EXECUTIVE SUMMARY :

FINAL REPORT

to

NASA

by

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EXECUTIVE SUMMARY :

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FINAL REPORT

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Full Text of 72 Attachment Documents Are Provided Under Separate Cover

1. INTRODUCTION

The staff of the NASA Project at the Center for Advanced Computer Studies (CACS) of the University of Southwestern Louisiana (USL) has significant, proven research, prototyping, design, application, and evaluation expertise in a number of computing areas. The major such areas include information system curriculum and associated educational workstation development, object-oriented systems and associated design paradigms, database management systems, expert systems, advanced computer graphics, user/system interface prototyping and evaluation, information storage and retrieval system simulation and usage, and scientific, engineering, and educational PC workstation design, networking, and evaluation. This Final Grant Report Executive Summary is intended to provide an overview of our past accomplishments and current interests and capabilities in these areas.

Chapter 2 of this document provides an overview of the three primary NASA-sponsored projects being conducted by the Center for Advanced Computer Studies of the University of Southwestern Louisiana and serving as the integrated framework for addressing the R&D areas identified above. Each of these projects represents very extensive research and development activities with a serious commitment of both NASA and USL resources and a very significant useful lifetime. For example, the USL NASA/RECON Educational Project (overviewed in Section 2.1) serves as the primary foundation for a major innovative educational program that is being developed specifically to be implanted into, and utilized within the curricula of a very large number of colleges and universities throughout the United States for many years to come. Additionally, the USL NASA/JPL Space Station Project (overviewed in Section 2.2) has served as an important component of the NASA Space Station R&D Program.

Chapter 3 presents additional generic information concