preliminary study has, of course, not produced a solution to the problem, but it clearly is a problem to which a Ce/NCoReL would need to give attention not only in the form of initial, possibly pragmatic decisions but also very probably in the form of long-term research.

Research Tools: Documentation and Communication

One of the major impacts of this study upon the principal investigators has been a highly enhanced awareness of the communication problem among research scientists in these fields. In fact, as the study progressed, a feature of almost every visit with a prospective user was not only to find out what that user was doing and in what way he might make use of a Ce/NCoReL but also to tell him of other people who shared his interests and were working on similar projects. Awareness of this communication problem turned out to be central or at least important to many responses concerned with the prospective role(s) of a Ce/NCoReL. The following comments are representative of many statements on the general subject of the need for documentation of research, and communication concerning that research (documentation is obviously a part of communication, hence its inclusion in this section and in some of the remarks cited below):

> What I do think would be helpful is an increase in the likelihood that if you were doing something that I should know about, I will hear about it and vice versa. I think in computational linguistics we have done better than in regular linguistics through The Finite String, but the way that this kind of information really gets passed around seems to be in the informal parts of meetings that we all get to. If this kind of getting together and passing things around could be combined perhaps with a current awareness center, I would think this would advance the field more than any specific hardware or software aggregation. (Letter)

Another important function of Ce/NCoReL would be to act as a broker bringing together researchers needing a certain kind of processor and those having either the requisite processor or one which could readily be adapted to meet such a need. For example, I need syntactic analyses of dictionary definitions. I could submit my request for inclusion in the SIGLASH Newsletter, I could scan the project listings in recent issues of Computers and the Humanities, but surely a better way would be to search a Ce/NCoReL file of regularly updated descriptions of available processors with the aid of even a very elementary information retrieval program. A similar sort of information retrieval capability is needed for locating programable rules (e.g., for handling certain types of constructions) "raw" "corpora", corpora for which structural analyses have been encoded (e.g., (partial) analyses of the syntactic, semantic, or discourse structure of each text therein), and various other kinds of linguistic data sets. If such an information service came to be widely used by researchers in linguistics and allied fields, Ce/NCoReL personnel could derive from it useful information as to needs which are not currently being met. Presumably the identification of such needs would be one of the research tasks of Ce/NCoReL. However, for this purpose it could not rely exclusively on data derivable from an information service of the types referred to above, since material which is not believed to be available would tend not to be requested. (Letter)

A research scientist from an industrial concern stated that:

Based on requests I continually receive for information about and/or access to various language-processing programs (and, less frequently, data bases) I think there is a demonstrable need for a SHARE-type clearing house for programs and data bases in the language-processing area, backed up by a computing center which can not only copy and distribute cards, tapes, etc., but can also maintain and run programs for users on sight. (Letter)

Another research scientist from industry said:

The main purpose I can see which would be served by a network or center is the exchange or multiple use of large data bases and large programs. There is often a considerable investment by the initial researcher in making both kinds of material useful for his linguistic research. This investment is then too often lost to the linguistic community because of the physical or bureaucratic difficulties in effecting the transfer, particularly to a number of different potential users. A mechanism which could be activated just once by the supplier would eliminate this load. The implication is that the center would be responsible for the duplication and distribution of materials in a manner similar to the original SHARE organization. (Letter)

A manager of consulting services for a large computer center says:

> From my point of view, Ce/NCoReL would be most beneficial if it would gauge the need of its users, write or acquire the appropriate programs, maintain and distribute an index of available programs and data, and provide programs and data together with documentation to interested computing centers on request. Furthermore, in my opinion, the most important service it can offer is to educate the potential users and keep them abreast of new developments. This is especially important in many of the humanistic departments where inexperience in and distrust of computer techniques prevent these departments from taking full advantage of computing power. Ce/NCoReL can communicate with these humanists far better than computer center personnel. (Letter)

A linguist expresses an interest in collecting

> all the available information on bibliographies and/or individual manuscripts, articles, reports, unpublished papers (in various languages) relevant to the language theory and description, and to create from this information a Bibliographic Language Information Center (BLIC) in Computing Center, and make its information available to any worker in the field by terminal hook-ups or written questions which would be keypunched. . . (Letter)

Another scholar feels that

> it would also be of considerable value if Ce/NCoReL attempted to develop a computerized system of "research documentation" with a view to subsequent expansion toward a retrieval system that would retrieve research results rather than merely bibliographic or locational information. (Letter)

During the meeting on April 9, 1972, a conferee noted that

> there is a particular problem in this whole area of language analysis--bibliography. Up until now this material has been scattered everywhere and a great many people who come from traditional disciplines have no idea of what's available and where. Any kind of center is going to have to address itself to the problem of making a large amount of bibliographical material available. . .and it's going also to involve a very sophisticated retrieval system to get at this because primarily the material appears outside the standard disciplines. . .any kind of retrieval system or bibliographic service is going to have to be interactive because we are talking about such a vast amount of material. I don't think it can be run from a batch standpoint because the person is not going to start out with a really definite notion of what he's going to get at. He's going to have to explore things that look promising.

Also at the meeting on April 9th, it was suggested that a Ce/NCoReL should be concerned in general with disseminating information about research in the symbol systems areas to be comprehended by a Ce/NCoReL.

A number of people have commented on the facilitation of communication among researchers that a Ce/NCoReL should provide. One scholar specified the communication function as "terribly important." Another researcher, although noting that communication can take many forms ranging from telephone conversations to conversations via teletype or terminal display equipment, pointed out that for some scholars interested in, for example, some aspects of graphic symbol systems or kinesic symbol systems, "it may be that color T.V. communication will be absolutely necessary."

A linguist and a psycholinguist spoke to the need for two rather different communication functions a Ce/NCoReL might fulfill. The linguist argues that

> the greatest need is public relations, advertising among linguists. The great majority of linguists young and old are prone to ignore computers or dismiss them contemptuously. Partly this is a result of earlier overselling and a bad credibility gap. (Programmers say 'oh, yes, I can program this for you' and several years and a lot of machine time later there's still nothing working), but partly it is simply ignorance. (Letter)

The linguist is speaking of traditional, traditionally-trained linguists, concerned with the structure of natural languages. The psycholinguist, on the other hand, is concerned with the needs of sophisticated computer users. He would like for Ce/NCoReL to dispense information as to who is doing what and, very importantly for him, he would like a Ce/NCoReL to facilitate, through institutes, seminars, and other such meetings, opportunities to talk with other researchers informally so as to gain a more complete sense of their research than he feels possible from perusal of journal pages. Scientists

need to congregate, he argues, to guard against becoming ingrown.

Almost all the above remarks stress researchers' concern about isolation from other research workers, from information relevant to their own research, or both. Clearly, one way in which a Ce/NCoReL could be a valuable tool for this community is to try to ameliorate these communication problems. Whether technology will obviate the need for many face-to-face meetings remains to be seen, but certainly the development of network technology would seem to indicate possibilities for communication which will help reduce the isolation in which many researchers or research groups currently operate. On occasion, DELPHI-like techniques which permit interested researchers to communicate with each other without knowing who is saying what may be preferable to conferences which physically bring people together. That is, a DELPHI-like approach may foster a certain frankness and openness which would not occur in a conventional kind of conference. One could imagine, for example, that a bright graduate student might have some reluctance to criticize a prospective 'employer's' ideas openly even though the criticisms were well-taken and valuable. For other purposes, however, both the intense and sustained interaction made possible only by a more traditional conference or seminar would be desirable.

In a working conference on February 13, 1972, a computational linguist mentioned another aspect of communication which is very real to many research scholars and scientists who either have moved from one institution to another or whose homesite computer configuration and/or operating system has been drastically changed. He pointed out that he wants to be able to get at his own work, which is tailor-made for his own needs and has entailed a lot of effort. This issue is discussed in greater detail in the sections in this

study concerned with software and hardware but it does represent an aspect of communication which should also be mentioned here. A Ce/NCoReL must provide for the user who, for one reason or another, cannot use the computer at his home institution. It is quite likely that such a prospective user would have no access through his home institution to a Ce/NCoReL, whatever its configurational realization might be. Some provision must clearly be made either for dial-up services and entry through a remote terminal to a dedicated node or given node within a Ce/NCoReL net, or for bringing that researcher to a dedicated node or node congenial to his programs.

One aspect of communication among research scientists and scholars is publishing, and at least two respondents have suggested that a Ce/NCoReL might function in this area. In a letter, one says, "I see the center also as a publishing device for programs and papers" and the other pointed out during a meeting on April 9th that "machine-aided memo interchange can replace publication in a professional journal and it is accomplished much faster."

An example of an information, communication facility for a network may be seen in some of the services provided by the Network Information Center (NIC) for the ARPA Network. At present a subset of documentation for use of the ARPA Net is maintained in hard copy and made available in this form to all nodes on the ARPA Net. Each node site has one individual who is responsible for maintaining available information concerning that site as well as information concerning other nodes, especially the identity of the information contact person at each of the other nodes. The computer system developed at the NIC keeps track of the dissemination of documentation

and maintains catalogues and directories for users of the ARPA Net. It also provides a journal, maintained in computer-accessible form, which contains a record of items submitted to it from users. Items may range from bright ideas that they want to file in this computer-based diary to excerpts from conversations held with other research scientists. NIC also has provision for the retrieval of articles and their display on CRTs with the article page at the top and the reference shown on a split screen at the bottom of the CRT. NIC leadership looks forward to the time when computer-based communication nets serve the public in much the same manner as the highway system. We are still a long way from that goal. But it is clear that even the relatively small subset of the public represented by prospective Ce/NCoReL users need much more facilitation of communication than they currently have in order to achieve the productivity which will enable them to help meet national and international needs in the areas of education, scientific cooperation, man-machine cooperation and others specified at the beginning of this chapter.

Basic Research

Much of the basic research to be facilitated and initiated by a Ce/NCoRel is implicit in the remarks cited above specifying the types of research tools desired by prospective Ce/NCoReL users. In general, basic research will be concerned with the structure of languages/symbol systems. Thus, it will be concerned with the location and specification of units within those languages and symbol systems as well as with the exploration of the ways such units combine. Another major area of research will be concerned with mappings between and among notational systems, and another

possible area would be concerned with the symbol processing capacities of the central nervous system, itself.

Traditionally, the study of structure in natural language has been concerned with the units of sound (phonology), the combination of these units into units which have meaningful content (morphology), and the combining of these units, in turn, into sentences (syntax). Until recently semantics was essentially omitted from theory concerning the structure of natural languages. In part the very recent emergence of semantics as an important aspect of natural language theory is due to efforts to use the computer to deal with natural languages; almost all such efforts have demonstrated the necessity for semantic processing--a necessity which has pushed for the development of theory in this area.

Clearly, not all the areas appropriate to natural languages are directly applicable to other symbol systems. Notable would be the apparent lack of utility for phonological or acoustic theory of symbol systems such as those used in graphic displays or in kinesic communication. On the other hand, the interrelationship between, for example, kinesics and phonetic data may be extremely important and very strong. In a given language community particular facial expressions may characteristically be accompanied by a specific range of sounds, or given hand gestures may very frequently imply certain vocal utterances. On a more detailed level, certain visible tensings of the jaw or neck muscles may occur only during enunciation of particular syllables, words, or phonemes.

Morphology, which is concerned with specifying the minimal units bearing meaning, as well as syntactics and semantics do tend to be useful

categories for a number of symbol systems, e.g., natural languages, programming languages, formal languages and probably for others such as art and music although, for the most part, they have not been explicitly used for those symbol systems. An important point here is that once methodologies such as the mathematics related to automata theory are developed for the study of, say, syntactics in natural languages, they also may be applied to other symbol systems for which the general categories such as syntax or semantics are applicable. A number of scientists interested in programming languages would like to see a strong research effort in the area of semantics for programming languages. This is an area which is relatively little developed but for which a category initially thought of as appropriate for natural languages is seen to be important. By bringing together research scientists and scholars interested in a range of languages and symbol systems, and making them aware of the range of theory and methodologies being used for the study of the gamut of such languages/symbol systems, a Ce/NCoReL should help provide a major thrust toward cross-fertilization and insights which will produce progress in the characterization of languages/symbol systems.

Among the comments either directly or implicitly related to basic research to be encouraged by a Ce/NCoReL,a number here follow. With reference to phonological and acoustical data, one scholar mentions the 2,000 hours of audio tape containing records of American dialects that he has and would like to have processed. Processing it without the aid of the computer seems the work of perhaps more than a lifetime and processing it with the computer means much basic research on computer-based analysis of such data as well as upon the mapping of the acoustic analytical categories used onto

categories meaningful for a description of dialectology. A research scientist implies many of the same research requirements when he speaks of moving in the reverse direction--that is from a printed page to audio output. Such a capability is requisite, for example, to the Reading for the Blind project underway at Haskins Laboratory. When a linguist speaks of the importance of the computer for language teaching, he, too, is expressing a long-term need for research on the phonological/acoustic elements of data. Among other natural language linguists, several have been interested in using the computer to aid the linguist in the field. Typically such field work entails both talking to informants and transcribing what they say phonetically, as well as taping such discourse for phonetic transcription. Transcriptions may then be typed or keypunched into a form which is accessible to the computer. Ideally, as was pointed out during a working conference on April 23rd, inputting the spoken word directly into the computer and having it perform the transcriptions would be the way to conduct such research. The hope was expressed that in ten to twenty years there may be a way to have such direct input handled by the computer so that a set of phonetic and phonemic descriptions could be produced automatically. Such capacity is, of course, important not only for linguistic field work but for any analysis involving auditory data. And much research remains to be done in this area; for example, although it is now possible to recognize syllables in such direct input about eighty percent of the time, the success rate for recognizing word boundaries is much lower. Clearly, these are problems which must be solved in order for man to be able, for example, to communicate with a computer by voice rather than through "written" instructions; the former is a major thrust of the ARPA-supported Speech Understanding Project.

Musicians are also interested in analyzing acoustic data using the computer; and although the sounds they analyze seem rather different from those of other kinds of languages, it may well be that the statistical and mathematical methodologies they employ will be helpful in the study of other types of acoustic data.

Although morphological analysis is implicit in expressed needs for research on syntactic analysis, several scholars expressed interest specifically in morphological analysis. One notes that

> within my Slavic field, I would of course like to see further support of morphological analysis; I think this may result in a new view of the nature of the morpheme itself. Further, a lot of preliminary work on syntax was done at Rand; I have the tapes (e.g., one million words of syntactically-annotated Russian text), and more should be done with this. (Letter)

And when another speaks of the need of linguists for programs to deal with "affix systems", he, too, is speaking to the question of morphological analysis.

Many prospective Ce/NCoReL users spoke of the need for parsers, grammars, grammar testers. All such efforts imply the need for work on syntax, either in isolation, or as part of a grammar including other components such as semantics. Many such references have already been cited in comments directed toward the types of programs a Ce/NCoReL might provide. Thus, when a communications scientist refers to the need for adequate parsing of sentences and a linguist talks about grammar testers they are speaking about work in syntactics. It should be noted that although a number of parsers have been implemented on the computer there are still no such parsers which can be used efficiently for many information retrieval tasks, for computer-assisted instruction, for stylistic analysis (all for natural languages)--

not to mention the paucity of work on syntactics in visual data such as graphic languages, kinesics, and so on. The successful use of syntactics for some types of picture processing indicates rich possibilities which have been relatively little exploited.

In his comments on a possible area of research concentration for a Ce/NCoReL, a linguist suggests an effort which would imply research using all the categories mentioned thus far as well as semantics, the category of primary interest to a number of respondents to the question concerning possible research emphases of a Ce/NCoReL. He says:

> It seems to me that one increasingly challenging possibility is that of evolving a universal taxonomy for the natural apparatus of human thought. As this universal taxonomy is evolved, it will be possible to confront this universal apparatus of human thought with the surface structures of a given language in massive mapping operations. . .To keep track, however, of the particular universal deep structures which are encoded in the surface structures of given language on a worldwide basis, undoubtedly will require computer facilities. I tried something of this scale in eight languages by hand filing and found it most frustrating and maddening. In my recently completed New Guinea report, I, in fact, include data from only three languages. It is evident that any very massive attempt to keep track of deep discourse levels in hundreds of languages throughout the world is going to need computer assistance. I would envision storing of this data in massive computer storage, then being able to ask the computer program specific questions such as "How is contrast encoded in the following 100 languages?" or "How is alternation with excluded middle or exclusive disjunction encoded in these languages?" "How is coupling (non-chronological) with the same actor encoded in these languages?" or "How is instrumentality encoded on the clause level?" It may be a bit harder to keep track in some taxonomic way of the surface structures of given languages since they vary so greatly. Nevertheless, by classifying surface structures hierarchically according to the hierarchial levels mentioned (stem, word, phrase, clause, sentence, paragraph, and discourse) it should be possible to cut down some of the confusion and classify the data in some accessible form. (Letter)

When this scholar speaks of deep structure he is referring to aspects of semantics and when he speaks of word, phrase, clause, and sentence he is

referring to aspects of morphology and syntactics. His reference to the paragraph and discourse levels shows another emerging trend in linguistics and that is to examine units longer than the sentence. As linguistics begins to interest itself in semantics, it discovers that the sentence is no longer as satisfactory a unit as it was for syntactics. Scholars interested in literature obviously have been interested in longer units. Linguists are now beginning to profit from some of the categories used for literary analysis (e.g., "point of view") and are at the same time moving toward more rigorous definitions of some of those categories which, in turn, will be helpful for the study of literature. Obviously such work is important not only to linguistics and the analysis and teaching of literature, but to teaching composition, to analyzing dialogue among scientists working on a project, to analyzing and structuring diplomatic treatises, and in many other ways as well.

Although semantics has been alluded to in comments cited earlier in this chapter, its centrality to the thinking of many prospective users should be stressed, and to do so the following comments are provided:

> . . .despite the many questions which still remain open about how to get syntactic information about a sentence I think it [Courant Symposium on Semantics in Natural Language] also showed that to get more information about the semantics and for 'understanding' what is really said in language use, we have to look more closely at how people manage to do the incredibly complex things they do. Many basic linguistic tools are available in a sufficiently powerful form, I think, to begin detailed studies of the performative aspects of meaning. There was a general concern over providing some foundation for this type of analysis.
>
> . . .The thing that is most lacking. . .is a rigorous definition of a formal theory of semantics that can really account for the answers to the problems. . .I have done some work on this, which I haven't written up yet. The conference showed a major division in thinking on this subject, between those who think syntax has

> nothing, fundamentally to do with conceptual meaning of discourse . . .and those who think it does. . .and those who don't think the distinction is totally relevant but agree that no existing procedures are sufficient. . . (Letter)

> Given the bias I have acquired in some twenty years of work in language analysis and computational linguistics, I would not hesitate to state that the subarea most urgently in need of concerted research is that of semantics and especially the investigation of the relational concepts underlying the various forms of concatenation manifested in natural languages (i.e., syntax, discourse connectivity, anaphoric reference, etc.). . .Basic research in both m.t. [machine translation] and information retrieval was quite lavishly sponsored by several agencies for the better part of ten years. . .there must have been the general feeling that both these problems need to be solved. Since no viable solution was produced, the need must still be there. I think most people who are in one way or another involved in the efforts of that fascinating decade would by now agree that the failure was due almost exclusively to our ignorance in the field of semantics. Hence, I should say that there is a very definite need for protracted basic research in that area and that an organization such as Ce/NCoReL would have a good chance of achieving the 'breakthrough' everybody has been waiting for--provided the researchers involved. . .are not put under constant pressure to work for makeshifts rather than for a break-through." (Letter)

> Priorities for areas of research might include speech understanding, complex grammars, errorful grammars (performance grammars), semantics. . . (Letter)

> The conceptual structure underlying language, thus semantics and logic, interest me more than language per se. (Letter)

In this same vein, when a psycholinguist speaks of "conceptual parsing of natural language," he is expressing a need for dealing with semantics.

Another linguist expresses an interest in

> new areas which seem promising such as automatic semantic analysis and synthesis. . .We could improve the quality of translation. . .by introducing semantic codes. However, the latter could be introduced only after serious semantic theoretical research had been carried out successfully. It is our opinion that semantic processing as carried out in various places is on the molecular level. In order to be economic and useful, the semantic structures should be represented on the atomic level, and possibly reaching the semantic plasma (de Saussure's pre-

> thought chaos). It is our feeling that the additive aspects should be included within the bundles of distinctive semantic features. The improved m.t. [machine translation] quality might be used as an additional aspect of studying the automatic oral translation. We would like to develop and test such semantic theories or systems that might be used in further improvements of m.t. and in related subfields. (Letter)
>
> Work on the formalization of semantic structure would have immediate applications for all natural-language work. (Letter)

And, as stated above, the importance of semantics is not restricted to natural languages. Meaning is presumably the salient feature of all languages/symbol systems and it is to be hoped that, as has been the case with syntax, research methodologies helpful for the study of one kind of symbol system can be successfully applied to others.

Another basic area of research has been alluded to a number of times, and that is the characterization of mappings between and among notational systems. One scholar touched on this area in his list of priorities for areas of research when he referred to "coding and notational communalities." Another scholar seemed to be addressing himself to this problem when he stated that

> one of the important areas of research should be to find homomorphisms of available formal languages for storing linguistic information. I see this as a key (a) for making linguistic data available to large numbers of users and (b) for developing suitable programs for analysis of such data.

The initial proposal outlining the need for a Ce/NCoReL noted that

> Many different languages or notational systems are in current use. These include the so-called 'natural' languages, programming languages, mathematical languages, kinesics (nonverbal human expression), two-dimensional languages used in computer graphics, languages for machine-to-machine communication, languages (as yet only sketchily formulated) used in photographic representation. Currently, it is not known sufficiently how to gain a sense of the systemic properties of languages so that models of the languages

> can be built, tested, and redefined, because we do not know what the parameters or variables of the languages are and we do not understand their interrelationships. We do not know how to relate various types of languages to each other in any coherent, systematic way; we don't know what the trade-offs are, what the intermappings are. We do not understand clearly what one language supplies and another lacks; we don't have an understanding of the interfaces between and among types of languages. For example, are certain programming languages more easily learned by speakers of a given "natural" language than others? Lastly, we do not know how to relate these "input-output" languages to the language or languages of the central nervous system.

Another possible area of research for a Ce/NCoReL is the symbolic processing which takes place in the central nervous system, itself. This area is listed as possible, not because it lacks centrality, but because, speaking comparatively, it is not clear how much a Ce/NCoReL could do at this point to further such research. At the very least, a Ce/NCoReL should keep apprised of research in the area and at most it should foster research in it. The desirability of such research was again noted in the proposal concerning a Ce/NCoReL concept study:

> With the human central nervous system regarded as a given, systemic improvements in symbol processing must flow from improvements in fit of languages to central nervous system properties and, in turn, the better designing of computers, etc., relative to the characteristics of languages well-suited for human use . . .At present, there is much too great a sense, for the human, of adapting his needs and modes of symbol manipulation to those of the computer. It may well be that hardware and software manuals seem uncongenial to many people not simply because they are badly written but because the structures described do not mesh well with those employed by the human central nervous system.

At a conference on April 9th, a conferee noted that one desirable aspect of such research is that the consideration of the central nervous system as an "information processing device" is demandingly interdisciplinary and thus would force a Ce/NCoReL to explore the full possibilities of cooperation and interaction.

Intermediate Application Areas

At the beginning of this chapter, we listed some major problems for which the research performed in connection with a Ce/NCoReL would be highly relevant. During the course of the discussion of the basic research tools and research areas appropriate to a Ce/NCoReL, a number of applications intermediate between that research and development and the major areas cited at the beginning of the chapter were mentioned. It seems appropriate at this point to list some of these intermediate applications as designated by prospective Ce/NCoReL users; in some cases the designation is according to a traditional discipline and in others according to a particular application.

A number of prospective users are interested in research whose application might be classified under psychology. Among those references which might be described as psycholinguistic are the following:

During the working conference on April 23, 1972, there was a suggestion that research on communication disorders might be a desirable research thrust for a Ce/NCoReL. In somewhat the same vein was a suggestion that a Ce/NCoReL application might be to language pathology, e.g., aphasia and schizophrenia. Also at the meeting on April 23rd, there was an expression of interest in research on emotional state and speech parameters in discourse. Psychiatric interviewing was also suggested as a likely application area for a Ce/NCoReL.

Several people expressed interest in modelling or characterizing cognitive processes. An interest in a conceptual parser was cited earlier in this chapter. Also cited earlier were research interests in "memory and semantic models" for non-human organisms, e.g., chimpanzees. Another scholar concerned with this area has stated that

I anticipate that in the future alternative algebraic models of cognitive process systems will be formulated with some statistical components; it will be helpful if assistance could be provided in the simulation of those models so as to determine which one for each class may have the best-fitting set of human information-processing characteristics." (Letter)

Yet another scholar states that

As a researcher in the field of cognitive processes, my interest is in the development of what Neisser (1967) calls "executive routines." These I interpret to mean problem solving procedures involving simultaneous comparison, recombination, and organization of sources of information. Piaget has provided a starting for research on these procedures in his investigations of classificatory, spatial, and numerical thinking. If we follow Piaget's lead we may direct our efforts to describing the initiation and course of maturation of operational sequences by which children categorize and understand events in the world around them. We may also be interested in the modification of these sequences through specific experience.

My own research interest is the assessment of problem solving strategies over types of tasks (contents) and the modification of approach (translation) required of the child when going from one content area to another. Such a computer-based language research center could be invaluable for data which would identify operations and estimate the parameters of variability of cognitive processes within domains of specific content. Plotting individual idiosyncracies in mastering items might be analogous to comparison of that particular version of a language which an individual speaks with the consensually validated version of it. Contrast of these organized procedures with the concurrent construction of matrices of semantic features could be made. Di Pietro (1971) suggests, for example, that there may be a universal matrix of semantic features and a set of universal selection rules which establish the basic patterns of human cognition. We have hardly begun systematic study of these.

The study of the interrelationships in development of the higher processes, some of which have been briefly described, and the empirical context within which behavior takes place would be worthy objectives of such a computer-based language center. I might even suggest that such a center provide the sets of theoretical problems to be tested in empirical research at the masters and doctoral level at universities remote from centers which unite symbolic and behavioral analysis. Perhaps this might reduce trivial research and provide a data base from which to realign theory with facts gathered from independent observation. (Letter)

A linguist's interest in a "universal taxonomy for the natural apparatus of human thought," described at length in a citation earlier in this chapter also might be classified as modelling cognitive process. There are a number of other research scientists and scholars who have an interest in this area and who have expressed the hope that a Ce/NCoReL could prove catalytic for such research.

One other suggested application which is partly within psychology and psycholinguistics is the study of language acquisition. Another application, clearly related to psychology and psycholinguistics but also to speech and physiology, is speech understanding--an area suggested by a number of scholars.

In addition to a letter cited earlier in this chapter, there were other expressions of interest in the sociolinguistic aspects of Ce/NCoReL research: one scholar listed among possible applications "social interaction--husband-wife, mother-son, black-white, 'rich'-poor, cop-ghetto resident." A linguist listed as a possible application the problem of social interaction where many dialects prevail, and the political implications of languages, as in India. A sociolinguist wrote:

> I propose a computer simulation of the network of language communities in the United States. This would include specification of (1) all identifiable language communities, (2) the degree of linguistic interchange between all pairs of these communities, and (3) the degree of linguistic influence from mass media on each community. The model would simulate the diffusion of linguistic innovations from the mass media to each community and from one community to another. Once such a model is achieved, it should be useful for a new task: simulating the diffusion of attitudinal and ideological innovations from one language community to another, and from the mass media. I assume here that new attitudes and ideologies flow along the same pathways followed by linguistic innovations.
>
> As I write this, I think of insidious uses of the model--perhaps the manipulation of public opinion. Something in the nature of

> the proposed center would have to guard against this sort of exploitation by government, or by a private elite. On the positive side, such a model should enormously aid our understanding of public opinion, mass movements, and shifting values and demands of the society. (Letter)

During the working conference on April 23, 1972, a conferee suggested that sensory supplementation and sensory aids were important application aspects of the more general area of man-machine cooperation. Sensory supplementation and sensory aids may be interpreted in many different ways. But, in general, if one thinks of research tasks for which the computer and its related technology can serve as a complement to those tasks which man does well, one will hit upon applications which fall into this category. Indeed, in a sense, almost all, if not all, the research suggested for a Ce/NCoReL would use the computer for this kind of assistance and supplementation. However, certain applications have been traditionally thought of in this respect and they will be listed here. They include machine translation, information retrieval, question-answering, automatic abstracting, and other related tasks.

In a comment already cited, a computational linguist refers to both machine translation and information retrieval as problems needing to be solved.

An information specialist says "from my own point of view I am eager to see progress in the applied fields which interest me particularly--machine translation, information retrieval, question-answering, and the like." (Letter)

When referring to desirable programming packages, a psychologist also suggests application areas:

> Language processing systems such as those of Wood, Winograd, Sager, Kay that actually exist and can serve as a basis for

> experimental grammars, Q/A [question-answering], conversation, and application systems. (Letter)

Later, when he discusses desirable applications he notes:

> Applications to information retrieval, CAI, publishing technology, intelligence data processing all come instantly to mind. In every case there even now exists at least rudimentary technology for each of these applications and one can expect continued rapid development. Priorities again are a social question that might well be settled on a case-by-case analysis by an executive or advisory board with referring. . .I think the main thrust of the center might well be towards the development of language processing systems that are largely programmable in natural language. Such systems should aim generally at capabilities for question-answering, paraphrase, conversations of various types, tutorial dialogue, and translation. A secondary thrust towards systems for linguistic, stylistic and content analysis will also prove valuable. Such a program would provide a balance wheel of practical problems to orient the more theoretical research. Priorities might be decided with relevance to the overall goal of socially useful language processing technology. (Letter)

A linguist also refers to the desirability of research on machine translation, automatic abstracting, and automatic indexing.

Indexing and concordancing programs are often part of information retrieval systems. They are mentioned separately here simply because they received specific attention from a number of scholars. One notes that

> as need for programs which might be generally applicable arises, they could be developed gradually; some such programs, now commonplace except for some housekeeping details, might be indexing and concordancing routines. (Letter)

Linguistic field work, an applications area which would depend upon much the same basic research as machine translation and information retrieval efforts, is given extended attention by a linguist:

> My own interests, as you know, center more in the area of getting as full information as we can on the little known vernaculars spoken around the world. Field work in this is usually thought of as collecting texts, compiling a dictionary, and writing a

grammar. Recently our notions of what a grammar is have expanded considerably, though my guess is that our new discourse grammars are not going to be necessarily more complex than the old sentence grammars were.

As far as texts are concerned, we have been processing text collections into concordances for some time. . .with considerable payoff for people who are writing grammars. I suspect that we will continue that, but for people who use the rest of the system we will also want to make their text collection available on line so that they can apply parsing routines to it. (People constructing teaching programs will also want considerable text available.)

The dictionary I am thinking of would be an outgrowth of the one I am building. . .now. . .

I tend to think of the grammar in two parts: a prose part, and a set of rules that the parser can get at sprinkled through the prose. I would think of a phonology as a special kind of limited grammar. We would want to drive a simulator from underlying expressions that we run through the grammar to test it (with the possibility of specifying part of them randomly). We would also want the grammar to control a parsing program. There are quite a few parsing models around, so that I would hope to offer alternate strategies in order to arrive at the best possible grammar.

In addition there are a number of useful but not terribly sophisticated routines that I think most linguists would like to have access to. One looks for empty spots in paradigms and asks how to fill them. Another probes for analogies in semantic role sets, using Fillmore's approach to grammar. Another works on sequencing: affix systems, rule systems, or teaching sequences.

I think a package like this would speed up work on the field considerably, not to speak of its effect on keeping the results internally consistent. Using it could also give students a real insight into the way language works, especially if we could have them look at it through models as diverse as those of Friedman, Kay, and Quillian. (Letter)

When asked to indicate which natural language should receive first research priority in a Ce/NCoReL, a number of researchers opted for English. In a statement cited earlier, a psychologist says that "one of the main facilities of such a center is to make cumulative progress on English analysis." Another scholar responds: "Oral English. We know more about English than any other natural language. Data is readily available." A linguist

says "certainly the focus should be on English, though we need to concentrate on other languages as well, say German, Russian, French, Chinese, Japanese." Others also specify, explicitly or implicitly, English as having first priority.

A number of people refer to the desirability of work on pattern recognition and, what might be considered a synonym for pattern recognition and generation taken together, stylistics. Pattern recognition could be said, in fact, to include all efforts to locate and define structure in languages and symbol systems. So that in this sense, pattern recognition and its obverse, pattern generation, could really be specified as basic research areas for a Ce/NCoReL. They are listed here rather than under basic research simply because pattern recognition and generation are terms which have been applied to a range of intermediate applications, including character recognition, analysis of pictorial data, and so on. For a rather extended discussion of the use of these terms in the humanities and fine arts, the reader is referred to Appendix I in this study.

An area rather like pattern recognition and generation because of its confusingly wide reference and application is artificial intelligence. Much work in artificial intelligence is in fact focused upon the recognition of characters, or on the configuration of blocks on a table, or on efforts to simulate conceptual processes. In general, artificial intelligence tends to imply efforts to build insights into computer programs which will enable the computer to solve problems in ways which are either analogous to some aspects of human problem solving capabilities or which enable the computer to behave in such fashion that, if a human being were to behave that way, the behavior would be termed intelligent.

Another applications area specifically mentioned by several research scientists and scholars is computer-assisted instruction. A Romance language professor listed "teaching strategies (CAI)" first among desirable Ce/NCoReL applications. And elsewhere in his letter, he says "I reiterate the need for massive development of CAI programs."

During a working conference on April 9, 1972, a conferee spoke of the importance of CAI and of his effort to use a network to facilitate making CAI widely available.

When speaking about the use of a major set of data analysis routines for students and their teachers in the social sciences, one conferee noted that although the teachers early criticized such efforts, thinking that the programming package would be a toy, faculty are now using the computer more as a result of their experiences with the package.

Several linguists have spoken of the value of the potential research at a Ce/NCoReL for teaching foreign languages. One says that "another possible aspect is the <u>teaching of foreign languages</u> via certain self-teaching automated systems."

Another, in the course of a discussion of desirable language aids which might be provided by a Ce/NCoReL, says:

> As I mentioned, the package I have in mind involves two main phases: the preparation of language teaching materials and the analysis of languages in the field. The total system would include modules that would be used in both areas together with modules specialized for one area. I suspect that many of them are things you are going to need to have written anyway for other parts of your network plan.
>
> Randall Jones. . .has put. . .thought into computational aids for preparation of language teaching materials. In his estimation the obvious place to start is in keeping track of where and how vocabulary items and grammatical structures are used in a teaching sequence. This implies being able to parse exercises and potential

> readings so as to establish their level of difficulty and to flag things in them which, if they were explained in footnotes, would allow them to be used at a more elementary teaching level. We should also be able to exploit the inherent connectivity of a language teaching package to help us put its elements into sequence and group them into blocks.
>
> Every teaching effort depends on a good reference grammar. Constructing a reference grammar for teaching is just like writing a grammar in the field as far as the computational side is concerned. Several of the languages for which we are writing teaching systems . . .right now could undoubtedly profit from more detailed reference grammars: Burmese, several dialects of Chinese, Japanese, Thai, Sinhalese, Javanese, Indonesian, and Romanian. The accompanying reference dictionaries and the glossaries that are extracted from them are also the kind of thing for which computational aids ought to be exploited. Eventually we might even plug into the connectivity structure of the grammar and the dictionary in order to form individualized review sequences for computer assisted instruction, but we are not concerned with that yet.

For an extended discussion of the implications of a Ce/NCoReL for a new, socially-significant higher education option, the reader is referred to Appendix I.A., "Knowledge Systemics."

Research on readability is also closely related to computer-assisted instruction applications. The bibliography included in this study in Appendix II provides a number of references to research in readability for which a Ce/NCoReL could have major implications.

At the meeting of April 23, 1972, one conferee suggested that lexicography might in itself constitute an important research area for a Ce/NCoReL, and that emphasis was vigorously spoken for again at a later meeting.

Another application of Ce/NCoReL research is suggested by a surgeon:

> In the area of medicine, it appears to me that language presents a number of serious problems. We now are looking for ways of using automation to gather a good deal of the information base in history taking. This is somewhat feasible in a homogeneous, upper-middle class group of people. However, if we try to apply these techniques broadly we run into great language difficulties and one wonders what the nuance or difference of meanings would be if information was collected in and a system worked out in southern California American if it were transferred to Danish or even to Northeastern American.

> Thus, it seems that if this isn't impossible that there needs to be some way of being sure that the same questions and nuances are asked in one dialect or language as in another. In addition, it seems to me that it might be a very interesting area in which one could have an objective measure as to whether this is achieved because one could cross correlate the accuracy of the method in various languages and therefore determine whether there was a common base for these questions. (Letter)

Implications for research in natural language at a Ce/NCoReL are contained in comments by two computational linguists as they identify potential users for this research area. The first says:

> I divide computational language users (potential and otherwise) into three groups
>
> I (roughly 5000 people & up)
>
> Scholars in literature, languages & linguistics who have a need for low level data processing involving, for the most part, prepackaged programs such as concordances, parsers, grammar rule testers, statistical packages, etc. They need little training in computing other than in the I/O conventions of the prepackaged programs. Many of the packages they need are currently available at their home computing centers, but these users lack simple awareness, elementary training, and/or funding.
>
> II (roughly 20 to 100 people)
>
> Computational linguists who build programs that aid linguists and other language researchers in their normal occupations; e.g., transformational rule testers, linguistic analysis field aids, historical comparative routines, etc. At the present time, most researchers in this area are either deficient in programming background or in linguistics. Usually they must rely on grossly inefficient programming languages such as SNOBOL because of lack of systems programming ability to make efficient use of superior programming techniques.
>
> III (perhaps 5 to 20 people)
>
> Those who would use the computer as a basic tool for theoretical linguistic research, making it serve as a vehicle for testing models and hypotheses about language. Training demands strong linguistics background with at least M.S. level in computer science.
>
> In support of my classification I offer the following quote from D. G. Hays on degrees of computer participation in linguistic research:

> "The lowest level uses the computer merely as a compiler of data; programs to make concordances or maintain dictionaries are effective, but merely clerical aids. The middle degree is computer testing of information gained in other ways, as when a machine-translation program and table of translation equivalences is tried out on new text. The highest degree is reached when the computer program actually embodies the linguist's analytical ideas; a device that could be parachuted into a jungle to learn an unknown language without supervision would be participating in linguistic research to the highest degree."
>
> ...Hays, Introduction to Computational Linguistics, American Elsevier, New York, 1967, p. 180. The statement is made in elaboration of ideas expressed in Garvin, "Computer Participation in Linguistic Research." Language, Vol. 38, No. 4, Oct.-Dec. 1962.

Effects of Time on Groups I, II, III

> Given the proper training and a Ce/NCoReL, the size of Group I could be expected to grow until it encompasses nearly the entire membership of the pertinent fields (as the computer becomes a basic tool in language research education). Estimated time: 10 years for attainment of 50% level of potential growth.
>
> Eventually, the membership of Group II should drift either into I or III.
>
> The future of linguistics as a science hangs on the encouragement and growth of Group III. The nature of its potential growth is too hothouse to make predictions about. Any center should be prepared to devote a disproportionate amount of its resources to III on the basis of its significance for the future of linguistics. (Letter)

The second says:

> There exist four or five major centers for language processing research, now (with 10+ researchers and students) and many isolated small groups as well as isolated investigators. These are the immediate clientele numbering, I suppose, about 500 scientists and students." (Letter)

Although the second comment says nothing about explicit types of research, we cite it because it suggests yet another estimate of the number of scientists and students involved in language research. As nearly as we can infer, the above estimates refer to research on natural language only, very likely excluding speech; and the second estimate of 500 probably refers to the types of researchers comprehended under Groups II and III in the first com-

ment. If, as we and many respondents to a prospective Ce/NCoReL believe should be the case, estimates of potential Ce/NCoReL users were to include scholars working on speech, as well as other languages/symbol systems, the estimates would be very considerably increased.

Whatever the initial user estimates, it is clearly the belief of many potential users that a Ce/NCoReL would help provide the resources needed in order to provide more rapid progress in our understanding and use of languages/symbol systems. And the national and international need for such progress has been stated in this chapter, as well as elsewhere in this study, notably in "The Ce/NCoReL Concept" chapter.

Important aspects of critical social events and processes are language/symbol system 'sub-events.' It is dangerous to so ill understand them as we do at present.

SOFTWARE

The software support for a national center/network for computer-based language study can be roughly divided into the system support software and the software with which a person using the center/network interfaces.

If Ce/NCoReL takes the form of a network or a component within a major network (i.e., a virtual network within an actual network), those aspects of the system which are peculiar to networking can utilize and build upon work which has already gone into such nets as the ARPA Net. Should, as seems unlikely, Ce/NCoReL take the form of regional centers, then the software support systems utilized by such regional centers as Dartmouth and the University of Iowa might provide helpful guides. It seems quite possible that function-oriented networks could become a combination of an ARPA Net-like structure and regional networks. That is, a number of large computers would be connected as they are now in the ARPA Net and for a given type of computing a number of users would be tied into a given host computer, as they are now in the Dartmouth net, the Iowa net, and other regional nets.

A major goal of the ARPA Net has been reliable transmission of information among computers of varying design and manufacture. Insofar as the physical transmission of data is concerned, that goal seems to have been met. Many problems remain to be solved, however, before a network of this sort can be counted upon to serve the user easily and swiftly. For example, thus far the ARPA Net has not been subjected to a high rate of usage. Thus the need for dynamic allocation on the basis of load level at prospective hosts, or for allocation on the basis of the available host best suited to a particular processing job, has not arisen in a pressing way. These two types of allocation pose similar problems because dynamic allocation on the basis of load

would mean that if a given host were too busy to process a job quickly another potential co-host would need a copy of the program desired by the user; dynamic allocation on the basis of type of processing requested would probably also imply the desirability of redundant programming packages and system support for them at several sites. At present, the user of the ARPA Net specifies the host computer he means to utilize and he must understand how to use the system of that particular host computer as well as the specific program or programs he is requesting. If the host computer is busy, the user must wait in the queue until his job can get on to the pre-designated host. The desirability of making a net more easily accessible to the user would indicate a need for research into the feasibility of such system development as would provide at least some types of dynamic allocation, i.e., alternatives to host pre-designation.

Whether a network or a single central computer is involved, the supporting system must be designed so that a user need not, unless he so opts, become involved in choosing among a great many options in a highly intricate system. Either the system must be so sophisticated as to make such detailed user involvement unnecessary, or it must be so simple that the necessary details are minimal. Whichever option is taken, an effort should be made to give the sophisticated user great flexibility to move around within the variables of the system as completely as he wants to, so long as system and file integrity are fully, fail-safe protected.

Two major criteria affecting software systems at the human interface level are availability and reliability. Availability would seem to comprise, first, the actual design and coding of programs (which in turn is dependent

upon available programming languages and programming packages), but also documentation, and provision for the distribution, portability, and accessibility of the programs. Topics related to reliability would include validation, standardization, and maintenance.

It is doubtless significant that a majority of the potential users of a Ce/NCoReL who commented on software were concerned with topics related to availability. They gave the distinct impression that researchers in this field are, unfortunately, still obliged to struggle to get onto the computer in a useful, efficient way. Although reliability is clearly important, the visibility of this importance becomes more prominent when availability is good. For example, the concern of numerical analysts with topics related to reliability indicates the accessibility of the computer for their needs. The burgeoning of packages applying numerical and statistical methods has resulted in an awareness of the unevenness in results produced by routines which have been presumed to perform the same operation.

With the exception of research on programming languages, researchers concerned with language have often found that the available software is uncongenial and that a system is so set up that in effect it militates against fast response for programs directed to various aspects of language research. For example, natural language research tasks often utilize large data banks (e.g., thesauri or dictionaries) too large for either the computer store or the partition of store available for a given job. Such programs entail a great many I/O operations between disk and central storage, and certainly some multi-programming systems handle wait states so that the user with a good deal of I/O within his program is disadvantaged as to both

time and money. As a result, programs often run much longer than they should (often effectively wiping out the greater speed gained through technological advances) and the researcher finds himself not only paying more than he should but also having to wait longer in the queue for a run. Again one sees the advantages in configurations dedicated to the needs of a particular single class of computer users, in this case the language researchers.

Most of the comments on software from prospective Ce/NCoReL users concentrated on programming languages or types of programs to which they would like access. Programming languages specifically mentioned include LISP, COMIT, SNOBOL, PL/I, APL, IPL-V, and FORTRAN. At least one user would like access to interactive and batch FORTRAN which has list and string extensions. On the other hand, another user who feels that the researcher should be able to get into interesting aspects of programming quickly, would rule out all languages which require attention to trivial detail--hence "FORTRAN with its formats and mixed mode problems, PL/I with its declarations and conversions, LISP with its parenthetical functional notation" would go. Some prospective users have stated that they have difficulty with LISP (even while admiring some of its features) and others wish to use nothing but LISP. Many prospective users express an interest in SNOBOL, but one researcher refuses to use it because in a given implementation it has no access to auxiliary storage. PL/I is described as having many attractive features but being too much of a conglomerate. In short, arguments for and against almost every known programming language have been encountered during the course of this study. In addition, new languages have been proposed. Several respondents to the question as to what languages should be available for a

Ce/NCoReL have responded either by saying "all" or by naming several languages and then adding "etc., etc."

In general, researchers comprehended by a Ce/NCoReL need good string handling facilities, good numerical facilities, and good structure-handling facilities. Because much language data is linear, string handling facilities are desirable. Because much language research entails pattern recognition, which is then described statistically or mathematically, good numerical facilities are desirable. And because much language research entails the generation and/or analysis of data structured in such varied forms as trees, nets, clusters, rings, etc., languages which deal easily with structures are desirable; it is in this area that either extensions of present languages or entirely new languages are badly needed. In general, and again with the exception of programming language research, a researcher tends to become addicted to a particular language--often because he learned it first and often because it met his needs at a given moment--and sticks with that until his needs force him either to use another language or tinker with the one he is using until it satisfies his requirements. The former is often a nuisance for the research scholar and the latter is the bête noire of the personnel responsible for systems. It may well be that Rapidly Extensible Languages will solve some of these problems both for the researcher and the systems programmer, although there is some sentiment that the expected promise of REL's five years ago has not been realized.

As is the case with all other aspects of this proposed center/network, a major concern as to programming languages is to permit and foster diversity where desirable and, at the same time, to foster collaboration and

cooperation where that is desirable. Diversity is desirable because new ways of manipulating and structuring data lead to insights; and indeed, as indicated above, languages do not exist which permit easy manipulation of some kinds of structures. Further, as should be evident from the summary above of languages desired by prospective users, a language which is easy for one researcher to conceptualize and use may be extremely uncongenial to another. For all these reasons, a diversity of available programming languages is not only desirable but necessary. On the other hand, some research scholars have been involved with an unwanted diversity of programming languages simply because the language which they first used became unavailable through either system changes or hardware changes, or both. For example, two research scholars speak of the difficulty of "keeping IPL-V available to us through. . .changes of computer. . .Because of the difficulties in maintaining IPL-V and because it is not so common as FORTRAN-based languages, most of our present work is being run in FORTRAN and LISP." Such unwanted, forced diversity has often delayed individual research projects as much as two, three, or more years. As is the case with continuity within a given research project, it is also the case that collaboration among a number of research scholars ordinarily implies their having access to a common programming language.

For researchers moving from one location to another or where hardware and systems are shifted, programming packages have often contributed to sustaining continuity in a given research project. The implementation, and then the maintenance, of such packages on a system for which they were not initially designed often requires a considerable investment in terms of man hours

and computer time. Thus, at many computer installations, there are lively discussions as to whether it is more economical to implement someone else's package or to use procedures which have been "home-grown." As a result, it is often difficult for a researcher to continue to use a package to which he has become accustomed even though ostensibly it is available to him. The packages most used for language processing which are available at present are statistical packages. A number of prospective users of a Ce/NCoReL have expressed interest in packages for text-editing, for parsers, for concordance programs, and for other programs which are analogous in that they represent processing needs common to many research projects. For the most part (see discussion below of distribution and portability) these programs are not easily available to users at sites other than those for which they were designed.

In addition to the programming languages and packages available, the third major element to consider in program design and coding is who will do it. Many prospective Ce/NCoReL users have urged that the programmers be well-versed in the applications for which they are designing programs and systems. As researchers in this area have discovered, the educational background and training of many programmers is not geared to the types of applications falling within the scope of a Ce/NCoReL; mathematical symbol systems represent a possible exception, but they are often not thought of, and studied, as languages, themselves.

Another important aspect of software availability is good documentation. The desirability of good documentation seems almost universally recognized, but agreement as to what constitutes good documentation is much more diffi-

cult to achieve. LISP enthusiasts point out that the structure of the language ensures that the coding of the program will itself provide excellent documentation. This point is very probably correct for the researcher who uses and therefore reads LISP. On the other hand, for the nonreader of LISP the program itself will clearly not be very useful documentation.

An increasing emphasis in recent years has been given to the provision of comments within the body of a program which describe the actions designated by a given set of instructions. It is probably safe to say that there is general agreement that this form of documentation is absolutely necessary. Flow charts are often used but the detail provided in flow charts varies considerably. It might be best, if flow charts are used, to provide a number of flow charts for the same program. One type of flow chart would be general so as to provide the researcher with a casual interest in the program an overall indication as to what the program is doing. A more detailed flow chart would indicate the kinds of decisions and branchings involved in the program's operation, and an even more detailed flow chart might prove desirable for the actual implementation of the program or package on a system for which it was not initially designed.

Since for very complicated programs flow charts become so extended and involved that they themselves almost require guides, it has been suggested that decision tables be used to provide a compact guide to program structure. For those scholars who are verbally oriented (and there are many such in the areas for which a Ce/NCoReL is needed) extended verbal descriptions which are separated out from the coded program itself often also seem desirable.

Given the diversity of responses to questions as to needed types of programming languages, it is probably also the case that there is a diversity

of response to various forms of documentation. It seems likely, therefore, that several forms of documentation for any given program or package of programs would be necessary. Operationally it would seem that a minimum standard or specification of documentation should be established for all programs or packages made available to other users through a Ce/NCoReL. Documentation beyond this minimum standard would depend upon the frequency of use and the specific difficulties encountered by users. Specification of even a minimum standard would require guidelines concerning program structure, the components of that structure, and thus the elements which must be described. Help in this area may be expected to come from the NSF-funded project concerned with software validation and distribution currently in progress. (The Principal Investigators for this project are Lloyd Fosdick, Department of Computer Science, University of Colorado, and Wayne Cowell, Argonne National Laboratory.)

A third major aspect of availability is that comprising the distribution, portability, and accessibility of programs which have been produced. Prior to the advent of ARPA-type networks, distribution of software was very closely tied to portability. Manufacturers and researchers interested in making programs available to users having varying systems and even varying hardware have used higher-order, procedure-oriented languages in an effort to facilitate portability of programs. Although this effort has been helpful, it has by no means ensured program portability. Even users having access to a hardware configuration and programming language almost identical, or actually identical, to that for which the program was originally designed, often find that the programs will not run at their home site because of a difference in the operating system; or, if the system is the same, a configura-

tion is slightly different; or a local dialect of the language won't run; or the program as it was originally coded used a local dialect of a procedure-oriented language. As a result, even for sites which look very similar, exchange of programs often has not been successful. And for sites which are dissimilar, exchange of programs can be counted upon to imply rewriting of some parts or all parts of the programs. As a result, programs of interest to researchers in the fields comprehended by this Ce/NCoReL effort have not been widely available. Many of the programs, such as parsers or semantic analyzers, imply extensive code as well as data banks of rules, lexicons, etc. The writing, or even adapting of such programs, implies considerable effort and most sites cannot muster the critical mass of economic and human resources for either paying to have the programs implemented at the site or pressuring the computer center into providing the implementation. Thus, a few sites have been able to produce programs which represent promising beginnings toward the use of the computer for a given type of symbol processing, but because of the portability problem these programs have not received wide distribution and use. This situation has seriously hampered research and development on the nature of languages/symbol systems.

Several approaches to the distribution problem are currently being explored. One approach is exemplified by the NATS (National Testing of Software) project based at Argonne National Laboratory. This effort, concerned with a particular class of programs (Wilkinson algorithms for matrix manipulation) produces program code which is tested on, and certified for, specific machines and operating systems. For example, a subroutine package labeled DEI-F1EI--has been tested on and certified for IBM/360 models 50, 75, O.S.

releases 19 and 20; CDC 6000 series, SCOPE XXX; UNIVAC 1108; EXEC-8. A description of these programs (which are written in ANSA FORTRAN), including purpose, calling sequence, error conditions and returns, and other such information, is distributed to interested users. If their hardware and systems match those on which the routine has been run they should be able to use the program. This approach implies rather extensive testing of the programs because of the range of hardware and available operating systems; and it presumably also implies rather continuous editing and updating of documentation.

Another approach to the problems posed by distribution attempts to eliminate the portability problem by giving the user access to the program at the site for which it was designed--this latter approach is, of course, networking. Regional networks, with one central computer serving a number of terminals, represent the simplest case of such program use. That is, any given user has access to whatever programs are available on the central computer. The ARPA Network is exploring the possibility of tying together large computers (each in turn can, of course, have satellite users) so that programs on any one of the large computers are available to users of the other computers in the network.

The feasibility of communication among computers on the network now seems thoroughly established. Many problems remain to be solved, though, before a network can provide the easy, steady accessibility necessary for a major national effort directed toward the use of the computer for the study of languages. For example, there is the problem of formatting data so that it will run within the specifications of a given program. Three

approaches to this problem are: 1. to get everyone to agree on a standard format; 2. to provide software which will translate a given set of data into the format necessary for a given program; 3. to agree on a general format with provision for variants or variations which can be taken care of by software. The first approach, agreeing on a standard format, seems impossible to achieve, as well as antithetical to the fostering of the diversity which must be one thrust of any such center/network. The second approach--providing software translators to reformat data for the specifications of a given program--seems more appealing. The economic implications of this approach are by no means well defined; it might be possible to relate some of the operations research procedures applied to problems of library classification to these analogous problems of classification or formatting data. The third alternative, which is a hybrid of the first two, might imply simply setting aside a specified number of fields (presumably a very large number) and specifying gross but not detailed allocations. Using traditional memories and addressing techniques, this approach might be too wasteful of storage. On the other hand, some form of associative addressing might permit easy collapsing of unused fields in any given data set. Or, if associative addressing were not desirable or feasible, a directory for a given data set might well effect economies in storage allocation.

For sophisticated language processing it will very probably be the case that during one processing session on his data a given user will want to employ programs located at several sites. For example, to group words together having the same root, he might like to use a morphological processor based at one site, and to assign syntactic tags he might wish to use

a parser from another site. It might be possible for him to use these programs in sequence, but it also could be desirable to call in the morphological analyzer for information about suffixes when using the parser to assign syntactic categories. It is also possible that some of his data might be at one site and other information banks--such as a dictionary--at another site. The ARPA Network has little or nothing worked out as far as data formatting is concerned, and it has apparently concerned itself very little with the problems caused by scattered data and scattered programs to be used in a given run on data.

Long term, it would seem that short of the utterly unlikely standardizing on a single computer and operating system, networks will provide the answer to the distribution, portability, and accessibility aspect of availability. Such networks would seem to promise most for both the collaboration and diversity which must be integral to a healthy scientific approach to the analysis of language/symbol systems. Thus, it seems desirable to begin moving toward the solution of problems such as those mentioned above which currently limit the accessibility of the computing power represented by computer networks.

Since availability has had prior claim upon the attention of researchers in the area comprehended by this study and because availability has posed such serious problems, reliability, although deemed important, heretofore has received relatively little attention. Early efforts to make programs available--such as SHARE--were not able to provide great assurance as to reliability. More recently, the Argonne NATS project and exporters of packages such as the UCLA Biomedical statistical package and the OSIRIS package

for social scientists have been seriously concerned with the reliability of programs made available to the user community.

As to the validation, the Argonne NATS project has set up a field testing program. Under this arrangement, a number of institutions have agreed to test programs being written at Argonne, Purdue, and Texas. Errors in the programs as they operate on given machines under specific systems are recorded and, where practical, corrected. The documentation distributed with the programs then indicates the types of errors which may occur, indicates the restrictions imposed by certain machines and systems, and provides information concerning the results of random argument accuracy tests on a range of machines. The documentation includes a statement of certification which says "The NATS project fully supports this certified routine in the sense that detailed information on the testing procedures is available and reports of poor or incorrect performance on at least the machine and operating systems listed above will gain immediate attention from the developers. Questions and comments should be directed to" the individual at the point of origin responsible for that program. Other exporters of packages, such as OSIRIS, test the packages at the homesite, make the package available to users for use or implementation at their own sites, and rely upon informal feedback concerning operating problems. Thus, other users with similar systems can be warned and, when desired, modifications can be made in the package, itself, when a new release is being prepared. The OSIRIS package developers report that "periodic efforts to get user feedback are undertaken for OSIRIS II, but the older installations do not provide much response."

For a Ce/NCoReL, the level of validation might well depend upon the use to whch any given program is being put. Some programs may be explicitly experimental research tools which have been more carefully debugged in some areas than in others; for example, a sentence generator might be handling some classes of verbs to the satisfaction of the program designer but the facility for adverbs, although included, may not have been thoroughly checked out. If another researcher were interested in using this program, he would have to accept it on the understanding that it was not thoroughly checked out and any results based on the unchecked portions might not be viable. An exchange of such programs among researchers engaged in experimental and developmental work is often desirable and should not be hampered by rigid constraints on the level of validation to be achieved before a program can be made accessible to other users. On the other hand, programs which are being used for production runs or as a production component to prepare data for experimentation should meet some standard of validation before being released. Otherwise, users, and most especially naive users, may make assumptions concerning results which are, in fact, unwarranted. For a Ce/NCoReL, at least initially, validation would not imply testing on a range of hardware and systems. Rather, it would imply validation of programs for a particular dedicated central computer or host within a network to which the user would send his data over some form of network communication channel. Alternatively, if, against expectations, the concept of networking should not in the long run prove viable, then a Ce/NCoReL might need to provide validation services for many types of hardware and many different systems.

As is the case with validation, program maintenance has a rather different complexion for a Ce/NCoReL than it does for packages which are distributed for implementation on various computers. In the latter case, when systems and machines change, each site which implemented the program must decide whether the package will be modified so as to operate in the new environment. Given these circumstances, maintenance of programming packages is uncertain and, as is the case with programming languages, researchers often find themselves wiped out so far as the use of a particular package is concerned. A Ce/NCoReL, whether implemented as a center, as dedicated nodes within a network, as special projects at nodes within a network as well as one or more dedicated nodes, or as a stand-alone network, would have to ensure maintenance, either at dedicated nodes or at a central computer, of programming languages and procedures in demand by users. In the event that maintenance of a given language or program package is no longer desirable--either because user demand has disappeared or because other languages or packages are adjudged by the users to be clearly superior--a Ce/NCoReL should facilitate the transition from one language, or package, or program to another for those research projects which are either productive or have promise of productivity. Such facilitation would imply retraining of the researchers involved as well as reprogramming support. Decisions as to when a given programming language is made obsolete by another, or when a given programming package or program should be supplanted by another, lie at the heart of a type of study which might be undertaken by a Ce/NCoReL: that is, the development of a methodology which will provide comparisons of notational systems or languages so that power gained and power lost, as well

as essential equivalence, can be measured and identified. The development of such methodology is central not only to the software capability of a Ce/NCoReL but also, obviously, to communication in general.

Inasmuch as maintenance of software has, thus far, posed relatively serious problems, there has been little rational consideration of maintenance's opposite--a self-destruct or, at any rate, destruct capability. Although the very apparent and troublesome failure to maintain systems has clearly resulted in destruction, this destruction has for the most part been the adventitious result of economic and human pressures at a given site at a given time. A Ce/NCoReL should concern itself from the outset with both the necessary conditions for maintenance and the necessary conditions for phasing out a given language or programming system.

The third aspect of reliability, standardization, must be treated with great care lest it hamper desirable diversity. An occasion for desirable standardization might occur when, for example, four concordance programs exist, all of which produce identical output but differ as to the special characters used for specification of input options, or as to the order of the fields in which special options are indicated. In such an instance, it would doubtless seem more economical to maintain one version of the program for present and future users and perform any necessary translation of data already prepared for the versions being dropped.

At this stage in the development of a Ce/NCoReL, it would clearly be undesirable to standardize on a single programming language. No currently existing language satisfied all potential users of a Ce/NCoReL nor, as noted above, is enough known about characterizing the strengths and weaknesses of

various languages to design a language which maximizes the best features of existing languages for Ce/NCoReL users. Even if, and when, this does become possible we must assume and hope that advances in research will force changes and additions to any language that might seem temporarily satisfactory. One practical decision that a Ce/NCoReL would have to make is when, if ever, a particular version of a programming language should be regarded as a standard for Ce/NCoReL program designers and users. Such a decision entails the same careful consideration of questions concerning maintenance and phase-out mentioned above. It is quite likely that the experience of hardware vendors with both operating systems and releases of given programming languages will provide both guidelines to follow and indications as to what to avoid. One central computing facility would presumably make the problem of standardization easier to deal with because through its operation, in effect, it would be establishing standards for a wide range of users. A network would provide for great diversity, and the problem there would be to achieve whatever standardization would contribute to the overall effectiveness of a Ce/NCoReL. These are problems to which Ce/NCoReL task committees would need to address themselves further.

HARDWARE

As is the case with software, the hardware needs of the prospective users of a Ce/NCoReL range over many types of equipment--over what is currently available, as well as what is expected within another decade or so, and in some cases what is still 'visionary.' Since, like most computer users, prospective Ce/NCoReL users are not intimately acquainted with detailed design of hardware, it is probably most accurate to describe their assessment of hardware needs in terms of general functional properties. These functional properties can be categorized in terms of I/O and processing. In addition, there are characteristics such as reliability and accessibility which apply to all current and prospective hardware functions Ce/NCoReL users would be interested in.

Among those functions associated with I/O, a salient concern for a number of prospective Ce/NCoReL users is getting data into computer-accessible form. Indeed, this input problem has been a significant obstacle to work on data in a number of symbol systems, most notably on 'natural' language data. Language data in both graphic and acoustic form are involved, but it is the graphic form (e.g., typed, printed) which has posed the most frequent I/O problems. Acoustic data can be converted into digital representations in a fairly straightforward manner using an analog to digital converter; the only problem (which can be a serious one) is the input rate sometimes needed for work in real time. Graphic data, on the other hand, ordinarily has had to be keypunched, typed using a special type ball, or otherwise manually re-keyboarded in order to put the data in a form accessible to the computer. Some graphic data has been made available through programs which convert into computer-accessible format punched paper tapes used by publishers to

drive composition machines, and some data is input through optical character readers. But for the most part, character readers have functioned with texts that have been retyped or otherwise specially prepared so as to be amenable to the character reader's capacities. More versatile character readers are now said to be available, but financed demand for such versatility has been insufficient to make them cost effective and competitive. The combined demand of prospective users of Ce/NCoReL might well produce the added impetus that would provide optical character recognition for the large quantities of data which are of prime significance for computer-based research on language--including dictionaries, thesauri, encyclopedias, as well as other reference works, documents, and texts of all sorts. If such service does not become available, a Ce/NCoReL must count on a number of technical/support staff members giving all their time to getting graphic language data into computer-accessible form.

A Ce/NCoReL presumably will deal with a number of character sets and symbol systems. Even if its initial emphasis were upon natural languages, it would need the capacity to cope with a range of alphabets. And, if one assumes that it will deal with music and art as well as with programming languages, formal languages, natural languages, and kinesic languages, it will be coping with a variety of symbol systems. Thus, the input/output hardware should be selected and designed so as to permit the easy input and output of, for examples, Chinese and Russian as well as English, and videotape records of kinesic communication as well as language texts.

The I/O hardware should cope with a range of input and output media as well as acoustic data. (It should be noted that acoustic data, especially that produced in music synthesis, requires a good listening envi-

ronment. A number of researchers have pointed out the problems posed by the fact that most computer environments are extremely noisy.) These media should include graphics input and output (black and white and also color), paper, cards, microfilm, as well as intermediate storage devices such as disk, tape, laser stores, possibly holography, and any other promising device technology makes available to the symbol processor.

Another important desideratum for Ce/NCoReL I/O hardware--especially for intermediate storage devices such as disk, drum, etc.--is speed. For intermediate devices, speed is a matter of fast exchange of data between the intermediate devices and the CPU. For terminal devices, speed means getting the data in and out as quickly as possible. Speed at the terminals is affected by factors including the speed with which any human being can use a light pen or a teletype, and the bandwidth of the communications link between a remote printer and a CPU or an off line device. Clearly some of these variables are more susceptible to planning and design than others--that is, it is probably not feasible to arrange for human fingers to type in parallel so as to increase input speed in that mode, but it clearly is feasible to do something about bandwidth of communication links, about printing speeds, etc. The access time for intermediate storage is of prime importance for much computer-based symbol processing. Storage demands often force data for such jobs onto peripheral storage; and the subsequent need to access that data often slows jobs down so disastrously that researchers find themselves far back in job queues because of the time their job will demand. Thus, at best, they get very poor turnaround and, at worst, they may find their jobs aborted because even the generous estimate as to time required has been exceeded and the operator terminates the

job. As a result, for the researcher time, money, and patience are lost. Hence, once again, the evident need for a sympathetic computer environment for a large, special class of users.

For the purposes of this discussion, central processing unit (CPU) is used in that sense which includes main storage. Of all the hardware needs expressed by potential users of a Ce/NCoReL, an extremely large and fast central store was probably stressed more than any other single hardware component. That point needs underlining because it has been rather common for at least some hardware designers to say that language symbol processing is basically an I/O problem and, since the CPU has to wait for data to be brought in and put out, there is no need for it to be extremely fast. As noted above, it is true that many symbol processing jobs have been forced to use peripheral storage because central storage is inadequate and, as a result, the advantages of a fast CPU are lost. It is probably fair to say that at least some hardware designers have not been exercised by this problem because they have tended to catalog language symbol processing under the general rubric of business data processing. Apparently, much business data processing consists of moving linearly through data such as payrolls and inventories for which slow I/O and a relatively slow CPU is not disastrous. However, as noted above, for language researchers inadequate central storage when combined with slow I/O is disastrous. Language researchers' hopes were raised by the advent of much larger central storage, only to be dashed by the partitioning of that storage so that, in fact, a user often had access to less storage in a third generation computer than was true with some second generation machines. To emphasize the interest in large storage capacities, a few remarks by researchers in the field might be cited:

Re research on speech understanding: "I would want interactive vector-display capabilities in a time-sharing environment with large core capacities and much larger peripheral storage--perhaps personal disk packs or paging." (Letter)

Re speech analysis and synthesis: "Real-time analysis requires a sampling rate of 60-80 kilobits per second." This scientist also pointed out that a magnetic tape will hold five to ten minutes of digitized speech. (Conference, April 23, 1972)

Re music synthesis and analysis: "What we need is a way of converting samples of wave forms that occur on the order of 30,000 per second in an audible signal so as to be able to get continuous sounds of six minutes or more." In later remarks, it was noted that "a tremendous amount of number-crunching can take place. You can easily get 100 to 1 ratios between computation-time and real-time. The speed of the computer helps." (Conference, June 18, 1972)

Re question-answering and natural language processing: "Optimal design certainly includes multiple processors and gigantic core memories supported by vast quantities of disk storage for users' files." (Letter)

Re computational linguistics: ". . .more compatibility among different I/O options and lots of fast core." (Letter)

Re machine translation: "There can be little doubt that machines with operationally highly versatile central cores of billions or even trillions of bits that can be used as conventional memories or holographically will be far more suitable for linguistic problems than machines that are available at this moment." (This scholar goes on to say that at present he would settle for a machine with fast core of at least one million bits.) (Letter)

Re artificial intelligence approaches to language analysis and synthesis: "I have a feeling that what is needed is a fairly powerful computer facility. . .At the same time you are handling raw data, you are simultaneously handling a variety of hypotheses while, at the same time, making necessary systems and consistency checks." (Conference, June 18, 1972)

One aspect of natural language processing which is really now just under way, and for which storage requirements will be very large, is semantics. Although it is not yet clear whether semantic information will be stored in the form of conventional dictionaries, of networks, lattices, rings, or in yet other data structures, it does seem clear that the storage requirements will be very large. And it also seems clear that successful machine translation, automatic abstracting, question-answering, synthesis of coherent discourse--i.e., any processing or generation of natural language which is concerned with content, or meaning, or ideas--all will be heavily dependent upon successful processing of semantic information. For any kind of satisfactory efficiency (notably in interactive systems, but in batch systems as well), it will be necessary to get large quantities of the data being referenced into fast storage.

Another type of symbol system processing which demands large and fast core is statistical analysis. As part of one of our own research projects, a graduate student in computer science at The University of Kansas is using contingency tables to determine how the occurrence of words of a particular length influences the length of other words which then occur. He would like to look at this problem using a number of dimensions, but the matrices quickly become so large as to push him out of core and into inefficient processing procedures. We have had similar problems with transitional probability

matrices for character strings; many other researchers could contribute similar reports.

To reemphasize, the need is for a very large, fast store. The researcher who is doing semantic processing, or statistical processing, or analyzing acoustic data, needs to have that data in core and needs to have it accessed quickly.

Getting data in a hurry isn't simply a matter of having it in core with a fast access time. It is also a matter, where possible, of doing several things simultaneously. For example, when performing a syntactic analysis of a natural language string, an early step often consists of looking up each word in sequence. Often it would be advantageous if the dictionary lookups for a block of words could be performed simultaneously. Or, to take another example, one component of every content analysis program is a search of the text being analyzed to see whether particular words occur in that text. The search is conducted one word at a time. Again, most programs are constructed so that it would be advantageous to perform simultaneous searches for a number of words. Many other examples could be adduced to show the desirability of a hardware capacity for parallel processing. It is not clear whether the parallel processors currently under development will provide the kinds of capabilities desirable for some aspects of symbol processing. It seems important either for the needs of symbol processing to be made known so that they can be integrated into current design; or for new designs to be undertaken so as to facilitate symbol processing; or both. In terms of fast access to data, the relevance of associative memory should be explored. More satisfactory hardware means for coping with three-dimensionality also should be explored. Three-dimensionality is an important aspect of a number of symbol systems, including kinesics and the graphic representations of

mathematical and statistical concepts. Systems for holographic representations should be seriously explored for their Ce/NCoReL implications.

It has been somewhat the case for software and certainly for hardware that in the past the needs posed by prospective Ce/NCoReL users have been pretty much ignored by designers. Thus, it may be that, per force, at least initially and very likely on a continuing basis for some time, an important aspect of a Ce/NCoReL will be the design studies of hardware especially well suited to Ce/NCoReL users. Simulations and prototype realizations of designs also could be undertaken. It should be noted that such design should not ignore "number-crunching"; analysis of acoustic data as well as statistical processing imply the desirability of sophisticated arithmetic capability.

In responding to the concept of a Ce/NCoReL, a computer scientist notes that, "If research into computer systems for language research is to be supported in the Center, then a suitable experimental hardware facility should be established." He goes on to state that, "My colleagues and I have been involved in a rather broad investigation of computer system realization ("emulation") using microprogramming as a primary, but not only, technological approach. One of the premises we carried into this work is that one advantage to be gained from a flexible computer structure lies in meeting data requirements of various application areas, even more so than their instruction needs. Our work since then has in no way altered this perception." He goes on to note that "It appears extremely unlikely that this system would provide significant resources in a network." (Letter) In other words, he suggests that the experimental hardware design facility for a Ce/NCoReL should be just that: it should be experimental, rather than a service facility.

Almost all prospective Ce/NCoReL users emphasize the need for interactive use as well as batch processing. Some language processing systems, such as question-answering, are interactive by nature, and for other systems the interactive mode is desirable for program design, writing, and testing. If a Ce/NCoReL were to consist of just one central computer, the need for interactive and batch processing would imply partitioning of core--which would run counter to the need of some programs for, practically speaking, all the fast core available. Initially, program scheduling could be set up so that jobs demanding all available core did not conflict with demands for interactive computing. It is likely, however, that before too long demands for both types of service would be so great as to produce serious conflict. Hence, for this reason among others, the notion of a network with its provision for a greater range of services seems attractive. In time the optimal arrangement might well be a dedicated node for runs demanding very large core and another for interactive processing. Initially, a dedicated node for both modes might be attractive. To say that there might be a dedicated node is not to say that researchers would not have access to other nodes in any network of which a Ce/NCoReL were a part. Rather, the suggestion of a dedicated node is in response to requests from many prospective Ce/NCoReL users for a service and research facility they can count on being oriented toward their needs--the provision of a sympathetic and effective computing environment. At present, many of them find both the hardware and software to which they have access uncongenial for research on symbol systems.

The above remarks are related to another desirable hardware attribute--accessibility. Researchers want easy, efficient access to computing power. In a network configuration, they would like terminals giving them access to

a host as well as to other network nodes through the host. A possible configuration would be analogous to a regional network, entailing a number of terminals and small computers acting as terminals tied into a large central computer, which is in turn tied into an ARPA-like network comprising other large computers and their satellite systems.

A further aspect of accessibility is the man-machine interface. The man-machine interface has not been attended to very extensively for any group of users; but insofar as it has, the group of users in question has not been primarily those concerned with symbol systems. Work on hardware design should not ignore this important aspect of system availability. It may be argued that many information retrieval system efforts are not having the impact they might as a result of too little attention to user habits, expectations, and needs. The importance of the man-machine interface received a great deal of attention not only from prospective users of a Ce/NCoReL, but also from computer center directors and hardware and software designers who attended the working conferences held in connection with this study. One hardware designer succinctly represented many of these concerns when he noted, "You are going to have to start out by paying attention to the input problem and the human interface problem. . .that should come first." (Conference, June 18, 1972) And an anthropological linguist, after eloquently outlining some of the difficulties faced by potential users of the computer, suggested that "unless language people band together for a facility dedicated to language research we may never solve some of the problems." (Conference, June 18, 1972)

Another major concern for hardware, as for software, is system reliability. The work on distributed systems at the University of California at Berkeley and at Irvine represents an approach to this problem. Both systems

promise very high availability, a term which, especially as used in the Berkeley effort, is rather synonymous with reliability. That is the latter system is to be made up from elements comprising CPUs, disks, and memory modules which can be called in to meet the need of a given user or of a given subsystem when any of the elements within that subsystem fails. Within this PRIME system, a computer is constructed for each user from the elements in the pools. Each subsystem is separate and several are in use simultaneously. One subsystem serves as the control monitor, and any subsystem can assume the function of control monitor. Because there is neither interference nor access between processors, highly interactive data base sharing is not feasible in the PRIME system. On the other hand, the system is designed to deliver the availability already mentioned, as well as privacy, cost effectiveness, high performance file access capability, simplicity, and excellent interactive access for the user.

The Irvine approach is a distributed system over a net of small computers configured in a ring or loop. Control is distributed or shared by the computers and the data base is also distributed. The system emphasizes high availability at the expense of efficiency, if necessary. The application first being tested on this system is a text-editing programming system.

ORGANIZATION

There are a number of rather diverse aspects to the question of how a possible Ce/NCoReL might be organized. One set of issues has to do with the sequence of stages involved in the initial establishment of such an organization. Numerous other questions relate to the structure a Ce/NCoReL might have at various times once it had been initiated; there are some who have rather detailed ideas as to how, once begun, a Ce/NCoReL might develop. Various opinions were expressed as to the composition of its advisory or trustee boards. Similarly, there were quite varied views as to levels and sources of funding and as to how funds should be managed, just as there were variegated conceptions of what the relationship to the federal government of Ce/NCoReL might be. And various models derived from existing organizations have been proposed and reflected on for Ce/NCoReL. Without trying to be comprehensive, one might also mention that other aspects of its organization that have been considered include its role in training, and what that implies as to the structure of Ce/NCoReL itself; there has been discussion of issues bearing upon the personnel proposed for a Ce/NCoReL, heavily contingent, of course, upon other decisions made about its organization. These and other aspects of the question of how a Ce/NCoReL might well be organized we will discuss in this chapter of the monograph.

As is true of other aspects of this study, we have with reference to questions of organization a considerable volume of detail which the scope of this report will not permit us to include. But if it does come to pass that further steps are taken toward developing the kind of national research capability which we feel is needed for language research, then much of that detailed reflection can be put to good use at various stages of planning.

There are many different axes along which scholars and scientists located their observations as to how a Ce/NCoReL might be organized. One of the principal axes is the degree of formal organization needed and the extent to which the elaboration of such a formal organization should be related to existing bureaucratic structures, such as the federal government. One suggestion is that a Ce/NCoReL should be integrally associated with the kind of national academy of language science proposed more than a decade ago by the late Professor Léon E. Dostert; Professor Dostert had worked out a fairly detailed organization plan for such an academy. Following upon his ideas, one scholar has suggested that a Ce/NCoReL should serve "all users of any kind of 'stringed' structure, and, most importantly, natural language." Within this comparatively formally organized research structure, it was suggested that there be as many principal researchers as there are "subconcepts" within the conception of a Ce/NCoReL; and that at each of various universities in this country a principal researcher would head a team--and each team would work out a detailed plan for developmental research stages with reference to each of these subconcepts. Among the many interesting details suggested in the elaboration of that idea of organization is the suggestion that a Ce/NCoReL advisory board would itself nominate consultants on special topics as needs arise. Insofar as there is an inclination to profit from formal organizational experience bearing upon structures for scholarly research facilities, one can turn also to the experience and the documentation generated by such organized efforts as have been long underway--including, for example, the National Bureau of Economic Research and its By-Laws and the National Center for Atmospheric Research and its planning documents.

Another kind of model suggested for the organization of a Ce/NCoReL derives from the experience of organizations accustomed to large numbers of visiting research workers, with The RAND Corporation and Project MAC cited as illustrations. It was proposed that at a site to which such research workers could come the initial emphasis would be on the development of a single time-shared utility, which would gradually be opened up to remote users. For this type of Ce/NCoReL it was further argued that an advisory board should include representatives from the fields of "linguistics, computational linguistics, computer science, artificial intelligence, psychology and philosophy"; it was also suggested that the group of scientists serving in an advisory capacity should include representatives of industry and government, as well as of university departments. One aspect of the further elaboration of this particular idea might be quoted in extenso:

> Very flat organization of the Director with technical staff and Project heads or representatives, supported by a purely clerical administration arm. Interface with universities and other organizations might well be limited to Project personnel in those places. Funding would obviously begin with government sponsorship augmented by private foundations. The future might include the development of profit-making activities if this is consistent with the charter. Otherwise the pattern of the free non-profit research corporation may still be viable. Special expert knowledge would be generally accessible via the network of inter-relations among researchers at the advanced fringe of computer science.

A rather different proposal called for, as an administrative ideal, "one man or very small group," with advisors chosen for specific in-puts.

In another sort of view one looks at organization as in itself less important for the future of such national research capability as we are discussing here; and, in fact, in that view emphasis is on keeping organization to a minimum, although stressing the desirability of physical proximity to

other researchers with shared interests and to a supportive neighboring environment, such as that of a major university. It was argued that the mandate or charter for doing research on a significant problem was most important, with a sequence of development running from a small working group at the start, going on to a computing facility, and then perhaps to a network. And it was argued that the management and administration of the facility that emerged should have as their most important function the interpretation of the research output and performance to the world beyond the research organization and, notably, to its sources of funding support. In the following quotation we see an instance of the scale and range of types of researchers whom, it was felt, it would be helpful to provide organization support for as they seek to interact more effectively in their research:

> First, let me affirm my strong feelings about the desirability of more communication and cooperation among those involved in research on language viewed broadly as you have. The beginnings of cooperative activity can be noted in the emergence of psycholinguistics and sociolinguistics as substantive fields of study, the determinant effects of formal languages on linguistics and of linguistics on programming language development, and the interest in coding pervading molecular biology, music, neurophysiology, and dance to name exciting examples. Computers used as algorithmic processors or interactively, have played and will continue to play a major role in establishing communication and conceptual communality. Consonant with that view, there is an emphasis on the continuing desirability of interaction between research workers utilizing a network structure and the wider scientific public interested in their work. (Letter)

A rather different way of looking at what a Ce/NCoReL might be like organizationally comes from the perspective of 'the laboratory model.' The arguments advanced for the laboratory model for a Ce/NCoReL tend to emphasize the importance of special physical facilities as the independent, critical variables; and other features of a center are, to one degree or another, seen

as derived from a suitable laboratory facility arrangement. The view was expressed that it would be best to start with one or two physical centers suitably equipped as to computational capacity and as to technical staff chosen on the basis of suitability for tackling a particular major problem. Here the argument was that instead of letting problems emerge--as has often happened--from working with the apparatus that happened to be at hand, a problem should be chosen first, the appropriate instrumentation established for work on it, staff chosen with that research objective in mind; and only later should various sorts of satellite arrangements vis-a-vis one or two such centers come into existence. Ultimately, it was suggested, there might be as many as four major centers, each of them with satellite centers and dependent networking. Some of the practical considerations attended to in the design of this sort of organization included the provision of satisfactory lodgings for visiting researchers close to the laboratories, as also for graduate students working for a period of time with technical and research staff at center sites. With reference to this laboratory-type model for the organization of Ce/NCoReL, it should be emphasized that its appropriateness is substantially conditioned by considerations of scale: more especially, it was argued that the instrumentation needed for significant research on language problems which were socially salient would imply a scale of operations such that the one or two or three individuals interested in any given such problem at each particular university would be unable to provide the needed apparatus for themselves. In this organizational structure there would be a "modest core of resident researchers" as well as a technical staff to build and maintain hardware and software facilities and to provide assistance to visiting scholars.

A somewhat comparable orientation towards some of the relevant dimensions of organization produced the suggestion that there might be a number of centers, each one of which served for the nucleus of a regional research activity, where each region had its own specialization. Each of these regional centers would have full-time staff funded on other than a university budget basis and each one of those centers would have its own advisory board; additionally, there would be a national advisory board coordinating the activities of the regional boards and, especially, allocating the award of funding above some threshhold magnitude. The notion of regional differentiation of research activity--with each region having something in the way of its own independent computational capacity--was advanced by a number of people. Among them opinions varied as to what type of 'connection' was needed for linking these various regional centers. One specific suggestion called for an East Coast center located in Boston and a West Coast center in the Bay area "with provision for rapid flow of data and programs between the centers." The scholar who offered that suggestion also made another comment which would find resonance among many other commentators on Ce/NCoReL-related issues: that Ce/NCoReL should be so budgeted as to be able to fund proposals directly out of its general research fund without having to forward each project for separate funding by some governmental or foundation authority. In general, it might be said that people seem to feel that if the request for funds were small enough it should be possible for the administrative staff of a Ce/NCoReL to disburse on its own authority the needed allocation; for somewhat larger projects the argument seemed to be that some sort of specialized and, perhaps, regional board of advisors would have the

authority to fund; and for the large research projects a nationally-constituted advisory panel would have the necessary authority--with a residual class of projects of such size that special efforts at funding for them would need to be undertaken.

In addition to the models for organization as a whole, just cited, there were a variety of observations apropos separate aspects of organization. We will look at these next.

One argument advanced for bringing into existence an organization of some sort is that heretofore a great deal of work undertaken on individual campus or other research sites has not been utilized as well as it might have been for want of a means of maintaining and distributing the research accomplishments. Irrespective of many possible types of organizational arrangements in detail, it is clear that organization alone--provided certain levels of support, in conjunction with the assignment of priorities, were agreed to--could provide a way of seeing to it that much good work was not lost to its potential scientific public. We take it for granted, of course, that there would be much work which would not be maintained and distributed, just as there would be much language research in no way directly associated with the efforts of a Ce/NCoReL. And just as sometimes some people are concerned about the lack of ready availability of the work of others, at other times some people are concerned about possible consequences of such ready availability leading to some type of premature settling on a particular model or method; an argument which, in a way, addressed itself to both those diverse types of concern suggested that the organization of efforts in this field of research could be done in such a way as to facilitate making

available alternative taxonomies, etc. The view expressed was that varied conventionalizations need to be made available, and that such an undertaking was very different from encouraging standardization.

Again, without reference to a specific pattern in organization, it was argued that some method of organizing research in this broad area might have the effect of facilitating the funding of such work generally. It has been argued that organization here could enable assistance to flow more easily to such research, not only from several components of the National Science Foundation, but also from the National Endowment for the Humanities, and from other funding sources. Some prior experience in other fields of research was taken to imply that the greater visibility and effect which organization of effort can provide will often lead to the flourishing of the field, including an enrichment of funding. A number of people argued that it was desirable to build on past and present research experience and activity in this area, and that a way of doing so was to strive to foster what was going on at existing sites, at the same time in various ways seeking to link them together. In this connection, on a number of occasions it was urged that it would be healthy to consider a network organization in particular because of the way in which that would lead to increased support for current activities at a number of sites among which the organization of a Ce/NCoReL could foster enhanced communication.

Again, a variety of suggestions has been made as to the role of any central component within a network vis-a-vis individual research sites or network nodes. Depending on the role which is proposed for the central component, the size, character, and funding implied for it would, of course,

vary widely. Many people would like to see a guarantee of funding continuity for a central component such that the central component had sufficient funds to itself support basic research. A vigorous case was made for autonomy on the part of a Ce/NCoReL itself in disbursing funds made available to it in support of basic research at one node or another. While some felt that the advisory panel or the like which disbursed the funds should have within itself all the necessary competence to make judgments as to whom to give money to and for what purposes, others provided for the utilization, as needed, of technical consultants by those researchers. In yet another role for consultants, it was proposed that Ce/NCoReL might be able to provide technical consulting capability--or, at least, the financing of it--to researchers at particular nodes. Various people gave thought to how to provide reasonable assurances of continuity in funding so that what was gained would not be lost through casual vicissitides; here one contention was that a five year budget for Ce/NCoReL would be desirable, with a fresh five year commitment settled on each year--that is to say that a new fifth year would be provided for each year. It was also pointed out that for such continuity in funding, with a constant five year horizon, it was more practical to try to have all of the funding (or practically all) emanating from, or at least directed through, one single agency.

Nodal specialization was rather widely assumed to be highly desirable, and for those who did so assume, it tended to follow that they proposed a representative from each node participating in central decision making for Ce/NCoReL as a whole; some scholars would argue that the board or panel or committee guiding the administration of a Ce/NCoReL should be made up exclu-

sively of individuals who were themselves directing operations at major Ce/NCoReL sites, while others provided for some nonparticipant sources of advice and counsel. One scholar proposed that initially there might be one or two meetings a year at which representatives of approximately a half dozen language research teams would meet to discuss their common problems.

For some commentators, questions of organization were answered in part at least by beginning with assessments of probabilities as to available network technology and policies toward that technology. Thus, much attention focused on what sorts of organizational arrangements might make sense if the activities of Ce/NCoReL were conducted on the ARPA Network. And some commentators started from a set of assumptions about the probabilities for and certain characteristics of a National Science Network and then let questions of organization be resolved in part through the set of conditions which they surmised were likely to hold under a National Science Network or, for that matter, some transformation of the ARPA Network into a National Science Network. In one such approach--cited here as an example of the way in which detail could follow from these more general concerns--the way in which agenda were established for organizational meetings followed significantly from present and prospective network capabilities for managing communications interaction among people who were widely dispersed geographically but having access to a common network and some type of network information organization. By contrast, organizational arrangements looked very different to people who were thinking about a Ce/NCoReL on the analog of existing single center arrangements, particularly such arrangements as are found in research centers devoted to a single class of research activity--where there is only one site

and its users come to it physically and there is only one major class of users, etc. For such a center the managerial and advisory structure can easily differ from what might be appropriate to a Ce/NCoReL of the network type. One obvious disadvantage to a single-center form of organization would be the lesser--dramatically lesser--contact with other researchers, who would be unable during a teaching year to be physically present at the one center site, by contrast with the communication that would be possible on a fairly frequent basis through the joint use of a network itself. Of course, by contrast, there are certain advantages to having in one place all the types of data that might be used, rather than having the data sets scattered.

One may suppose, however, that many of these issues could be rendered nuggatory from a pragmatic point of view--if, indeed, it does come to pass that, nationally viewed, computing for research comes to be a net of networks, with five or six different scales of network (ranging from mini-nets associated with small laboratory computers on to intermediate computers at the level of, say, a department, linked in turn to university computers to form yet another kind of network, and then university computers linked both in regional nets and, somewhat separately, into larger nets of major computers such as we already have emergent with ARPA, and, should there be a number of networks of ARPA-type scale, then a higher level network of nets). If projects such as the CONDUIT effort succeed, there may even be a greater amount of interchange among smaller networks which are not superficially compatible.

A further source of ideas as to ways of organizing a network operation involving diverse users and types of users may come from the further development of the Museum Computer Network. Their current planning and prospects

may point to a far more extensively used and more fully elaborated interactive arrangement than has been the case during its development phases to date.

It was also suggested that the structure of National Institutes of Health study sections might be looked at for possible use as a model. That idea is very compatible with another thought--that the advisory or trustee body should be

> a body of experts who are expert enough not to have to resort to 'technical committees' or other outside judges for the appointment of principal investigators or the evaluation of final reports. It should, of course, also be a body of individuals who are not and are not likely to be put under pressure by the Government by political parties, computer manufacturers, or other factions that might have an interest in starting, stopping, or directing research.

It was argued that such a "truly independent research authority" would be "in a much better position to organize interdisciplinary research than are universities or industry." So expert an advisory panel, it was argued, would be able to choose wisely principal investigators and research teams; and it was assumed that their sophistication in research administration would be conducive to their giving the active researchers a very considerable autonomy which would not be abridged by any intermediate level of administrative authority between the advisory panel and the research groups for whom they were able to provide financial support (i.e., no analog of the individual project monitor). It was argued that such an advisory panel should have on it representatives of the major areas of language research, and it was also suggested that there should be some sort of explicit provision made to guarantee that it was not only those major types of users whose interests were represented; the thought was that "fringe" users should also have their support and organizational leverage.

* * *

One question upon which opinion varied rather widely was whether a Ce/NCoReL should be organized in such fashion as to facilitate training and education for graduate students and more advanced scientists working in these fields. The obvious extremes of view are represented, ranging from a "no" with reference to the possibility of Ce/NCoReL sponsoring institutes on through the suggestion that training institutes should be sponsored by Ce/NCoReL, not at its inception but after it had a good record for effectiveness; yet another view holds that eventually training institute functions would fall by the wayside simply owing to a putative growth in knowledge of programming and computers, even at the precollegiate level. Among those expressing opinions favorable to some form of training institute, one view held that it was appropriate to organize Ce/NCoReL facilities for such purposes, but that any staff explicitly and primarily associated with Ce/NCoReL should not be called upon to develop and conduct training institutes; others felt that Ce/NCoReL's role with reference to these types of training should be that of assisting through its sponsorship in the generating of funding for institutes which would be actually conducted by universities or other institutions--as the Social Science Research Council and the American Council of Learned Societies, for example, have provided such sponsorship in particular areas over the years. It was also argued that in the arts and the humanities computers were at present underutilized and it would be very helpful to provide for graduate students and for faculty even the most fundamental knowledge of computers. One scholar put it this way:

> The only general principle I can suggest is that it makes more sense to take a literary scholar and teach him what he needs to

> know to get along with computer people than it does to take a computer expert and teach him to become a literary scholar, and to teach the literary scholar makes a very great deal of sense indeed.

It was also proposed that Ce/NCoReL should be so organized as to be able to offer training institutes which did not define their scope narrowly, i.e., training institutes that reached out to include coverage of such topics as "formal logic, Boolean algebra, theory of sets, groups, semi-groups, theory of probability, etc." Another scientist put a part of his argument in these words:

> A most important role of this center is educational; so training institutes, advanced seminars, symposia, etc., are all to me essential features. I think such a center may be the model for scientific training at the graduate level in the increasingly common multi-disciplinary areas of science and scholarship.

And another scholar, in this instance in French literature, suggested that all levels of training should be provided and he urged the use of specialized, full-time staff personnel for that purpose, while at the same time, proposing that particular types of training be conducted at those nodes or sites which had well established specializations in the general area of the computer applied to the study of language. The beneficial effects of various types of summer institutes were mentioned, including that of the institute at the University of Colorado on the computer in relationship to the social and behavioral sciences; it was estimated that fifty to sixty percent of the people who have attended one of those Colorado summer institutes have changed the direction of their own research and, in some degree, the research directions of the educational institutions with which they are affiliated. An example of the sort of summer institute experience that a group of natural language scholars might engage in included familiarization and testing a number of different

parsers, where the parsers could be compared and evaluated with inputs from those intimately associated with their development and/or use. Such summer gatherings, it was contended, would enable scholars on widely separated campuses to be more effectively aware of what was going on in their fields--a type of post-doctoral training.

Some computer center directors stress the importance of a Ce/NCoReL as a means of providing a responsive, computing environment for language researchers. It was urged, in that connection, that Ce/NCoReL might be so organized as to provide for the training, or more accurately the retraining, of computer center personnel so that they might better be able to interact with language researchers. Some of the material in our 'archive' is quite detailed as to what should be done by a Ce/NCoReL organized to conduct various sorts of training; for example, an argument was made for teaching SNOBOL IV in explicit preference to other languages. It was also urged that a Ce/NCoReL should think of making available these training resources to nationals from other countries, especially from the emerging and developing countries--an idea which might be developed in conjunction with the notion that it was desirable to extend the effectiveness of the training function of Ce/NCoReL through the use of video communications in place of the physical transportation of people.

And we also have some estimates as to the very beneficial up-grading effects on the field which such training efforts could be expected to produce. A related consideration was the notion that if there were good user interface for the application of the computer to the study of language and if, then, that good interface were made available to students, that in turn would have

the effect of bringing to the surface much latent demand for the use of computers on the part of faculty who theretofore had not shown much, if any, interest. On that matter one is reminded of the impact of the teaching of statistics on middle-aged economists in the decade following World War II--when the statistical education of the younger men led to a type of professional advance for all but the oldest generation of members of the discipline. The Dartmouth experience with growth of faculty computer use also comes to mind.

There was strong agreement that Ce/NCoReL should opt to provide for fellowships, and a variety of suggestions was made as to the type of fellowships that should be provided. One point of view called for project assistantships, pre-doctoral fellowships, post-doctoral fellowships, and a system of flexibility in terms of appointment. Another view, while endorsing the idea of fellowships, urged that they be "only for people with a past record of interdisciplinary research, knowledge, and, preferably, publication." Sabbatical-type research fellowships were also endorsed to provide access to an appropriate facility, on the assumption that there would be several nodes; it was suggested that these fellowships should be offered at existing research centers which would be nodal within the system; more specifically, in one instance two-year-long, well-paid post-doctoral fellowships to learn how to use the computer in linguistic research were endorsed. Another scientist argued for fellowships not only for advanced graduate students and on a post-doctoral basis, but also for scientists working in industry--all of the fellowships to be awarded on the basis of refereed proposals. It was also suggested that there be two classes of fellowships, some of a purely honorary sort without monetary support. A somewhat different sugges-

tion called for the provision of fellowships to be used in shorter term collateral research adjunct to relatively long-term, in-house projects, with the addition of part-time consultants whose interests coincided with the long-term research. One version of the argument for a variety of terms of appointment called for the possibility of a small number of open-ended appointments; the point was made that there are circumstances under which a commitment of a few weeks or a few months was preferable to the commitment of full semesters or years.

* * *

Observations as to personnel needed in a Ce/NCoReL organization range from commentary on the composition of advisory boards through discussion of characteristics of technical/programming personnel.

In one view it was a matter of great importance that the people who constituted the Ce/NCoReL organization should be funded entirely from non-university sources and that to a Ce/NCoReL organization such full-time, independently-funded people were much more essential than consultants.

A number of commentators on these issues--interestingly enough, including some computer center directors--urged the importance of recruiting technical personnel who have a broader outlook than is characteristically found in university computer centers; it was suggested, for example, that even for the technical staff (including the programming staff) familiarity with the content of a specific field of language research should be a sine qua non, and only from among those meeting that requirement should a choice be made of individuals who also had the necessary computational skills. Beyond that, it was urged that these people needed to know how to relate to the professional

people from the language research area whom they would be interacting with. Here is one comment on that subject:

> The staff of an up-to-date center must be prepared, first of all, to offer service. Professional skills do not preclude courtesy and understanding. Their primary job is to bridge the gap between the software/hardware complex and the users' needs. This is to be accomplished as much as possible by using the staff to tailor the system to the needs of the users rather than forcing the users to understand what, to them, are matters unrelated to their research.

We received a number of types of suggestions as to the technical personnel who should be supported out of a Ce/NCoReL budget. One suggestion included the following observations:

> As to the staff, I think there is a very great danger that they overspecialize in one approach. At least some of the staff should understand statistical inference. A balance is needed between syntactic and semantic interests. Expertise is needed in file structures, including the representation of graphs. Efforts are needed to serve the different users and help them integrate their work rather than build a super system of their own. This is a hard endeavor to staff, for it offers less opportunity for creativity.

As with other aspects of a Ce/NCoReL's development, some of the commentary on this topic proposed a sequence of rough stages with respect to the types of personnel who would be needed for a Ce/NCoReL. One such 'scenario' reads as follows:

> At present a majority of computer users in the social sciences and the humanities are not programmers. Thus this group will need a maximum amount of programming assistance and training. During the next decade I expect that more and more of the active users will be people with solid programming experience who will be capable of doing their own work. Thus, I expect there will be less need of analysts to design the full programs and more need for student coders who can work from basic, generalized flowcharts.

A certain stress was put on the need for systems programmers. One linguist and computer scientist had this to say:

> "Systems programming staff must be the best that money can buy in order to save money in the operation of the center, and of course to guarantee success of the more serious programming efforts." "One must be prepared to pay systems programmers salaries as high as $20,000 to $25,000 per year."

Another well-experienced scholar in these fields called for "a central core of systems men for the development and maintenance of basic language processing systems."

Those who felt it was desirable to begin with activity at a number of sites suggested that each should have a full-time senior programmer and the usual associated staff for programming work, broadly defined. Since the subject matter competence of the programmers was so often emphasized as important for successful language or symbol system research we quote another such observation which, also, includes the sort of glimpse of the future which informed other comments as well:

> One critical need at present in the area of computational assistance is for programmers with enough subject matter competence to mediate between the specialists and the computer. . .In five years, if programming languages and computer interfaces do accommodate to nonprogrammers, subject matter specialists should be able to control the computer without intermediaries. Perhaps ten years is a more reasonable period of time within which to expect that to happen.

During the course of one of the conferences it was suggested that one or more computer science departments might make something of an effort to develop curricula appropriate for personnel involved in work at the interface between computer science technique and language or symbolic behavior research. It might be borne in mind that some have felt that the most likely recruits for such study would come from the symbol system fields rather than from computer science, per se; but, in our judgment, they are likely to be found on both sides of the fence; and, of course, we expect that computer science

itself will become increasingly directed toward research on the nature of language symbol manipulation, and that as such an emphasis becomes increasingly explicit it will lead to computer scientists who in virtue of their training in that field are more and more well qualified to work on research projects focused on languages and symbol systems.

If there were a single center, initially at least, it was suggested that its head should be "exceptionally well grounded in computer science and technology but multi-disciplinary in his understanding--in terms of accommodation of linguistics, logic, mathematics, psychology, and computer science." Others who favored the idea of linking together a variety of sites (including research nuclei already at work) as nodes in some type of system, sometimes suggested the desirability of a part-time director at each research node, with the selection of his special, required competences flowing from the specialization that is unique or distinctive for that node.

At the core of a Ce/NCoReL, it was urged, provision should be made to sustain a modest corps of professional staff who are able to do, and are doing, significant, exciting research; one of the consequences of such staffing would be the attraction of the site as a place to visit and work for other people who felt the need for further professional exchange with individuals thoroughly committed to their kind of work, broadly defined. It was suggested that, ideally, a specific tangible problem with practical applications, but which also implied theoretical work, was the sort of research effort that would, all other things being equal, most effectively and profitably draw other researchers into effective interaction at the core of a Ce/NCoReL, or, for that matter, at an individual node.

In one view it was argued that it was really difficult to make a distinction between which disciplines should be represented among the full-time staff of a Ce/NCoReL, which among its consultants, and which among members of an advisory board. It might be suggested that one could strive for total balance by increasing the representation in one category when there was underrepresentation of a particular discipline in one of the other categories. Among the disciplines which, in one role or another, it was urged should be represented were, in the view of one scientist:

> Linguists, programmers, systems analysts, computer-information scientists generally, logicians, lexicographers, artists, musicians, choreographers, psychologists, anthropologists, sociologists, literary specialists, humanists broadly conceived, statisticians, neurophysiologists.

Another commentator made the point that while all of the central disciplines involved needed to be represented there was certainly no necessity that they be equally represented.

As indicated earlier, there were those who felt that it would be desirable for Ce/NCoReL's own independently administered budget to include funding that would allow for the full-time sponsorship of research by scholars and scientists who could give approximately two or three years to major interests of their own. One letter to us contained the strong urging that it be recognized that with the increasing teaching focus of many universities the desirability of full-time opportunities for researchers is greater, since teaching loads and other nonresearch responsibilities are so heavy that the part-time support of faculty is not so likely to be practical in its effects.

Another salient concern that we have mentioned before is the contention that special efforts must be made to guarantee continuity for the activities

of such individuals as are supported in a Ce/NCoReL organization, lest unanticipated, short-lead-time reductions in funding leave much good work half done and personnel unprovided for.

* * *

As to views specifically directed toward the financing arrangements for a Ce/NCoReL, one caveat which was vigorously presented at one of the conferences in the spring of 1972 concerning Ce/NCoReL emphasized that there should be complete openness about the ultimate sources of funds for Ce/NCoReL or any other organization whose sources of support are at least partly federal; more especially, it was urged that a full familiarity with sources of funding on the part of the individuals administratively responsible for an organization was certainly not sufficient, and that it was important that everyone who was associated with any research which was at least partially government-sponsored should know, or at least have available to him, in detail, the (inter-)agency and/or (inter-)departmental sources of all government funds.

To some--ourselves included--the importance of the research programs which Ce/NCoReL would make possible, as discussed elsewhere in this report, is such that funding for it should have the very highest priority, if only on the grounds that all other research is in some of its critical components a set of special cases of symbol system behavior which, if thoroughly understood, might be much more adequately utilized. One conferee felt so strongly about the importance of high priority, continuity, and suitable scale of funding for the kind of network capability which Ce/NCoReL could so thoroughly employ that he urged the analog of the federal highway system: i.e., that

major computer networks are of such importance that there should be no more prospect of subsidization for their maintenance disappearing than would be true for federal subsidization of the highway system. As to the length of time over which there should be some guarantee of continuing support for Ce/NCoReL in order to allow for research planning and accomplishment, the yearly updating of a five-year budget, such as is done for the National Center for Atmospheric Research, was mentioned on a number of occasions; in a letter from a psycholinguist the argument was made that the indispensable assurance of continuity for basic language research might well be such as to make ten years look like a short time; stress was placed on the importance of this sort of assurance of continuity irrespective of any usefulness for intermediary results, in order to have what, in that scientist's judgment, was a sufficient opportunity to do well basic research in this field. Earlier in this chapter, and also elsewhere in this report, we have mentioned other instances of the emphasis which was placed on the importance of the strongest possible assurances of funding continuity for research which might be undertaken with the assistance of a Ce/NCoReL.

Any realistic assessments of the costing implied by a Ce/NCoReL must, of course, wait upon the analysis of particular options among the many which are open at this time. And the development of federal policy in the area of networks of computers will certainly significantly condition costs for a Ce/NCoReL. Nonetheless, some research scientists interested in Ce/NCoReL have offered gross estimates as to what, in present dollars, funding levels appropriately might be; one such estimate calls for a four million dollar start-up cost, including the acquisition of hardware with a budget thereafter

at approximately one million dollars a year. Among the numerous sources of information concerning costs for this type of operation, mention was made of the National Bureau of Economic Research's new center for software efforts on behalf of economists and business administration students, as well as the National Center for Atmospheric Research. One interesting suggestion apropos of funding--made in the context of assumptions that Ce/NCoReL itself would be funded but that there would also be coordinated funding provided for research efforts in which use was being made of Ce/NCoReL but which were not themselves directly supervised by Ce/NCoReL--was that provision should be made for language scientists to choose in some cases to have the administration of funding allocated to them as principal investigators administered by Ce/NCoReL rather than by their home universities, on the grounds that at times there are now serious conflicts of interest between a university's stake in the overhead and other funding associated with a grant and what the individual research scientist may construe as in the best interest of getting his work done. But to return for a moment to the issue of cost estimating for various possible Ce/NCoReL arrangements, other sources of useful input may be the studies undertaken at the National Bureau of Standards under the direction of Dr. Ruth Davis, on the costs of networks, the costing calculations associated with Dr. Lloyd Fosdick's and Dr. Wayne Cowell's studies of software validation and distribution (conducted at the University of Colorado and at Argonne National Laboratory), and the study of methods of financing and managing university computing needs currently under way at the Denver Research Institute of the University of Denver under the direction of Dr. William Dorn and Mr. Martin Robbins. (W. A. Sedelow is a member of the advisory panel for this DRI project.)

There is some real enthusiasm for the coordinated quest for funding--perhaps in a way loosely analogous to Project CONDUIT, where a number of universities are each receiving a separate grant at the same time that there is a general grant for the central operation of the project housed at Duke University. Some of the funding allocated for a core administration in Ce/NCoReL might be expended on the efforts needed, when desired, to coordinate research requests--so that there would be a minimum of unintended overlap and a maximum awareness of opportunities to relate to the ongoing work of other researchers. A linguist pointed out that "decentralization of funding also makes it easier for the emphasis in the field to shift with relative rapidity rather than having to overcome the inertia of a center administration." And it may be appropriate to mention here, once again, the proposition that was urged on a number of occasions to the effect that the establishment of a center, or network, for research in a field can have the effect of giving a greater appropriate visibility to research in that area taken as a whole--with the result that in total far more work is funded than one might expect to be the case without a center. It was also suggested that in some cases such centers actually provide some 'prestige' which rubs off on the institutions associated with them.

In other approaches to the matter of funding it was suggested that researchers might cover at least some of the costs of their work done on a Ce/NCoReL computer and with the assistance of Ce/NCoReL staff; in some cases that might be achieved through the allocation of grant or contract funds by principal investigators to Ce/NCoReL for those purposes, and on another basis work might be done at the expense of institutions which were

members of a consortium associated with Ce/NCoReL (perhaps somewhat analogous in its arrangements to those which have been worked out at the University of Michigan for scholars working principally in the areas of political science and political history). In a variation on an idea already mentioned, it was suggested that qualified researchers might elect to pool their resources as one aspect of the operation of a Ce/NCoReL, deriving the provided resources on whatever basis they found feasible, whether from public funds, foundation funds, contract work, or the like. In this instance as in many others the proposer of the idea urged the utilization of a careful refereeing procedure for plans offered by those who would be associated with Ce/NCoReL as researchers.

As to the expenditure on research of funds provided for a Ce/NCoReL, in one instance, at least, it was argued that special provision should be made out of Ce/NCoReL's own budget for meeting the needs of researchers who were working in inter-disciplinary teams when they might find it difficult to locate any one agency which would support their work. Some of those who have given thought to certain issues raised in this study have stressed the wide demand for relatively unsophisticated research assistance for many researchers in this field, including the writing of comparatively straightforward programs and certainly debugging of programs and even coping with various kinds of job-control language problems. Various cost details would flow from particular kinds of projects, such as, for example, getting the Oxford-English Dictionary into machine-readable form. Other cost factors may be determined by the rate structure set up for various networks, such as the ARPA Net.

* * *

For a next stage in moving toward the possible organization of a Ce/NCoReL, we propose that the following major planning functions be initiated, taking into account suggestions already cited which were made during the course of this study:

A. Organizational Planning

1. Structural

a. to plan in detail the initiating phases of a national center/network for computational research on language, including

i. --the final definition of the functions of any advisory panel for the initiating phases of Ce/NCoReL

--further definition, in consultation with members of the initial advisory panel, of the responsibilities of an Advisory Committee for an established Ce/NCoReL

--delineations of the functions and responsibilities of the administrative personnel (Director, et al.), in consultation with the initial, advisory panel

--identification of the formal responsibilities and modus operandi for an Executive Committee consisting of a subset of the Advisory Committee in addition to one or more of the senior administrative personnel (If in the start-up phase there were more than one site involved--e.g., activities at more than one node in a network--then each of those sites (e.g., campuses) should have from the start as its director someone also designated Associate Director of Ce/NCoReL, responsible for all Ce/NCoReL activities at his site, and probably he should be a member of the Executive Committee.)

ii. --preliminary explorations with faculty and administrators at likely nodal sites (e.g., where certain types of language research are already underway)

--development of technical work schedules (3 to 5 year schedules) in further specification of nodal roles, whenever (and insofar as) participating in a Ce/NCoReL would imply an expansion and/or alteration in use of computer resources

A. 1. a. ii. --definitive negotiations with faculty and administrators at nodal sites as to functions, responsibilities, and commitments (financial, personnel, and otherwise)

--provision of guidance and co-ordinating functions in the preparation of funding proposals from each nodal site where an existing or incipient research team was interested in submitting a research proposal as one of a set of such from a number of different universities and other research sites

b. to plan in detail the functions of the network administration and advisory groups in their external relationships or interfaces

i. --with NSF, and other relevant federal agencies such as NIE and NEH

--with other significantly analogous federally-supported centers or networks (e.g., the ARPA Net; the National Bureau of Economic Research center; CONDUIT; NCAR)

--with existing possible host networks

ii. with professional organizations (e.g., American Council of Learned Societies, and its Committee on Information Technology; Social Science Research Council; Center for Applied Linguistics)

iii. with professional societies and associations (e.g., Linguistics Society of America; American Sociological Association, sociolinguistics section; American Psychological Association, psycholinguistics section; Modern Language Association; American Society for Information Science; Association for Computing Machinery, and its Special Interest Group on Language Analysis. . ., and other appropriate SIGs; American Education Research Association; American Anthropological Association; Association of American Library Schools), including regional groups

iv. with existing foci of research activity for the use of the computer in the study of language/symbolic behavior (e.g., major grant sites; institutes; universities; departments; industrial and non-profit research laboratories)

v. with the class of prospective individual network users (not at probable network nodes, and not associated with major, current group research efforts) who might wish to achieve some single-terminal access

vi. with state and regional networks for academic computing

A. 1. c. to plan for staff recruitment, with reference to

i. projected needs for personnel by type, and over time

ii. personnel budgets

iii. procedures to be used in seeking personnel

iv. initiation of efforts for the first-phase professional/staff cadre

d. to plan with prospective users for meeting their research-assistance requirements, including

i. publications
e.g., a newsletter on Ce/NCoReL activities, network protocols and expositions of them, a technical report series, the network itself as a 'publication' medium

ii. procedures for joining the network

iii. research design aid

iv. statistical and mathematical aid

v. programming aid

vi. (a)periodic studies and information exchanging as to additional and/or substitute software and data set development and implementation

vii. short-course and summer institute training opportunities

viii. fellowship-type provisions for graduate-students and for faculty and other researchers, including service and personnel exchange arrangements

ix. technical conferences

x. staff assistance in developing new research proposals

e. to plan for the operation of a technology transfer effort with responsibilities in

i. identifying and forecasting both applications and requirements for post-research (and extra-pedagogic) utilization of Ce/NCoReL results

ii. facilitating the effective utilization of Ce/NCoReL research results

A. 1. f. to plan in detail how the Ce/NCoReL start-up and operational experience--both organizational and technical--can be utilized in the planning and implementation of other network developments

i. through studies and assessments of Ce/NCoReL activity

ii. --through establishment and assignment of inter-network liaison functions as a regular, ongoing activity

--through (a)periodic conferences with representatives from advisory committees of other networks

A. 2. Responsiveness Characteristics

a. Ce/NCoReL commitments to users as to

i. access conditions, including
--types of required protocols
--turn-around times
--file integrity
--file-security
--available software

ii. file-return provisions

iii. data-sets available

iv. software available

v. network information availability (Cf. SRI-Engelbart within ARPA Net)

vi. communication facilities

b. Participant opportunities/obligations re

i. software validation

ii. software distribution

iii. data-set formatting

iv. data-set access

(See also A.1.d.)

c. Non-research academic network utilization (e.g., CAI; science/technology transfer)

i. opportunities

A. 2. c. ii. priorities

iii. costs

B. Planning for Policy: development of high-priority tentative agendas for advisory panel/Advisory Committee program and policy determinations, including, for example,

1. details of preferred scale and scope of Ce/NCoReL activities at the end of its first 3-5 years; and projections for one or more such subsequent periods

2. a. preferred mix of types of research activity

b. sequential timing of major Ce/NCoReL-sponsored research undertakings

3. long-term relations to host network(s)

4. budget-cycles and procedures

5. staff personnel accountability and evaluation

6. safeguards for responsiveness to user needs (e.g., the possibility of general network assemblies--face-to-face and/or over the system)

C. Technical Planning

1. a. to develop a rank-ordered list of technical properties desired in a computer network capability for language analysis

b. to project alternative ways of meeting the conditions specified in A.1.a.: e.g., trade-offs between acquiring dedicated computer capacity at one or more sites over against utilizing capabilities of one or more existing or projected networks

2. to establish a 3 to 5 year technical prospectus, priority list, and 'critical path' plan as to types of capabilities to be developed to serve the user community, including

a. i. the systems/interfacing programming for utilizing existing network capabilities

ii. the systems/interfacing programming for developing new network capabilities

b. the standardization and storage of extensive language/symbol system data sets, both written and 'recorded'

C. 2. c. the validation of production-run software and promising software in the development stage

d. the development of new software routines and packages

e. a hardware study effort re new capabilities specifically needed for language analysis

f. a user-interface study effort to fully specify peripherals, their distribution, and human factors engineering requirements needed for effective compatability with user work habits, work situations, and unmet needs

g. a programming-language study group (e.g., re directed-graph parsing facilitation)

CENTER AND/OR NETWORK: SUMMARY AND RECOMMENDATIONS

Throughout the course of this study and this report the issue of whether a Ce/NCoReL should be primarily a center or primarily a network has received focal attention. Some of the issues have been mentioned in earlier chapters--especially the sections concerned with software, hardware, and organization. There has been, however, no opportunity to summarize other aspects of commentary concerning the optimal form a Ce/NCoReL should take. The summation which follows is by no means exhaustive, but it does, we believe, accurately represent the range of views and the intensity of those views on this issue.

First, statements favoring a network:

A network will facilitate communication and creativity:

"A network should allow us to look at each other's work to see how someone else, either historically or currently, attempted to recognize patterns, and a network should help us to develop tools with which we can change methodologies and categories for such applications. . .The generality of methods is of interest to me. This is another thing a network can promote." (Conference, April 23, 1972)

"I think one of the things that will happen when you put up a large-scale network like this is that a lot of people are going to be seduced into communicating with each other who wouldn't have communicated before. Computational linguists will find, for example, that they would like to try out somebody's system in California, but in order to try it out they must first learn something about that system. To do so they will talk to a linguist in California who has used the system. There will be many social benefits from a system like this. . ." (Conference, February 13, 1972)

"Once you have a network, once you can share the data, there are many other things you can find of value--shared operations, interactive support, plus the intellectual dialogue that goes on between people; as yet we are hardly aware of the potential. . ." (Conference, April 9, 1972)

"We are learning in the network experiment how to support a geographically distributed group which has common interests." (Conference, April 9, 1972)

With reference to network communication concerning program use and status: "Admittedly in the batch mode the difficulty of distributing manuals is very great, but in the case of the interactive program it should be possible to have the program communicate with you and leave messages when something has been changed or a bug has been found. . .So I think if one approaches a network with the notion that its special characteristics and potential should be used, you stand to gain very substantially over what you would get if you simply thought in terms of existing facilities connected by a communications link." (Conference, April 9, 1972)

"Access to the facilities should be easy, complete, and encouraged, contingent of course on space and funding. Such an enterprise should not be viewed as a self-contained entity no matter how valuable its products might prove to be. Rather, it should accept as a major charge the responsibility for inspiring and transpiring its results into the outside community. It is for this reason as much as any other that I favor a network structure. In principle, the net provides for indefinite expansion of any initial implementation. Decisions obviously have to be made on particular circumstances, but the principle should embody acceptance, whatever the source of funding (respecting political sensitivites). . .All the preceding

inclines me toward a network. My involvement in an ARPA project which includes as an integral part of its Work Statement the requirement to cooperate through a network with several other institutions in the research and development of a speech and understanding system may bias me. However, I rather think that reflections on the implications for organization of the fact that the focus would be on computer-based research on language makes the bias more rational. What I would like to see is support for somewhat larger local aggregates of people with varieties of activities going on at each site linked by a network, and with support for a substantial program intended both to forge the connective tissue that will make the network work and to educate people in its use." (Letter)

"I think people are more creative when interacting with other people than when working in isolation." (Conference, June 18, 1972)

Another general argument for networks is that a network reduces unnecessary duplication:

"The third argument for a network is the frightening prospect of duplication of effort at one or two hundred sites around the country and [per contra] the possibility of this being avoided through a cooperative, network effort. The possibility of some specialization is absolutely essential if we are going to make very much progress; the limited resources we have available really militate for some change in our approach." (Conference, February 13, 1972)

"One of the reasons for having the network is the hope that you'll avoid duplication of effort. If you knew how many time-sharing systems are developed, how many LISPs are developed simply because a user doesn't have access to one already in existence, then you'd begin to see that there is a lot of duplication of effort." (Conference, February 13, 1972)

"We have had at the universities an ingrained sense of trying to do everything at 'home' for prestige and practical reasons and we are going to have to break out of that habit; I think the network presents an opportunity to do so. As large-scale number-crunching computation becomes available on the network, we may be able to farm some of that stuff out and we won't all have to have number-crunching computers. . .The reasons the universities are in trouble is that they have tried to be all things to all people." (Conference, April 9, 1972)

"One of the justifications for the network is that there are some things we want to do that we can't do at home. Rather than beefing up our computing center to handle them we much prefer to set it up so that we can go somewhere else; we don't want the user to be tied necessarily to the local center. This seems to me to be important." (Conference, April 23, 1972)

"It would be very nice to have a network that researchers could tie into all over the country, especially for providing a centralization of data and document distribution, thus eliminating much of the duplication of such fundamental things as accumulating a lexicon, grammar, or even machine-readable text, and cutting the time now necessary to find out who is doing what." (Letter)

Thus, a network is seen as a guard against unnecessary duplication, but at the same time it is also seen as making available needed redundancy for some applications. One conferee, when talking of his efforts to distribute computer-assisted instruction across a network in order to achieve greater responsiveness, also noted that a network provides necessary redundancy so that if a given node goes down the user need not be left without other resources.

Another conferee touched on an analogous issue when speaking of the lack of continuity for a researcher even at his "home" computer: "At my university in three years I think we converted our programs three times. And when you were talking about 2.5 million records you were blowing a lot of money just in converting." (Conference, April 23, 1972)

Several people commented on the desirability of a network for a research effort implying a great range of processing tasks:

"We don't really know where language analysis is going to go. . .We don't really have any very good models. We are kind of flying by the seat of our pants. . .A great deal of number-crunching may be involved in trying to trace paths, trying to loop ring structures and things of this sort. So I think that any single-purpose computing facility will not ultimately be adequate for the kinds of problems involved. The nature of the problem in the present state of research demands that we have a multi-purpose kind of system which is probably not possible on a given machine." (Conference, April 9, 1972)

In response to the above remarks another conferee stated: "Given your remark about models, there is a consequence, or several consequences. One is that you cannot say exactly what kind of arithmetic or logical operations you may want to perform at the present time and certainly what you may want to do in the future. This means that you may not know what kind of machine you want, or that you'll, in fact, want a computer in the conventional sense. Judging from our own experience there are a number of things that can enter into the choice of a machine or the type of machine; we can anticipate fairly well simply on the basis of having well-defined models, the kinds of characteristics desired. . .What I am leading up to is the thought that in language

studies and, to some extent, in the social sciences when it is not possible to say at the present time what kind of facilities you need, there is in fact a particular kind of advantage in a network where you have a wide variety of choices of types of facilities from which you can choose. This vitiates a lot of my criticism [of networks in contrast to centers] this morning." (Conference, April 9, 1972)

The necessity and desirability of diversity and thus, in the opinion of some, of a network rather than a center, is also alluded to by another researcher when he notes that "one would not want all the good guys in one place." (Letter)

One scholar argues for a network with a dedicated node when he specifies that a Ce/NCoReL should be "single site (at the place with the lowest overhead charge) connected to other sites by network with central site grant paying CPU and line charges and users either getting own grants for terminals or with provision for seed grants to researchers and other universities from a portion of the main grant, or travel and visit grants, or both." (Letter)

A number of comments among which might be included those already cited concerning avoidance of duplication, argue that a network will have real advantages in terms of economy of scale: during the meeting on February 13th, one conferee referred to the much larger population of people who would be able to contribute some use time. In response to a question concerning the impact of very cheap, small computers on the network concept, the answer was: "I would claim that as processors become less expensive, the need and desire for networking will increase because now the processors will be propagating in places they've never been before, like my house. While I may have the processing power I will need, I won't have access to information. I cer-

tainly will not store everything I want in my house, especially since most of that information happens somewhere else."

Also during the meeting of February 13th, in seconding the suggestion that a network would facilitate communication among scholars and scientists, another conferee suggested that such increased communication might lower the possible danger of rigidity and inefficient operation at a Ce/NCoReL, because of the advantage of a sufficient number of people who see the uses to which computing capacity can be put; and that, in turn, constitutes a reason for producing something which is better--"whereas when we're isolated one from another the ability to get that sort of [better] thing is reduced." (Conference, April 9, 1972)

Again, on the topic of economy of scale, a national network was contrasted with an individual center or regional network tied into one large computer: "We can talk to people in far away parts of the country who are interested in hooking into us, but it's just out of the question to rent the phone line. . .We see in the long run that the network is something a person can hook in on occasionally when he wants to look at something that's available at the other end of the country. . .It is also clear that many of the computer requirements for an individual institution, for instance, its own information management systems, will continue to be provided by local computers. There seems to be some kind of mix. Some things you will do yourself and some you will go out on a network to do. I don't know what the dividing line is and I suspect we won't really know until we build a network and see what people actually do." (Conference, April 9, 1972)

Looking at another aspect of economy of scale--personnel--a conferee pointed out "it just may be possible that it is not economically feasible to

hire the level of expertise you'd like to have on a full-time basis and bring these people together at some central location. But it may be feasible to purchase one-fourth of the person's time, so that a group of people all over the country could work at a task for a given number of hours per week collaborating through some communication channel."(Conference, April 9, 1972)

On the question of funding a network one conference participant stated that an initial subsidy would certainly be needed, but that at a certain point in time it should disappear. Another conference participant argued that there should be expectations of continued subsidy for such a communication and research network, just as there is continuing subsidy for the maintenance of waterways and highways.

The comments above, when combined with statements in the section on software concerning program portability and those in hardware concerning diversity and reliability, constitute major arguments for a network.

Arguments for a center rather than a network, advanced by relatively few prospective Ce/NCoReL users but, nonetheless, very vigorously pressed, primarily center upon the delay in availability and upon the effort implementing a network would imply, simply because much network software technology remains to be developed (see chapter on software). Another argument against a network, made by one individual, was that it might reduce research diversity by providing for too much communication among researchers. A third argument opposes all networks in principle because of a conviction that they might be used improperly for surveillance and other potentially socially-damaging activities.

One user concerned about inefficiencies posed by attempts to have a network urged that a network theorist be included among consultants, going

on to urge that we "envision the case where there are perhaps 10,000 people trying to use a network--there are horrible pitfalls." This same individual added that "if I want to go to a new system I've got to have guarantees about long-term stability and I will not take pie in the sky. I really like a five year commitment so that I can have faith in the future. I would never undertake to do my work in a network until at least five years beyond the state of the technology as it currently seems to exist. [On the question of duplication of effort] Can the cross-over point in the state of development really be pinpointed--at what point it is really worth the extra hassle--at what point and level of development can the claim be made that in general there is a savings over doing it oneself. . . ? I would like to see, if a network really seems desirable: first a dedicated computer only for linguistic research and everyone tying into one place and perhaps coming out to visit. That would pick up most of the advantage foreseen in the network. Then in five years, that system could be linked into a network after the network had been developed." (Conference, February 13, 1972)

Some of the statements favoring a center can be taken as arguments against a network, although this is not true in all cases.

On the grounds of cost efficiency, a scientist associated with a center stated that "looking at it from the strictly economic point of view it turned out that the cheapest alternative (one, a center; two, terminals for remote job entry; three, a network) is simply to pay travel expenses to have people come to the center. . .A disadvantage and, in fact, the only disadvantage with the first of these alternatives. . .is the fact that many of the people who want to use the machine teach classes. . .That's a disadvantage from their point of view, but there is an advantage from our point of view and

probably from the outside user's point of view--that is, that we establish human contact with these people while they are at the center. In fact one of the objectives of the center is to try to maintain a continual flow of people through the center from outside at all times."

One argument for a center which is not necessarily an argument against a network is that "if you start your own computing center you can set it up so that it is doing the things you want right from the start." (Conference, April 23, 1972)

Another statement can be taken as an argument for either a center or a network: "It seems to me that the importance of off-site locations for scientists and advanced students is considerable. For to have access to the system without journeying halfway across the world (with necessity of getting subsidization for travel) it would be very desirable if there were some way that they could have access to computers at a few strategic places scattered throughout the world. My feeling is that in this respect, the program should be limited only by resources and funding available to make the program possible on a world-wide scale." (Letter)

Among the nearly 250 people who either wrote letters concerning a prospective Ce/NCoReL, in whatever form, or talked with the principal investigators concerning such an effort, only six responded negatively. Of these six, one later modified his reaction stating he would be glad to cooperate with such an effort; two others misunderstood the proposed goals, one thinking apparently that the issue was a center for research in the humanities and the other that it was to be a center for natural language research, excluding other symbol systems. In fact, this individual argued for exactly what we're proposing. Another simply thought the whole undertaking was impos-

sible (he didn't say why). We will now cite, almost in toto, a negative statement made by another of the six, most especially because his second point was specifically raised by a number of people who support a prospective Ce/NCoReL and, in fact, this point might be said to concern all of us:

"There are two main problems: first, such a center could lead to excessive standardization; second, such a center would commit a large portion of the financial support available for language research to a single center out of reach of many scholars.

"A center might succeed in sciences which have reached an advanced degree of development, such as nuclear physics or astronomy. Perhaps one could succeed in a reasonably advanced but more narrowly defined field such as cancer research. But linguistics has not reached that point, particularly if we construe the field as broadly as you propose. I have observed two language research centers at two different universities. Both attempted to be broadly useful, but neither succeeded for very long. One of them was a computer-based center, a small-scale version of what you suggest. It fared the worst, because it necessarily made more rigid commitments to particular methods.

"To the extent that funds are committed to such a center, those who are not associated with the center will be the poorer. I realize that. . . [one envisions] an open facility which would provide services to all, but this is unrealistic. The services provided could never be the ones wanted by everyone and not everyone would be in a position to decide what new services should be added. It would be necessary to provide those for which demand was greatest, and these will not always be the most productive. There is still room in language research for all the new ideas we can get." (Letter)

In response to the latter point--that is, taking money out of one pocket to put in another--our assumption and that of others has been that as the field becomes more visible and the importance of its research implications more apparent, relatively speaking at least, actual funding for all will increase. This in fact has been the case for NCAR, a major available analog to the proposed Ce/NCoReL. A scientist associated with NCAR has noted that "when the center [NCAR] was initially in the planning stage and early development, there was a period of a great deal of concern from the university community about this money coming out of one big pot that they all shared in. But they gradually learned that as a result of the establishment of the center, the visibility of the field became sufficiently large so that the whole total amount of support for the atmospheric sciences increased and the university support has increased."

The fear of excessive standardization is again something with which we are all concerned. Statements on this topic have been made throughout this report and some of them will be reiterated in the next section of this summary chapter. One question which might be asked here, though, is whether the situation as it <u>currently exists</u> does not promote undesirable and excessive standardization. One suspects, for example, that individuals working in relative isolation may tend to accept a popular theory simply because it is popular and because they have neither the means nor the skill for testing it sufficiently so as to thoroughly evaluate it or even disprove it, if it should be disproven. And, in the field of computer-based studies of symbol systems/languages, it is all too apparent that undesirable software and hardware standards have been imposed upon researchers and scholars in this field because of the needs of scholars and scientists in other fields and of yet other

people who were more able to apply effective pressure than have been the relatively isolated scholars and scientists concerned with languages/symbol systems.

Tentative Recommendations

The remarks which follow perhaps might better be termed suggestions rather than recommendations. A later stage of development for a Ce/NCoReL would entail the making of concrete decisions for implementation. At that point, many people would be involved; thus these recommendations can only be quite general and obviously in no sense prescriptive.

The goals of a Ce/NCoReL have been defined primarily in terms of research on a broad range of symbol systems/languages. Research on some of these symbol systems is further advanced than the research on others, and it is to be hoped that a Ce/NCoReL would facilitate, when appropriate, the use of methodologies proven for one symbol system for the study of others. It is also to be hoped that efforts to work on a range of symbol systems will prompt the development of new methodologies which will enable us to characterize more comprehensively than has hitherto been possible any symbol system. A sizable majority of prospective Ce/NCoReL users have indicated strong sympathy for what would constitute an interdisciplinary or metadisciplinary approach to the study of languages/symbol systems.

What is the configuration and organization which will best foster the goals of a Ce/NCoReL? In our judgement, the single best solution would be to combine the virtues of a center and a network. That is, there should be at least one central place for bringing people together for training institutes (if there are such), for seminars and conferences, and for advanced

study and research leaves, as well as for handling general administrative oversight for a Ce/NCoReL. It may well be that this "center" should have a computer which would be always available to researchers in the Ce/NCoReL research area; or, minimally, it should have access to a computer for which a certain number of hours would be regularly committed and available for Ce/NCoReL-type processing.

But a Ce/NCoReL should also either comprise part of a network (a 'virtual' network) or have access to a network. Networking would mean that groups of scholars and scientists could concentrate on specific types of research at particular nodes while, at the same time, isolated scholars or scientists could have access to one of the nodes or to the center computer, if there were such. If researchers at a particular node either had a computer of their own or had access to a computer at their home site, they might well choose to do much of their computing at "home." But, if they had no computer, or the computer at their home site were not appropriate for the tasks they wished to undertake, they could then use some other computing facility within the net which a Ce/NCoReL either formed or was affiliated with. Additionally, they might wish to use some other computer because of the programs, data bases, or both resident at that computer. Thus, networking should help maintain diversity while, at the same time, making cooperation available when desired.

A Ce/NCoReL presumably would develop in stages, and the characteristics of each stage would obviously depend upon the scholars and scientists wishing to be involved and their needs. If, for example, there were nuclei of scientists and scholars at various sites who shared certain goals and who needed a particular hardware configuration, it would be desirable either to try to

provide that configuration at one of the sites or to seek to have a configuration at the Ce/NCoReL "center" which would meet their needs.

It should be borne in mind that if a Ce/NCoReL begins as nodes within a network and if there is no one central computer on which users can count for reliable service on at least certain types of tasks, the lag between setting up a Ce/NCoReL and achieving any sophisticated level of cooperation among nodal research groups will in all likelihood be considerable. The latter will be the case simply because some sophisticated network system problems have not yet been solved. And we must also assume that as use of any network increases (as, for example, with stable service use in teaching) new problems will emerge which may require more demanding solutions than does the problem of increased usage on a single computer.

In the long run, some concept of networking seems desirable because it will presumably minimize the software portability problem, because it will economically provide the range of necessary facilities for prospective Ce/NCoReL users, and because its potential for synergistic impact is much greater than that of a single isolated center, no matter how good the center. On the other hand, a decision to go solely with a network promises delays and frustration, if not disenchantment, with the implications of the computer for the analysis of languages/symbol systems. We would urge the combination of a center, or a dedicated node, along with a multi-stage network development--so as to have the presumed faster and more reliable facilities made available by the center, but to have also the greater long-term scope and computing power made available through a network.

Some more specific recommendations for an immediate next stage in organizing a Ce/NCoReL effort are embodied above at the close of the chapter on Organization.

APPENDIX I

The following three sections--I.A., "Knowledge Systemics" by Walter A. Sedelow, Jr. and I.B., "Humanities Applications" and I.C., "Arts Applications" by Sally Yeates Sedelow--are included (i) to emphasize the importance of a Ce/NCoReL for education (I.A.), in ways additional to those cited in the chapter on Research Emphases and Implications, and (ii) to summarize research implications and applications in the Humanities (I.B.) and the Arts (I.C.) (Cf. references in Research Emphases chapter). Articles I.B. and I.C. are to appear later in The Encyclopedia of Computer Science, edited by Anthony Ralston, and to be published by Auerbach (Philadelphia, Pennsylvania).

KNOWLEDGE SYSTEMICS

KNOWLEDGE SYSTEMICS

In addition to the importance of a Ce/NCoReL for the basic and applied research discussed elsewhere in this report in some detail, another strongly motivating factor for our interest in a Ce/NCoReL is its importance for an educational program (particularly an undergraduate studies program). Such an educational focus as is proposed here would be heavily dependent upon knowledge concerning languages/symbol systems toward which Ce/NCoReL research would be directed. In fact, knowledge of the nature of information and of information transfer--one way of characterizing Ce/NCoReL research--is central to this "application" area, i.e., a new and socially significant higher education option. This option would make for a more coherent and "relevant" intellectual experience for the student. There follows a statement concerning the rationale and structure of this "Knowledge Systemics" approach to education.

Feelings about planning are mixed, and rightly so. We are all concerned lest we inadvertently plan ourselves into a box from which we would find it difficult to escape. And yet the alternative to coherent foresight clearly is a chaos too humanly expensive to envision. It even might be argued that the symbolic modelling of processes so as to establish outcomes in advance of actions is the central need of our day, increasingly (albeit implicitly) the main thrust of education, and a major point of convergence for many newly emphasized values in personal and group behavior.

Our behavior becomes more technologically implicated as we attempt to meet the complex and increasing expectations and aspirations of our neighbors at all distances. A seemingly inevitable by-product of the effort to avoid the consequences of thoughts and other behaviors frustrated by obdu-

racy in realities to be moulded is a logistics of knowledge, one component of a science of knowledge. In advance of ego-involving commitments to the realization of goals, or even of comparatively unstructured expectations and aspirations, we need to provide and utilize the appropriate resources of knowledge as to their various costs and other implications. To do so entails, inter alia, an effective modelling of the knowledge needs of entities of varying scale if they are to maintain steady-state and non-degraded characteristics when differing types and ranges of demand are levied against them.

In short, for individuals, organizations, institutions, and polities forethought needs to be taken to make provision for their needs in knowledge, if criteria for goals and system functioning are to be met. When human demands on the total environment were less pressing the ratio of knowledge to action was lower, and there was less need--and awareness of need--to plan for the provision of knowledge as a resource for social and personal action. Today the world situation has changed, and is more rapidly changing, into one in which there are great penalties in intraneural functioning--i.e., alarmingly severe frustrations with their attendant social and personal ills--when social logistics analyses have not adequately included knowledge requirements in plans for effective and satisfying action.

Since knowledge keeps growing, and we do not have adequate models even for the assuredly accurate prediction of rates of increase, and since the future behavior of knowledge-using groups and individuals is highly problematic, there is a necessarily great measure of uncertainty about the relevance of particular knowledge-system logistic estimates, as some function of the futurity of their application. But intellectual inaction is no

proper response to this factor of ignorance. Actually, science/scientific knowledge is essentially generated out of such efforts to effectively model imperfectly understood processes; and, for some, to carry further that sort of idea, science is ultimately an effort to refine stochastic models into determinate models. But since for all the foreseeable future it is contingency analysis that we may work toward, our problem is the more manageable: thus we must consistently indicate that any given logistical assessment of knowledge sub-system needs is contingent upon thus-and-such specific conditions (including particular goals and any criteria for establishing their realization).

In seeking successfully to estimate the knowledge sub-system requirements of systems or, more accurately, of higher order sub-systems, it is necessary to take into account prospective sub-system internal and sub-system environmental changes across time, as well as, of course, considering the putative interactions between the parameters of the higher order sub-system and the knowledge sub-system under any given set of conditions (i.e., at any given 'time'). The complexity and number of such inter-correlations among state values frequently makes almost mandatory the use of the computer for accurate modelling; in principle, paper and pencil computations might be carried out, but in practice the cost of doing so would be so high that the task would not be undertaken.

When, approximately a decade ago, military systems analysts began developing the concept of the personnel sub-system, a dispute emerged between those who regarded the personnel within a complex man-machine system as a sub-system in themselves and those who conceptualized human factors as rather pervasively distributed throughout the system as a whole--as not constituting

a true (isolable, primarily intra-active) sub-system, but rather a set of dimensionalities relevant, even critical, for the parametrics of many different sub-systems within a system. As we seek to understand knowledge in its systemic relationships, and information as a knowledge component, both of those types of verbal formulations probably will have their utility: modelling knowledge as, analytically, (1) a sub-system(s) within a set of non-mutually-exclusive man-machine systems, social systems, and eco-systems, and (2) a set of parameters entailed more or less tenuously/directly, in some sense, in every system and/or sub-system--although not always well understood as sufficiently isolable and intra-active to meet strict criteria as a sub-system, but nonetheless at times loosely called a sub-system in virtue of the cohesiveness and criticality of the dimensions in question. Parsimoniously put, information is energy which in its consequences--as perceived through a formal model--is above some conventional boundary-level as to the ratio of quantified out-put to in-put. Information, then, as distinct from knowledge, may be well-discussed on a 'black box' basis without reference to a processor--irrespective, that is, of whether the processor would be an organismic or a fabricated processing unit. Thus, information is in essence an energy interchange phenomenon and may be increasingly well understood as such with general physical process models; but with knowledge we have a systemic phenomenon involving processors, information, and environments inter-related in one or more types of loops.

In attempting to establish over time the logistical implications of a social system for its knowledge sub-system, it is necessary to consider not only the detailed formal education needed by personnel as of a near-present, but for some determinate future as well. It is necessary--increasingly

necessary--to regard formal education as a base on which to build career-long continuing education, which itself merges with the provision for meeting the day-to-day information requirements of the members of a political entity, an institution, or an organization. At a certain level of abstraction the information-system requirements of even a production-oriented organization begin to look less and less unlike those of a research and development group or an educational institution. This approximation to a common information system model for so many organized groups in our society loosely indexes the increased knowledge-dependency of our behavior, almost irrespective of role. And, further, in the way that information is processed we may find the increased dominance of scientific knowledge systems over others. To some it may even seem that we are moving toward a re-integration of culture, albeit by different routes and for different goals than certain earlier exponents of such an achievement urged.

In accounting for the increased similarities between educational organizations and other organizations, we note it is not only that the 'campus' is becoming more operative as a model for other than educational functions, but that formal education may appear to be just beginning a great transformation itself which would make it in several senses more truly social. In this transformation of schooling, individuation is the predominating new pattern. Technological innovation is creating both the demand for person-suited learning and its possibility; one may imagine that the uniformity of the classroom, with many listening to one, increasingly will be replaced by the diversity of each student moving at his own pace through the structured experiences provided by computer-assisted instruction. But computer-assisted

instruction itself will be, we may suppose, less and less a matter of 'courses' and, increasingly, a matter of complex data banks through which users may follow rather individual paths, as the answer to any given question will suggest rather different sequels of further questions to different users.

In such an educational transformation, in place of the classroom the predominant model will be, in a highly generic sense, a composite of the home, the library, the laboratory, and the studio. Ungraded instruction in the pre-collegiate years and research emphases (through honors programs, freshman research projects, etc.) in the college years are steps already being taken that lead to this new pattern in learning. But the 'library', data bank, or computer-accessible 'encyclopedia' that replaces the classroom as a characteristic setting for instruction in the years ahead will be a far more complex entity--informationally, technologically, and socially--than any analog of each that we know today. As we move toward becoming a nation of learners, of life-long students, and as more effective research is done on the learning process so that each of us may become a more efficient consumer andemployer of knowledge, then the scale of demand on our information storage facilities will reach far beyond present imagining. Knowledge logistics and, more generally, knowledge systemics will grow in salience. As those conditions are realized there will be considerable inducements for our knowledge to be stored in information transfer networks far more extensively than is being discussed today. The inter-connection of information 'stores' of different types will be one of the most striking features of national information system networks: for example, although specialized information banks may become more common during the next several

decades, studies are needed to produce the models we will require adequately to project the needed levels of access to their resources (their logistics), even by persons who are not close to them either spatially or in virtue of institutional roles; again, and to look at a markedly different aspect of this sort of development, to answer satisfactorily some of the questions a school child may ask relating to science or mathematics will require his on-line accessibility not only to a school information store, but sometimes beyond locally stored knowledge to the resources of a major, sophisticated data bank in one or more subjects or sub-disciplines.

The requirements of information transfer networks themselves and, especially, of the information retrieval systems at their nodes imply the design of computers to meet these needs. It is very common at present to take an installed computer, or range of comparable computers of which one is to be chosen for lease or purchase, and then seek to take advantage of the opportunities it affords by developing new applications (library and information retrieval applications, for example). Far more often and far more thoroughly we will want to shift computer facility variables into dependent status--indicating what characteristics would be needed in a type of computer installation within a type of knowledge system(s) in order to achieve certain social goals, letting the design of a computer depend upon these user requirements.

In a general way, then, the vast need for knowledge system studies is clear. The application of systems analysis as it is currently practised to help with solving particular problems in traditional libraries, often by bringing into action the capabilities of already available computers, is one small part of a beginning at one specific aspect of such work. Beyond

all such specific detail, we need to begin, thought-experimentally at first, to juxtapose contemporary behavioral/social/policy science with traditional procedures for estimating information needs and (as recently suggested in the Carnegie Commission's "Fourth Revolution" report) with the possibilities now afforded by the new technologies. This juxtaposition is needed so that we may adequately understand the knowledge system requirements of all sorts of organized groups (industrial, educational, governmental, medical, etc.) and polities, if they are to reach their only emergent, their developing goals; and it is a juxtaposition needed as emphatically to choose a logistically appropriate specific solution to any of these knowledge-system requirements once they are understood. The current assemblages of computers, books, buildings, equipment, procedures, and statements that at present constitute data banks and libraries are but sub-sets of the resources now becoming available through science and technology for meeting information sub-system requirements. We need to learn how to learn about putting together available knowledge resources to ensure the realization of our social goals. In a very knowledge-dependent society the facilitation of the individual's quest for information in depth is a critically important function, for the individual and for the society. To provide systemic conditions for that facilitation implies a far-reaching improvement in our understanding of human symbolic behavior and its social entailments, of language generically viewed and its pragmatics. In turn, that improvement is conditional upon the more effective utilization of the computer as the key research instrument--to symbolic behavior what the telescope was to the macro world and the microscope to the sub-visual world. Hence the urgency for language researchers distributed over many universities and other organizations to learn how to

jointly develop and employ a major computer center/network in a use environment sympathetic to their needs.

* * *

With any traditional high-culture form there can be a wealth of associated humor, chaos, and complexity beguiling to the mind and personality--beguiling for the young, and especially for those over thirty long used to positive reinforcement for certain established cultural acts. Here we have a dead weight that can pull us to perdition, for day by day and year by year the cultural deed that has been approved of may continue to provide enough satisfaction to obscure fundamental irrelevance, as with the school and university Latin requirements that lasted for centuries after pertinent writing had ceased to be preponderantly in Latin, or even more than rarely in Latin. And now we have this same problem with much contemporary collegiate education: those, students and thinkers, who see the knowledge systemic implications--even the disasters--implied by 'more of the same' do not have good and quiet ways to retard or rechannel the flow of rewards through the channels of social feed-back so as to facilitate reinforcement for what is good for decades and continents rather than only for immediate neighbors and present hours. Under the circumstances need we wonder about a dissatisfaction among intellectuals, and the occasional obstreperousness of students grown desperate with the established folly of their elders in persisting in teaching what is trivial, fragmented, ineffective and without direction-giving value?

In our culturally-favored metaphors of motion and geometry, we might say that "progress" is at stake--that unless we can provide an education

good for comprehending and refining our various environments, as we move to reach one good we may find ourselves further from others. And those other goods may be more consequential than what they have been unconsciously, unwittingly traded-off for, the proverbial "mess of pottage." In the details of daily life, repetition, cycling, continues to decrease; we aspire to helicality, to upward movement through the rounds of our days and years. For such an image of 'forward and upward through life-space' to seem appropriate, it is necessary that at least on average prior gains are not lost--and that, if possible, along no line does one regress. In an alternate locution, the life volumes within which the minds and symbolisms of man have established understanding and capability vis-a-vis nature are not only expected to expand, but in no dimension to contract. We need, in short, to so understand our total bio-socio-technical ecology in its interactiveness that we can effectively guarantee at least minimal conditions for human functioning; the most insistent demands in a hierarchy of needs must be met up to such a level that individuals have the sense and the fact of freedom for self-realization, creativity, self-transcendance. The production of tea takes precedence over the tea ceremony; a population so educated that it can readily arrange for the provision of food and drink and other necessities of life is meeting the most salient requirements for the presence of the more self-satisfying cultural forms, whether they be traditional or novel. What is unique and most significant about man's current situation is that he has broken into very complex systemic relationships--ecological, social, technological--to achieve limited ends, without having the science needed to foresee the sometimes regressive consequences of those break-throughs, and he is doing so at the very time in human history when far larger fractions of far

larger populations are forming ever more demanding expectations from their environments--from their biological, social, technical, and cultural ecology.

It is our settled conviction that for the entailed knowledge system needs to be met, a new type of curriculum of study should be made available both for undergraduate students and for graduate students. What we are arguing for is, of course, by no means a general transformation of undergraduate and graduate study, but, rather, the availability of a certain optional course of study. That course of study should make it possible for those who have successfully followed it to turn to better account than most others the capabilities of the computer for helping us to comprehend the ways and means of fitting symbolism to human need in coping with environment--to meet society's knowledge system needs. At the same time such a course of study would enable students and scientists to use the computer more adequately in the study of human symbology and its uses; it is only now, with the availability of high powered computers in configuration, that such a course of study can be undertaken. In short, the computer is the occasion for a further structural development in the character of higher education, just as it is a needed instrument in enabling us to utilize such an improved higher education for the solution of parts of problems of the highest national and international need.

It is our feeling that the need for fresh curriculum planning grows more urgent, both owing to the emergent consequences within the academic grove of a lack of suitable unifying vision and, even more, the alluded to press from the wider world on our resources of intellect. The argument we

want to advance is, in part, that what collegiate education might do is to induce competency for dealing with the inter-relatedness (systemic character) of what are perceived as salient aspects of that 'real world' which defines relevance for students today. We also think that, pedagogically, it is wise to have a curriculum which is comprehensible at a glance, as to its overall structure--and a curriculum of which the structure does not seem arbitrary.

We argue, then, for a four-year program in which in its implementation as an undergraduate course of study the freshman year is entirely given over to what we know about Man, from as many perspectives as possible and with an emphasis on Man as knower; the sophomore year, to Symbols and other inventions besides our various languages--notably computers--which serve as scientific and technological instrumentation in modelling reality; the junior year, to the study of some hunk of Reality that interests the individual student, using the understanding of man-as-a-knower and the symbolization capabilities clarified in the first two years as facilitation for a relatively sophisticated grasping and employment of accumulated scholarship relevant to a subject of prime interest to the student; and the senior year, to an intensification of the specialized, topical study of the third year, with a crucial addition, that the topic or subject of interest to the student is now also to be understood systemically with the aid of general Systems theory, cybernetics, graph theory, automata theory, field theory, and other forms of transdisciplinary abstract modelling, many of which imply rather directly the utilization of the computer itself. The better students would, in this fourth year, pick up on the topics of the sophomore year for giving attention to the properties of the formal languages in which such modelling is done.

Whether it is with respect to a conventional academic topic or a 'real world' problem, it looks to us as though skills and understanding as to the inter-relatedness of reality are a central need of the present day. Theory construction as a scientific undertaking quite general to many disciplines is an example of a type of skill needed for that understanding of the inter-relatedness of reality which we postulate as a central contemporary intellectual need. Students feel this need, and in their post-student incarnations as professional people and interested citizens that need is, and certainly will be, even more important to the public welfare. A general education such as is here proposed in the first, second, and fourth years of this curriculum--a general education as to man and the symbolization and other devices he uses in relating himself to his environments--when combined with the experience starting in the third year of depth in applying that knowledge to some topic should add up to a better, more high-transfer value preparation for the change and uncertainty of the decades ahead than any currently available collegiate education.

Incidentally, the in-depth aspect of the educational scheme here proposed beginning with the third year forward should be comparable in detail with the intensity of a conventional undergraduate major, whenever such comparability is needed for articulation with the requirements of post-collegiate education. The focus on aspects of one topic each throughout the first year, the second year, and part of the fourth year should do much to provide for intellectual coherence and synergistic effects within each year of study--and also appropriately provide for a sense of community of interest among themselves which students now often seem to lament the absence

of. In addition to what we conceive to be the importance and appeal such a plan of study could have, we are also convinced of its institutional practicality: for to a considerable extent such a curriculum could be achieved by a regrouping of present courses and that should have the effect of minimizing the faculty/administration/trustee anxieties about the various costs of opening up a new program-of-studies option. Since it does make use of many current courses, but in new groupings and for additional ends, it is also practical as an option within a college that maintained a traditional curriculum--with as much or as little energy put into the new option as levels of student and faculty interest warranted.

Some of the details of this curricular design (e.g., for the freshman year the various types of information/models/research techniques re the nature of man to be pulled together from what individually might be traditional department course offerings) will be adumbrated below. The orientation which guides our development of all such detail includes the following propositions:

1. That both for general education and for advanced study preparation, in a number of critical respects the available curricular options are basically not well suited for the crisis decades ahead;

2. That there needs to be a general intellectual and academic response to the current and understandable cry for relevance;

3.a. That the computer as a device used in research and teaching apropos man's attempt to develop symbolism appropriate to his efforts at coping with his total environment is one of the central and critically important features of such a curriculum;

3.b. That the research fostered by an aggressive and effective Ce/NCoReL could have critically important curricular implications in helping us all to gain needed understanding of symbol systems--their syntactics, semantics, and pragmatics, as well as language design and architecture suited to both the landscape of the mind and that of external reality;

4. That the financial condition of the colleges indicates the need to consider again a 'core education approach,' partly because of its economies;

5. That both society at large and (prospective) college students in particular would be the more interested and motivated by a curriculum which was, ceteris paribus, intellectually comprehensible as a totality and self-evidently vital (through being adjusted to present felt social/human needs for the future);

6. That, especially as to the general content of the fourth year, the intellectual progress of recent decades opens up powerful new possibilities for higher education which are germane to meeting the concern for relevance and competence among students as well as the concern for vision, technique, and adjustability in dealing post-collegiately with the tangled skein of today's and tomorrow's world; and that, further, such intellectual progress is intimately, even symbiotically, related to the utilization of the computer as a research instrument for studying human language in its most generic form;

7. That although there have been some efforts which, in effect, point in directions not utterly far afield from those which this curriculum is meant to head us toward, from the present perspective they are encouraging

and desirable but not yet sufficient; the curricular developments at the University of California at Santa Cruz, particularly with respect to the study of the history of consciousness and the forms of consciousness are a good instance of progress in this general direction, as is also true for the more scientifically-oriented program in graduate studies relating to Cognitive Sciences at the University of California at Irvine; two instances of thinking about computer science as to its nature and curricula that also share something of this orientation are to be found in the address which Allen Perlis gave to the annual meeting of the biomedical section of the ACM, in conjunction with a Southeastern Regional ACM meeting, at the University of North Carolina at the Chapel Hill campus in 1968 and in the article in the June, 1971, issue (Vol. 14, No. 6, pp. 391-401) of the Communications of the ACM by Saul Amarel, "Computer Science: A Conceptual Framework for Curriculum Planning".

Now we turn to a slightly fuller discussion of the actual content of this proposed program of studies. And it is to be borne in mind that while this program of studies is here presented as appropriate for the undergraduate collegiate experience, with suitable modifications in coverage and in depth and in what can be taken for granted, it is also suitable as the definition of a program of study at the graduate level, as well as for various types of interdisciplinary degrees.

In the first year the emphasis in this course of study--which, overall, is focused on how man learns and knows--would be on the nature of man himself. The effort would be to answer the question What is man? from every point of view which can be mustered. One approach to answering that question

is by way of the biological sciences where one might seek to understand man anatomically and physiologically, and to do so in a phylogenetic context. Here, too, one might strive to understand man with the models of chemistry as well as those of physics. The chief focus would be on man neurologically, on man from a bio-psychological point of view, since the overall function of this curriculum is to enhance competence apropos man as one who knows. The neural sciences program under the direction of Professor Pribram at Stanford might well serve as a source of ideas as to how to organize some aspects of this part of the curriculum. The medical school at the University of California at San Diego is also developing an integration of the biological sciences as they apply to man neurally viewed. More particularly, one would understand neural functioning not only using the electronic models of circuits and switches but also what we know from neurochemistry, neuropharmacology, endocrinology, etc. In the social science departments at the University of California at San Diego there is also an interest in understanding man as an information processor, and those models, borrowing richly from information science ideas, should also be of prime interest. Other, obvious approaches to the nature of man as knower would lead us into the literature of philosophy and, more particularly, to epistemology; it would lead us, likewise, into theology. And for each of those disciplines, as well as for the others which we would use, an examination of the contributions in an historical context would also be appropriate; that is to say, one is interested not only in the current sets of ideas available philosophically and theologically and otherwise about the nature of man, but one is also interested in the way these ideas have developed historically. Naturally,

one would expect such approaches to be effectively cross-cultural, so that one would seek to know what high-cultural traditions other than our own have had to say on the nature of man. Of course, the social sciences would be levied upon heavily for further facets of our understanding of man: notably sociology and anthropology, in part for their cross-cultural perspectives. Those newer approaches within sociology and anthropology which we think of as the ethnoscientific approaches (including, of course, ethnomethodology, certain applications of phenomenology, and the cognitive sciences approach of the University of California at Irvine) offer interesting leads. And in addition to getting a sense of man socially and culturally and psychologically and biologically from those respective disciplines, students in this program would seek for further understanding through the various images of man that have been conveyed by the different arts in their realizations in diverse cultural traditions: man in painting, man in sculpture, etc.

In the second year of this curriculum the focus would be very directly upon the topics which provide one of the major intellectual fields to be tilled in a research way by a center or network for computational research on language. As indicated earlier, in this second year the students would concentrate on symbol systems--the languages, that is, and the other instrumentation which people have developed for understanding. We are looking, then, at the prosthetic devices which men have generated in their efforts to more closely comprehend themselves in their environments. That second year, thus, would be a time when various sorts of relatively designed languages are studied, such as logic and programming languages and various types of mathematics, including graphs as a language and especially directed

graphs. It is at this point in the curriculum also when both natural languages and the generalized study of them, by which we mean linguistics, would be to the fore. Given the emphasis of the curriculum as a whole, it is not surprising that an appropriate question at this point in it should be What characteristics of languages does man need for most effective instrumental interaction with his environment, given the characteristics of man and the characteristics of symbol systems?--so that, thereby, one type of question raised would be the setting of criteria for the design of possible new languages for men to use. At this stage, too, attention would be directed to other aspects of man's symbol system behavior. Not only should one look at the various kinds of notational modes, such as alphabets and symbol systems and logical notation systems, which underlie various sorts of languages; but one should look also at icon repertories which have been used in various aesthetic traditions to convey the iconographic content of art. Inasmuch as it may be argued that the style-content dichotomy is a false one, then one would also wish to pursue at this point an introduction to stylistics, more particularly stylistics across any number of different aesthetic modalities within any one culture. Music, particularly in its written form, could be examined as a symbol system as, indeed, other special purpose systems of symbols such as Braille or choreographic notation. And, at this time, in looking at technology insofar as it has been instrumentation for knowledge--such as surveying instruments, telescopes, microscopes--one would also introduce the nature and history of computers and other computing devices. Finally, some general issues would be raised, including those having to do with the nature of symbolism. Is the notion of symbols or languages a

bogus one? For example, in principle are they differentiable by a machine from the rest of reality and, if so, how?

Insofar as this overall course of study was being used solely for the purposes of a general education fit for the times, it would not be strictly necessary, albeit still desirable, to utilize the third year program discussed briefly below. Thus, without the third year's opportunity to begin an intensive study of some part of the environment or world of interest to a student, the program of study as a whole would be fully committed to the acquisition of the more general kinds of competence for dealing with man as a learner and as a knower (coping with coherent components of his environment through familiarity with the ideas and techniques appropriate for comprehending wholes): first the nature of man, then the nature of his general symbolic techniques, and, finally, his armamentarium for coping with wholes, Gestalts, and systems.

Here we discuss the third year of a four-year program of studies; and in that year the student begins to move toward depth in some aspect of his emerging competence. This third year in which the student is encouraged to develop knowledge about some specific aspect of reality may be used to pursue what amounts to a conventional academic major, the latter part of which would be completed the fourth year. Or the student may choose some theme, topic, or problem that is of interest to him--what would normally be considered an interdisciplinary major in a school where a definition of what was an acceptable equivalent for a major was a very ample one. But whatever he chooses to learn as much about as he can, the student beginning with his third year should find his efforts markedly facilitated by the two major elements in his education which he would have behind him in this course of

study: a relatively systematic introduction to the nature of man himself, especially in his noetic aspect and, secondly, his relatively systematic exposure to the nature of human symbolism and other devices utilizable by man to know. Notable among those devices studied in the second year would be the computer. For such students as did not themselves already have a commitment by the third year to gaining competence in depth of any particular sort, we would encourage the choice of some environmentally relevant topic, as being not only of topical and enduring significance for each educated person but also as being well suited for the exemplification of the type of understanding which is being sought here. For this part of the curriculum, it may be that the experience of the University of Wisconsin campus at Green Bay will prove to be a source of very interesting ideas for students, faculty, and staff concerned with the education of the third year. In drawing together the experience of the student toward the end of that third year, he might find it useful to begin to try to answer questions of this sort: Given the design of man and given the design of some aspect of his environment, what specific developments in the design of his knowledge, and, more especially in the design of his instrumentation and symbolism for developing knowledge, would be needed to improve the match between man and this selected aspect of his environment?

In the fourth year we urge attention to all those forms of symbolism which bear upon successfully capturing the fullness of things. Insofar as we focus with particular emphasis on the importance of the computer in this educational experience, some elements in the information and computer science curriculum at the University of California at Santa Cruz may be useful elements in this fourth year of study, in virtue of the use there of certain general

ideas out of cybernetics as the basis for selecting the topics to be covered in some of their introductory courses, including the mathematics relevant thereto. Examples of some of the books which might be used for acquainting students with the relevant ideas here would be, for some of the requisite mathematics, Birkhoff and Bartee, Modern Applied Algebra; for the cybernetic ideas, W. Ross Ashby, An Introduction to Cybernetics and Design for a Brain; for the introductory automata theory, Zamir Bavel's forthcoming Introduction to the Theory of Automata and Sequential Machines; for an introduction to general systems research, George J. Klir, Trends in General Systems Theory; for some social science implications of this work, both of Walter Buckley's books, Sociology and Modern Systems Theory and Modern Systems Research for the Behavioral Scientist. And for some of the historical context of these ideas, one might read selections from Josiah Willard Gibbs, Lawrence Joseph Henderson, Vilfredo Pareto, and Ludwig von Bertalanffy, as well as, for an example of a general over-view in the secondary literature, Cynthia Russett's The Concept of Equilibrium in American Social Thought. A central feature of the fourth year's experience would be the beginnings of skill in simulating and modelling on the computer some aspect of reality which was of particular interest to the student.

In the chapter on the research applications of a Ce/NCoReL, we tried to cover somewhat comprehensively its uses not only for basic research scientists and for those who work on well-defined and relatively narrow research problems of an applied sort, but we also discussed the ways in which a Ce/NCoReL might be of use in conjunction with efforts at solving certain major social problems. Nonetheless, in this immediate context of a plan of education which has a prospective interactive relationship with a Ce/NCoReL and in

the larger context of a discussion of knowledge systemics with its implications for bringing us some relief from a class of social pressures, let us note in passing certain educationally relevant attributes of a Ce/NCoReL. The development of such a center or network should have evident implications for teaching in linguistics, in computer science, in mathematics, in the languages and in literature, not to mention its possible utility in the arts and in music--where Dartmouth's provision of computer-implicated instrumental music synthesis to facilitate composition and appreciation is an inspiring example with adumbrations for the future. The research engendered by a Ce/NCoReL should provide teaching materials for each of those disciplines, just as traditional researches in those disciplines may be expected to generate questions of importance for researchers utilizing Ce/NCoReL's capabilities. But the urgent point to be made here is that the type of curriculum outlined above is much needed if we are to educate people well suited to coping with the knowledge systemic problems of the present and the future. The computer makes such a curriculum possible, and that curriculum should make possible, in turn, the more effective use of the computer through educational innovations well suited to prepare those who would effectively exploit its singular capabilities and do so in a way that would meet socially urgent requirements. Surely there should be at least one node in a Ce/NCoReL network at which education of the sort we are discussing could be developed in a way that Ce/NCoReL itself would markedly facilitate.

HUMANITIES APPLICATIONS

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The use of the computer in the humanities entails the preparation of information banks which are then used for applications involving either pattern recognition, pattern generation, or both.

I. The preparation of information banks implies preliminary decisions as to formatting and editing. Because many of the traditional categories in the humanities are not rigorously defined, investigators wishing to use such categories often pre-edit the text so as to be able to retrieve information concerning, e.g., syntactic or semantic patterns. Thus, at this stage of the use of the computer in the humanities, text formatting and editing sometimes makes use of weakly defined elements and weakly defined or, really, nonexistent models. As empirical data gathering, model building and model testing facilitated by the computer grow, the need for formatting information so as to anticipate the theory upon which the conclusions are based should decline. Rather, it should be possible to "bank" information in its conventional form and then provide rules for sorting the elements in the bank into desired categories. At that point, preparation of information banks will clearly be a step prior to and separate from pattern recognition and pattern generation applications in the humanities. At present, although the functional distinction is relatively clear, the methodological distinction is not.

Types of information banks currently used in computer-based applications in the humanities include, in machine-readable form, bibliographies, texts, dictionaries, historical records of all sorts, and rules for combining discrete elements of whatever artifact is being generated. For the value of

bibliographical data for information retrieval, the reader is referred to section X.2. in The Encyclopedia of Computer Science. The annual Shakespeare bibliography and the U.S. Modern Language Association's annual bibliography are examples of major data banks of this sort for the humanities. General purpose dictionaries (e.g., Webster's; Random-House) which are available in computer-accessible form are used by humanists (16, 19), for example, to search for literary themes; in addition, humanists are preparing special purpose dictionaries (e.g., The Old English Dictionary) for research related to their special fields of interest. (5)

An example of an information bank consisting of historical records is the eleven volume, eight-thousand page, three million word The London Stage 1660 - 1800. (7) These records comprise an

> exhaustive calendar of plays, entertainments, afterpieces, dancing, and singing, together with casts, box receipts, advertising, contemporary comment, and all available information about scenery, theatre construction, costuming, audiences, management, and production, compiled from the playbills, newspapers, and theatrical diaries of the period. (7)

If this material were not available in computer-accessible form, the scholar who

> wished to determine how many times actor X and actress Y performed in the same play together during their careers might find it necessary to scan a period of 15 to 20 years (possibly 800 to 1000 pages) to exhaust all the possibilities of intersection, and yet the list of joint performances might not fill a page. (7)

Historical records of all sorts, ranging from voting records to land use records, are being put into computer-accessible form for scholarly research. (8, 10, 27)

Information banks of recorded speech are of interest to humanists because research based upon such banks may provide useful analytical categories for

the auditory components of language and literature. Speech information banks require formidable quantities of storage (a magnetic tape will hold five to ten minutes of digitized speech) and techniques for copying with the data are likewise complex (see The Encyclopedia of Computer Science, [E.C.S.] X.3. Pattern Recognition).

Information banks comprising rules are currently of importance for pattern generation and will become increasingly significant for pattern recognition as the categories being recognized become ever more amenable to description through a precisely defined procedure.

II. Pattern recognition based upon data banks consisting of bibliographies is described in E.C.S., X.2. Pattern recognition based upon historical records is analogous to that involved in bibliographies--that is, searching for either a particular type of record (e.g., cast listings in the London Stage) or a specified word (e.g., the name of a particular actress in the London Stage).

Pattern recognition for which the data banks are texts in machine-readable form, dictionaries, and indeed sometimes bibliographies and historical records might be thought of as falling into three divisions: 1. recognition using categories which derive from standard graphic conventions; 2. recognition using categories which derive from traditional approaches to language and literature; 3. recognition using categories which derive from theories or models concerning the description of discrete and continuous events--from the mathematical sciences.

Examples of categories which derive from standard graphic conventions include characters, words, sentences, and strings longer than sentences.

Occurrences of single characters or short strings of characters are of interest to humanists concerned with manuscript stemma or with various edi-

tions of a given text. The derivation of one manuscript from another is of interest for several reasons: one is that the scholar would like to find the manuscript which is either the original or closest to the original manuscript of the text in question; the other is that shifts in spelling provide data for studies in the phonological history of a given language. (15) Comparisons of editions of a given text are undertaken in order to list the variants among them and thus either to arrive at an edition which seems best to reflect the presumed original or to arrive at an edition which at least exhibits internal consistency. (4)

The presence or absence of specific characters in a text may also provide guides to the style of the author. And insofar as linguistics is considered part of the humanities, the character and short strings of characters are important guides to morphology, e.g., the discrimination of roots, affixes, plural morphs, etc. Such morphological patterns are of obvious importance for the study of foreign languages, traditionally considered humanistic disciplines.

The humanities have used the word as a category most centrally in indices and concordances. An index is generally taken to be a listing of the word together with locations of its occurrence in the text. A concordance is a listing of the word together with a specific quantity of context for each of its occurrences in the text. For the production of research aids such as these, the computer is now regarded as an indispensable tool by scholars in the humanities. Words are also used to provide stylistic clues which are, in turn, sometimes used for author identification. (12) Manuscript and text collation also depend heavily upon words, as well as characters, for purposes of comparison. (24)

Sentences and strings longer than sentences, such as paragraphs, chapters, and books (as in Paradise Lost), are categories which derive from standard graphic conventions and may provide guides to various components of style. Decisions as to the units by which these strings are measured may well affect their usefulness for a particular problem. For example, although Mosteller and Wallace could find no significant difference among the sentence lengths of Madison and Hamilton when measured in words (14), Robert Wachal has suggested that there may be a significant difference if those sentences are measured in terms of syllables. (29) Whatever the measure, so long as the unit is defined according to standard graphic conventions, this approach to pattern recognition can be replicated by other scholars. And that is perhaps the salient point about pattern recognition based upon categories which derive from standard graphic conventions. The conventions can be clearly defined, departures from the conventions can be clearly specified, and experimentation is thus replicable.

It is with the next group of categories, those which have traditionally been used for studies in language and literature, that replicability and reliability become a serious problem. Among the categories which fit into this general class are those drawn from phonology, syntactics, and semantics, as well as terms which refer to readability, terms such as unity and texture which refer to other terms such as structure and content, etc.

Phonology is concerned with the sound of the spoken language and one might assume that there are categories related to phonology analogous to those such as characters and words which relate to the graphic representation of the language. It is indeed possible to produce information banks of digi-

tized speech and subsequently to make statements concerning acoustic properties such as frequency and intensity (amplitude). Unfortunately, the quantity of storage demanded by even short strings of digitized speech has thus far prevented storing literary or linguistic strings in sufficient length to permit the development or discovery of categories arising directly from the acoustic data--categories which would facilitate discussion of metrics, rhythmical patterns or rhyming patterns. If, given acoustic parameters, the latter categories no longer seem relevant, then acoustic patterns might be used to distinguish one utterance, or poem, or prose work from another.

Current efforts to map the short strings of acoustic signals that are available onto graphic conventions such as characters, combination of characters, or words are extremely complicated pattern recognition problems. Syllable recognition can now be achieved approximately 80% of the time but identification of word boundaries is much less successful. (For further discussion of the pattern recognition problem in speech see E.C.S., X.3.)

In lieu of direct input and analysis of acoustic signals, phonology has been studied on the basis of human graphic transcriptions of the auditory component of language and literature. Although linguists are extensively trained and become skilled at making such transcriptions, recording variabilities do introduce very serious problems so far as reliable replicability is concerned. Nonetheless, mappings from phonetic transcriptions onto graphic conventions and vice versa are of interest to humanists wishing to describe patterns of rhyme, of rhythm, and of other auditory phenomena. (28)

Syntactic categories are used for stylistic discrimination which is applied to author identification or to changes in the style of a given author

over time. The syntactic categories used depend upon traditional intuitions concerning parts of speech, upon those intuitions plus intuitions concerning the text being examined, or upon a particular linguistic model, e.g., transformational or phrase-structure. (6, 11, 13, 9, 3) The use of the computer to locate syntactic patterns for which the syntactic units are defined on the basis of traditional intuitions or even on the basis of many models usually implies pre-editing the text. Because the syntactic categories used in such pre-editing are not sufficiently rigorously defined, efforts to replicate the use of a particular set of categories may not succeed. Insofar as a given scholar is consistent in his use of a set of categories, he may well be able to make statements concerning use of the different categories in the text he is examining. But if another scholar questions his consistency and attempts to replicate his work, difficulties may ensue because the categories themselves are somewhat amorphous. (11, 13) Computer-based parsers have thus far not been used for extended studies of syntactic patterns in literary or other texts, presumably because such parsers tend to provide so many possible syntactic readings for a given sentence as to make analysis of such readings for extensive quantities of text extremely difficult and time-consuming. Probabilistic parsers which give the single best (most probable) parsing for a given sentence seem most promising for this application. (26)

Semantics, which is just coming into its own in linguistics, has long been of interest to humanists. Categories such as texture, theme, and tone presumably refer to semantic implications of words and to the relations among those words in a text. Computer-based efforts to utilize semantics

in literary analysis have depended upon interplay between words in the text and words in standard reference works such as Roget's International Thesaurus or portions of the Oxford English Dictionary. (19, 20, 21, 22, 25) For literary analysis large stores of semantic information are necessary; hence artificial intelligence efforts to cope with semantics (17, 30)--efforts which deal with very restricted universes of discourse--are not thus far viable for literary analysis. Rather, computer-based work in the humanities to date has relied on reference works (dictionaries and thesauri) reflecting general use of the language as both validated and modified through time. The difficulty in using such reference works is that their own structures--particularly of thesauri--are not sufficiently characterized so as to ensure that the research scholar knows the biases they introduce into his results. For such references to be used with assurance, research on modes of characterizing these reference works is necessary; some such research is in progress. (16, 18, 19, 20) When semantic networks both external and internal to texts can be more adequately characterized, categories such as texture and tone may either assume new meaning or completely disappear as viable indicators of literary style and structure.

Other traditional categories such as readability, dramatic climax, and so on depend either upon categories (e.g., syntactic and semantic) which fall into this general area of categories traditional to language and literature, upon categories such as word length which depend upon standard graphic conventions, or both.

The third major category area important to pattern recognition in the humanities is that derived from the mathematical sciences, especially statis

tics and probability, information theory, and analysis (especially relevant for acoustical phenomena). Models in the mathematical sciences can of course be rigorously defined and thus tested extensively against data. Because of its quantity, humanistic verbal data is especially appealing to mathematical model builders who, in the past, have sometimes been dependent upon the restricted number of subjects convenient to social science experiments or to restricted instances of any given case. On the other hand, the application of mathematical and statistical models to natural language data is often hampered by the very quantity of data. Contingency tables, transitional matrices, and other structures requisite to mathematical and statistical models quickly become so large as to exceed the capacity of even very large digital computers. Efforts to find models which fit data more adequately (e.g., non-parametric statistical models) as well as to find ways of managing data so as to increase its computability are likely to increase dramatically during the coming years as more data becomes available in computer-accessible form and as more model builders become aware of this large storehouse of data available for model testing.

III. In many respects, computer-based pattern generation represents the obverse of pattern recognition. At first blush, it might seem to be more difficult because it demands rules specifying the way elements being generated are to be combined. This would seem to be more complicated than, for example, a search through a text for occurrences of specified words. It is probably true that the most elementary generation of poetry is more complicated than elementary searches for words. But as pattern recognition efforts become more comprehensive, so as to include, for example, semantic relationships, the pattern recognition task then becomes more complicated than ele-

mentary generation tasks. An analog might be the greater ease with which computer-based transformational generative grammars are written than are computer-based transformational parsers. It is easier to generate acceptable sentences than to attempt to parse the infinite variety generated by man.

Pattern generation, like recognition, uses information banks such as dictionaries, thesauri, bibliographical information and banks of rules based upon models or assumptions appropriate to the artifact being generated. For example, generation of haiku poetry would entail specification of the number of lines, the length of lines, acceptable sequencing of syntactic classes, the vocabulary which falls into the general type of vocabulary appropriate to haiku, and some appropriate semantic relationships among the words. Specification of the latter has been minimal in poetry generated to date. For haiku, a verse form for which semantics is relatively obscure anyway, this specification is not so vital and, in fact, in some contemporary poetry semantic relationships among words are certainly oblique and often distant. The casual reader may not see a great deal of difference between "a great king packed in an acorn" written by a human and "dance, oh life, like a silent tumbleweed!" written by a machine. (2)

Inasmuch as sophisticated pattern generation of language and literature is extremely complicated, in large measure because of semantics, computer-based pattern generation in the humanities will doubtless be used in the foreseeable future for testing models or parts of models of language and literature. Although the computer may never write like Shakespeare, it may be used to tell us with precision about some aspects of the way Shakespeare wrote.

Although computer graphics represents pattern generation in a somewhat different sense, its use in the humanities as an heuristic, or aid to insight, should be mentioned. Graphics can help reveal patterns in the structure of a literary or other text. Thus, graphics can show which themes or ideas tend to cluster together in a text and which never appear together, which metrical patterns tend to dominate and where; in short, graphics can be used to represent any elements of the text which have been specified and identified by the computer. Most often, graphics provide visual representations of the results obtained by the application of mathematical and statistical models to data. (1, 23)

One of the major areas of the humanities for which the scope of this article does not permit coverage is instruction. Computer-assisted instruction is being used in the teaching of foreign languages and there is a growing effort to use it in teaching composition. For a detailed presentation of current work in computer-assisted instruction, the reader is referred to E.C.S., VII.8.

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ARTS APPLICATIONS

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As is the case for computer applications in the humanities, computer applications in the arts (here comprising painting, sculpture, film making, music, and dance) include information banking that is used in pattern recognition (analysis) and pattern generation (synthesis).

I. Just as libraries have traditionally served as data banks for the verbally oriented humanities, museums have traditionally served as data banks for the non-verbally oriented humanities. Efforts to use the computer to make museum collections more accessible to users have resulted in the development of a number of data banking projects for museums.* In the United States, the development of these systems has promoted the formation of a museum data bank coordinating committee, among whose functions are the following:

1. To develop comparative descriptions of the general information systems that are presently available so that a potential new user would have an objective basis for deciding which system was most appropriate to his needs.
2. To serve as a clearing house of data categories and minimal standard recording conventions for all museum data banks, so that data recorded in one of the systems will be compatible

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* These projects include GIPSY (General Information Processing System), used to record ethnographic museum specimens in Oklahoma, Missouri and Arizona; GIS (General Information System), used in the FLORA N.A. program, a large-scale, centralized data bank, designed to collect, analyze, maintain and disseminate diverse kinds of information about the plants of North America; GRIPHOS (General Retrieval and Information Processing for Humanities Oriented Studies), used by the Museum Computer Network, an organization of several dozen museums and related organizations, primarily to record art objects and archeological data; SELGEM (Self-Generating Master), used to record specimen inventories of mammals, conodont types, foraminifera, nematodes, crustacea and other collection; TAXIR (Taxonomic Information Retrieval), used primarily for the storage and retrieval of biological specimen data. (7)

with that recorded in other systems. Standard recording conventions would be recommended only for such categories as dates, proper names, etc., or when requested by a representative body of scholars for a particular discipline.

3. To serve as a central point for the communication of information to and from other data bank organizations around the world.
4. To coordinate the development of programs for the conversion of data from one system to another.
5. At a later date, when sufficient information has been gathered in data banks across the country (U.S.), to coordinate or contract for the synthesis of actual data for specific disciplines on a regional or national basis. (7)

These goals of the committee indicate the problems attendant upon massive data banking efforts.

Other types of information banks necessary for pattern recognition and pattern generation in the arts include bibliographies, special purpose catalogues, musical scores in computer-accessible form, and rules for combining elements and artifacts.

An example of a bibliographical project which includes abstracts as well as the standard author, title, etc., reference information is the Répertoire International de la Littérature Musicale (RILM). This computer-based information bank currently references scholarly publications on music from the year 1967 forward. After production problems are solved, the plan is to move backward from the year 1967 (while, of course, continuing to keep up with current publications) so as to provide in time a comprehensive computer data bank on publications in music. (2)

An example of a special purpose catalogue, again in music, is that proposed for French Chansons, which would include a listing of all manuscript and printed sources for Chansons, musical incipits, a melodic index, and other relevant information. (17)

Information banks consisting of musical scores are requisite for pattern recognition studies either focused upon a particular composer or upon a musical genre. No extensive data banking of musical scores has yet taken place, primarily because of the input problem. To date, almost all computer scores which have been put into computer-accessible form have been translated into teletype keyboard characters using either the Ford-Columbia system of transcription (DARMS) (37), the Plaine and Easie Code (3), or a system developed by an individual scholar for his own specific research needs. An alternative to transcribing musical scores into keyboard characters is the use of graphic input devices. One such experiment displays (on a cathode-ray tube) a musical staff as well as conventional symbols for musical notes, pauses, and other standard musical symbols. The scholar may then select the appropriate symbols and place them as desired on the musical staff. Although this system is proposed for musical editing, it is clear that such an approach could be used to input scores, once some of the limitations (e.g., the availability of upward stems only) of the experimental system were eliminated. (6) The use of graphic input devices has also been advocated for data banking information requisite to computer generation of music. An approach devised somewhat earlier than the one mentioned above considered the cathode-ray tube display as a grid across which the composer could draw graph-like lines to indicate amplitude, frequency, note duration, and so on. (25) Because this particular graphic input system did not use common musical notation, the user had to learn a notational system in order to input his data. Thus, the only presumed advantage of this system over transcription into keypunch characters would be the greater speed with which data could be input.

Another important type of data bank for both pattern recognition and generation in music is digitized sound. Breaking down musical acoustical signals into digitized form as well as using the digitized form to generate acoustical signals requires an analog to digital and digital to analog converter system with a speed sufficient for 20,000 to 50,000 samples per second and a quantization accuracy of from 10 to 13 bits. As is the case for speech (see X.3. and X.14. in E.C.S.), storage of digitized music poses space requirements which are sometimes a seriously limiting factor on the scope of the research being undertaken. (1)

II. Pattern recognition projects focused upon painting and sculpture are almost nonexistent. Thus far, fine arts museum information banks consist of listings of artists, works of art, dates when created, perhaps the date of acquisition by a given museum, and other comparable detail. Although there is a strong interest in providing content information (e.g., physical objects represented in a painting, the colors used in a painting, etc.) there is at present little effort to make such information available as part of computer-accessible information banks. Although there conceivably will be some effort to hand code such information, any such encoding, albeit useful, will be prone to the subjective responses and lapses of any given encoder. It seems likely that in time (whether measured in years or decades is not yet clear) pattern recognition efforts currently being pursued in other areas (e.g., aerial photography, artificial intelligence research on robots, character recognition) will be used to facilitate input of information concerning museum holdings. Current work on identification of two- and three-dimensional objects, on methods of locating and following edges so as

to identify objects, and on the use of regional analysis rather than edge delineation to describe objects, is all obviously relevant to pattern recognition of both paintings, sculpture, and other objects in museums. (32, 33, 34, 12, 13, 14, 22) A recent dissertation on computer analysis of visual properties of curved objects uses digitized photographs of apples, oranges, peaches, Bartlett pears, and sweet pears as data banks. Mathematical and statistical techniques are then used to identify and describe parameters related to shape (e.g., stems, protrusions, stem hollows) and texture (visual texture and tactile texture) so as to describe and discriminate among the types of fruit being analyzed. (22) The determination of characteristics sufficient to identify a few known artifacts is hardly comparable to digitizing and then describing the artifacts in even the smallest of museums. It also should be noted that the work on the fruit entailed only black and white images, although the addition of color apparently poses no serious additional problems. It may be that it will be many years, if ever, before it is feasible and practical to try to map categories such as boat or vase (let alone Etruscan vase as opposed to Grecian vase) onto parameters indicating shape (such as eccentricity), or texture, or alignment of edges, or whatever indicators emerge from digitized representations of artifacts. Nonetheless we may expect that the parameters which do emerge easily from such digitized representations will in themselves provide useful categories for the art historian or student of style and content in painting and sculpture.

In contrast to painting and sculpture, pattern recognition in music is a very active research area. Pattern recognition involving digitized acoustical signals faces the storage problem mentioned earlier. For example, an

effort directed toward an analysis of tones produced by a range of musical instruments used a hardware configuration which did not permit adequate continuous transfer of digitized analog samples to magnetic tape. As a result, only core storage was available in this particular configuration and, using 29,952 samples per second at a sample rate of 30kc, the maximum length of sound which could be digitized was 0.997 seconds. This block of information could, of course, then be transferred to tape and a new 0.997 seconds of acoustic signal stored and transferred. These blocks of data were characterized and graphed to show time-variant spectral information. (1) In general, work on digitized music can deal with such parameters as frequency or pitch, amplitude, and phase. When storage and processing speed problems are solved, there will probably be music information banks consisting of digitized music as performed, rather than, or in addition to, its appearance in a printed score. If and when such data banks are available, it may well be--analogously to possibilities for museum artifacts--that the parameters used for characterizing music will not all be mapped onto the traditional symbols of a printed score. In the case of music, what could eventuate, as well as in spoken and written language, is a parallel development involving, on the one hand, graphic pattern recognition devices and, on the other, acoustic pattern recognition techniques.

Much pattern recognition in music has depended upon information banks consisting of musical scores. Representation systems such as the Plaine and Easie Code or DARMS permit the scholar to encode in keypunch characters all the symbols in a written score. Written scores permit studies of styles of individual composers as well as groups of composers. Written scores cannot

be used for studies of interpretations of a given work by conductors or performing artists; presumably digitized acoustical recordings would have to be used for pattern recognition of this type.

Computer-accessible musical scores have been used for work on questions of harmony, of composer identification, of particular themes or motives within the works of a particular composer, and for ethnomusicology. Many of these studies concentrate upon pitch and combinations of pitches, although other information such as duration of notes, amplitude of notes, and various frequency distributions of notes is obviously available from musical scores. For example, studies concerned with harmony depend upon chords and patterns of chords which are described in terms of the pitches of the individual tones combined into chords. (11, 18) A study of motive, or musical theme, again looks at the pitch of notes and combination of pitches into chords but it is also concerned with changes of dynamics and tempo. (9) Studies of dynamics and tempo imply analyzing information concerning the amplitude (loudness-softness) with which the individual notes or chords are played and analyzing information about the duration of individual notes or chords. One project explicitly directed toward composer identification was concerned with root progression, which is a study of the way chords are connected--again, then, a study emphasizing pitch. (41)

Work in ethnomusicology is directed toward describing the music of a particular culture or, sometimes, comparing the musical habits of a number of cultures. (23, 38) A project directed toward analyzing Japanese music concentrated upon Fixed Melodies (F.M.) and variations on the F.M. achieved through its rendition by different instruments and through elaborations played on still other instruments. Once this data was encoded, the computer

was used to sort out and derive statistical summaries of the data. (23) It should be noted that implicit in the pitch of any given tone is not only its location relative to any given octave but also the octave in which it actually occurs (e.g., an A in the octave above middle C).

Pattern recognition in dance is of considerable interest because the dance notation systems that do exist are relatively little used. (27) Hence, dances exist principally in the heads of choreographers and the dancers, and often a particular dance vanishes when a particular dance company breaks up or a choreographer passes from the scene. In the context of a discussion of generating dance movements by computer, it has been pointed out that specifying human movement in any detail is exceedingly complicated:

> obtaining the equations for as simple a motion as walking would be formidable. A better attack on this problem might be for the computer itself to analyze human motion using devices which have just become available for converting pictoral data into machine digestable data. A library of basic movements could be built within the computer, and particular movements could then be put together at will. (27)

As should be apparent from the earlier discussion of painting and sculpture, the pattern recognition problems implied by this approach are complex. Walking entails the angles of legs, feet, and other parts of the body which are changing through time. As it is possible to imagine in the cases of painting, sculpture, and music that other than traditional parameters may be useful for pattern recognition, so, too, for parameters other than those to which the dancer is accustomed. Then, the preparation of information banks to be used for pattern recognition which could take the place of or provide the stimulus for dance notation would seem to imply a mapping from whatever parameters are best for the digitized information onto those which are best for the dancer.

III. In contrast to computer-based pattern analysis, pattern generation in painting and sculpture and their allied field, film making, is in a very flourishing condition. Computer generated paintings and films in two-, three-, and even four-dimensions have been produced. Output media have ranged from computer printers to cathode-ray tubes and input media from punched cards to light pens. One early approach which resulted in a so-called Sine curve man and a prize winning film, Hummingbird, used the following technique:

> (1) an artistic drawing was made with line segments of points of the subject matter to be used; (2) a drawing was digitized line by line with the resulting coordinates punched into cards; (3) decisions were made about the type of form modification and the mathematical steps required to accomplish it; (4) the mathematical algorithm was programmed for a computer which then generated the plotter commands; (5) at this point, another decision was made about the color and line width for the transformation; (6) the transformed image was plotted on a Calcomp 563 plotter. (8)

To produce a film from individual drawings, the figure of a hummingbird was transformed slightly in a succession of drawings which were then filmed and projected in the conventional way to produce the illusion of movement.

Currently, graphics packages are available which permit an artist or film maker to sit down at a display console, specify the number of x-y coordinates sufficient to define whatever figure he wishes to create and then transform it according to the specifications made available in the graphics program. Three of the basic transformations are scaling, translating, and rotating. Scaling implies modifying the scale of all or some part of the figure which has been created, translating implies moving all or some part of the figure to another location on the output medium, and rotating implies altering the position of the object so as to make it seem to move around an axis as viewed from the perspective of the artist.

The art generated has ranged from very geometrical designs to highly random, apparently chaotic patterns. Some efforts have been made to approximate the painting of styles of human artists. (29, 5)

Two-dimensionality is achieved simply through specifying x-y coordinates for a plane surface. A three-dimensional

> perspective drawing is produced by choosing a point (representing the eye and formally called the station point) from which the object is viewed. The picture plane is then inserted between the object and station point, and projection lines are drawn from the object to the station point. The points of intersection of these projection lines with the picture plane are joined together to produce the perspective drawing. (28)

Four-dimensional objects can be specified mathematically and produced by mathematical formulae analogous to those used for two-dimensional perspectives of three-dimensional objects. Although it is impossible to see a four-dimensional object, the three-dimensional (and, in turn, two-dimensional) projection of the four-dimensional object produces effects which differ from conventional two- and three-dimensional artifacts. It has been noted that "the programs and mathematical techniques for four-dimensional projections and rotations are quite general and can easily be extended to even higher dimensions." (28)

A number of programming languages have been especially designed for the artist and film maker. BEFLIX, a film making language in FORTRAN IV, provides drafting operations which draw rectangles, straight lines, arcs, other curves, and alphanumeric characters, as well as operations concerning the content of rectangular areas, the specification of the projection grid, operations related to elements labeled bugs (not to be confused with the undesirable bugs which occur in many computer programs) and miscellaneous operations having to do with output, debugging, etc. (21) TARPS is a two-

dimensional alphanumeric raster picture system for the production of designs, diagrams, and textures, usually for movies. TARPS contains operations such as ZOOM, which progressively enlarges the image by an integral factor, ESPEZOOM, which gives a clockwise (right) or counterclockwise (left) spiraling zoom, and SYM, which produces an enlarging kaleidoscope image. (20) EXPLOR--a generator of images from explicit patterns, local operations, and randomness--is a system for computer-generation of still or moving images from explicitly defined patterns, local operations, and randomness. EXPLOR produces output images comprising rectangular arrays (240 by 340) of black, white, and "twinkling" dots. Among its intended scientific and artistic applications are the "production of stimuli for visual experiments, the depiction of visual 'phosphenes' such as moving checkerboards and stripes, and picture processing." (19) This system may also be used to simulate a "variety of two-dimensional processes and mechanisms, such as crystal growth and etching, neural (e.g., retinal) nets, random walk, diffusion, and iterative arrays of logic modules." (19) EXPLOR is a macro language with sets of instructions for picture output, for changing the internal array, for defining patterns, for flow of control, and for instruction modification. It provides facilities for specifying periodic and/or random applications of its operations, and flexible means of specifying uniform or locality-dependent translation of internal symbols. Another approach to programming languages for the artist permits the artist to define his own vocabulary, built on an REL (rapidly-extensible language) support system, as he creates his art. (39)

The use of the computer for sculpture is ordinarily to use graphic facilities such as those already described for painting and film making to

display a range of design possibilities and perspectives for proposed sculpture. Programs which produce paper tapes which in turn are used to drive milling machines which actually produce artifacts have also been designed. (24)

Computer-generated music produces either scores which are then performed by a performer or performers, or music for which the acoustic properties are specified and which is then synthesized through the use of a digital to analog converter.

MUSICOMP is a compositional programming language which provides techniques for generating original musical scores as well as for synthesizing music. (16) An adaptable language which can be changed and expanded according to need, MUSICOMP consists of three basic parts: system regulatory routines, compositional and analytical subroutines, and sound synthesis routines. The latter "are not actual synthesis programs but rather routines that prepare and organize data that serve as input to sound generating programs." (16) Among MUSICOMP's compositional subroutines are a subroutine for choice of a rhythmic mode, a subroutine which provides choice of a range of pitches and then of a specific pitch from within this range, a subroutine which controls the melodic range rule--in a single line a limit such as an octave is imposed on melodic motion--and others. The routines provide for the generation of phrases and their imitations and permutations, generation of all the permutations of the given role of n items, the generation of similar rhythmic data from more than one instrument for any length of time, and the generation of dynamics indications in playing styles according to serial processes. MUSICOMP can be used in conjunction with FORTRAN.

Output of musical scores either uses standard printer conventions which can then be translated onto regular musical staffs, a cathode-ray tube con-

figuration such as that described earlier in terms of input of musical scores, or a plotter to draw a score. In one such program written for a CALCOMP plotter, the notation makes use of a select set of symbols already available in the CALCOMP library (triangles, circles, lines, and so on). The "language of the scores is given by the distribution, size, and position of symbols on each page of the scores; in effect, each page is a plot of dynamic level versus time. Once the performer is provided with a short introductory explanation of the notation, he is able to perform directly from the score." (15)

Computer-generated scores have ranged from music which is highly random in character to music which is intended to approximate some aspects of the style of a given composer or musical genre. In fact, in the course of some experiments, a range from greater to less randomness is apparent. (26) Analysis of church hymns (4) using Markovian analysis resulted in simulated hymns with considerable randomness when low order probabilities were used. The use of high order probabilities (probabilities of orders 1 through 8 were used in this experiment) produced parts of original hymns connected together. The Illiac Suite, one of the best known early computer compositions, was a string quartet comprising rhythms chosen at random, and melodies constructed according to some rules of classical harmony and counterpoint. Another computer-generated composition, Sonoriferous Loops, written for instrumental ensemble and tape, used four parameters: pitch, register, rhythmic unit, and rhythmic mode. Rhythmic modes (basic metrical patterns) and rhythmic units within those modes were chosen in accord with assigned probability distributions; probability distributions which differed for each

instrument and for different parts of the composition were also used to make choices between rest or play and for octave registers. (15) A recent effort to generate scores for western popular music proceeded according to the following sequence:

> the overall form of the piece is chosen first, the chords are chosen second, and the melody, last. . .the choice of chords before melody is to avoid the problem of deciding what chords should go with a given melody. The problem is reversed and simplified to constraining some number of the prospective melody notes to lie in the chord. The overall structure is similarly chosen first, to prevent attempting to derive the structure from the melody. . .The overall structure is decided upon by first choosing two numbers, the number of major groups and the number of minor groups. Each of these numbers is constrained to be a power of two times the number of beats per measure, a parameter supplied by the operator. The total piece length is then the product of the number of major groups times the number of minor groups times the number of beats per minor group. (26)

Two parameters implicit in some of the choices made in experiments with computer-generated music are the periodicity of the melodic line and the consonance and/or dissonance implied by the structures of chords. Periodicity implies the repetition and transformation of melodic groups. Consonance and dissonance are subjective matters, but some combinations of notes such as a perfect fifth or a major third are considered to be more consonant than others. (26) Another statement on consonance and dissonance notes that "tones are most dissonant when their frequencies are separated by a particular fraction of a critical bandwidth and are consonant when their frequencies coincide or are separated by more than a critical bandwidth." (30) This statement continues by noting partials that are "not crowded too close together at high frequencies" can be pleasing or consonant.

Composers who use the computer to synthesize sound rather than to produce musical scores are concerned with many of the same elements, although they are

parameterized according to acoustic categories rather than graphic symbols. The composer using sound synthesis must be concerned with amplitudes, frequencies, amplitude modulation rate, and wave-form specification. According to one set of specifications, the digital-analog converters used in music synthesis must be capable of converting 12 to 14 bit words at a rate of 40,000/sec. "The long word length ensures adequate dynamic range and the high rate, a sufficiently broad frequency response." (10) Additionally, for pleasant sound, the computer equipment must have adequate block transfer rates between auxiliary storage and main memory so that there will be continuous reproduction of sound without breaks. Because electronically synthesized sound lacks some of the variability to which the human ear is accustomed, composers who are generating sound electronically have concerns with which those who are generating scores are not troubled. For example, electronically sustained tones seem to provide a constant stimulus which may fatigue the ear. To achieve a timbre which is more pleasing, it has been suggested that any one of the following techniques might be used:

> 1. control of the amplitude envelope: crescendo, diminuendo, exponential decay, and so on. 2. variation of the pitch--vibrato or glissando. 3. variation of wave form. (31)

It has also been noted that

> another feature of electronic tone that the listener finds distressing, or at least unnatural, is that quality is independent of loudness. . .It is, of course, easy to correct this feature by introducing deliberate nonlinearities into the computer-simulated oscillators. (31)

As is the case with computer-generated art, the field of computer-generated music is very extensive and cannot be done full justice in an article of this length. For a useful survey of music composed with the computer, the reader is referred to reference 15.

Computer-generated dance is in a much more embryonic state. One experiment used the computer to specify the number of dancers on the stage at any given time and to indicate the positions they would occupy on that stage throughout the period of time they were on stage. (35) Another experiment used a computer display to delineate the spatial and arm movements of a group of dancers on stage. (27) The difficulties mentioned above when discussing pattern analysis for the dance also obtain for pattern generation. That is, specifying the intricacies of movements entailed by dance is exceedingly complicated and, as yet, beyond the reach of any current experiment.

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SELECTED ITEMS FROM AN INVENTORY OF MEASURES OF LANGUAGE

This listing of research relevant to the comprehensive measurement of language makes rich use of the cited bibliographic efforts of Richard W. Bailey, Dolores Burton, and Lubomír Doležel.

SELECTED ITEMS FROM AN INVENTORY OF MEASURES OF LANGUAGE

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SOME SELECTED BACKGROUND ITEMS IN THE LITERATURE ON COMPUTATIONAL LINGUISTICS AND INFORMATION RETRIEVAL

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SOME SELECTED BACKGROUND ITEMS IN THE CONTEMPORARY LITERATURE ON THE SOCIOLOGY OF LANGUAGE

This listing of research at the intersection of social science with linguistics makes rich use of, inter alia, the bibliographic aspect of Dell Hymes' work, i.e., Language in Culture and Society (1964).

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APPENDIX III

CONFERRING

Thanks in no small measure to the unusually helpful assistance given us by dozens of research scientists whom we've conferred with at their universities and laboratories across the country, we have accumulated a very considerable store of knowledge about the wide range of uses to which enhanced computer capability would be put in language research. We have conferred with faculty and administrators on more than 35 university campuses in conjunction with this study since its inception in the spring of 1971. (These university campuses include Boston University, Brown, California Institute of Technology, Carnegie-Mellon, Claremont Colleges, Dartmouth, Duke, Harvard, Massachusetts Institute of Technology, Rutgers, Saint Louis University, Stanford, SUNY-Binghamton, SUNY-Buffalo, University of California-Berkeley, University of California-Irvine, University of California-Los Angeles, University of California-San Diego, University of California-San Francisco, University of California-Santa Barbara, University of California-Santa Cruz, and the Universities of Colorado, Connecticut, Denver, Hartford, Illinois, Indiana, Massachusetts-Amherst, Missouri-Columbia, New Mexico, North Carolina-Chapel Hill, Oklahoma, Pennsylvania, Texas, and Virginia, and Washington University, Washington State University, and Yale.) In addition, among the participants in conferences held at The University of Kansas as a part of this study effort there will have been faculty members from at least six additional university campuses; and on the occasion of these conferences we have conferred with faculty from a further four universities. (These universities include Cornell, Pennsylvania State University, Southern Illinois University, SUNY-Stony Brook, and the Universities of Arkansas, Chicago, Iowa,

Michigan, South Carolina, and Wisconsin.) Thus, we have discussed issues important to the design of a center/network with relevant faculty associated with nearly fifty campuses. Additionally, we have conferred with relevant research or technical staff personnel at more than a dozen non-university organizations (including Bolt, Beranek and Newman; Brookings Institution; Center for Applied Linguistics; Haskins Laboratories; Historical Abstracts/ ABC-Clio Press; IBM-Yorktown Heights; Museum of Modern Art; National Center for Atmospheric Research (NCAR); National Gallery of Art; National Museum of Natural History; RAND; Stanford Research Institute (SRI); System Development Corporation (SDC)), including four or more commercial firms and at least eight not-for-profit institutions. Through conferences we entered into discussions of such topics with representatives of four more non-university organizations which might be expected to have an interest and competence in this area (Bell Laboratories; Educational Testing Service; Raytheon, Inc.; Summer Institute of Linguistics). In total, then, on a conservative count this study has elicited discussion on these issues with researchers within more than sixty academic and/or research-oriented organizations. Similarly, we have had approximately two hundred written or oral responses to a longish letter on a wide range of Ce/NCoReL-related topics from research-workers in this field. By the end of June 1972 approximately thirty scholars and scientists had travelled to The University of Kansas for small conferences on various aspects of the center/network concept under study. And we have participated in a number of meetings organized by other groups and professional societies at which we have had the opportunity to discuss Ce/NCoReL-related issues.

CONFERENCE PARTICIPANTS

Conference Participants

Four small, working conferences focused upon general themes relevant to this study were convened at The University of Kansas. The first conference, February 13, concentrated upon the largest current computer network effort--the ARPA Net; the second conference, April 9, brought together people already associated with either centers or some form of network (large or small); the third conference, April 23, focused upon problems related to large data banks; the fourth conference, June 18, was concerned with current and emergent hardware relevant for a Ce/NCoReL. In addition to experts in these areas, the conferences included some potential users (ranging across both types of institution and areas of interest), as well as computer center directors who could speak to some of the nodal or "local site" realities of a Ce/NCoReL. Naturally, because of the small scale of the conferences, and the nature of the topics, many scholars and scientists who might be centrally involved in a Ce/NCoReL were not involved in these meetings. A number of them, however, have provided highly useful written or extended oral statements; their names appear in the list of scholars and scientists consulted.

A composite list of conferees (51) includes:

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The names in this list include scholars and scientists who either responded by letter to issues concerning Ce/NCoReL or with whom the principal investigators made contact either by telephone or through a personal visit. The extent of the contact varied from very long, carefully thought-out written statements, to long conversations, to relatively brief conversations. Inevitably, names are missing which might reasonably appear--some individuals were contacted by letter who simply didn't have time to provide a written response and in both these cases and some others, the principal investigators were unable, because of mismatches in schedules, etc., to make contact by telephone or through a personal visit. Limitations of time and resources prevented an even more thorough canvassing; we hope the many other people who are interested will be involved in such subsequent developments as contribute to a national computational capability directed to research on language and symbol systems. (Although about ten of the people on this list felt they were either not qualified to respond or personally uninterested, we have listed them because they were either interested enough to respond by letter or to direct us to other people who could be helpful; thus, we appreciate their help, too.)

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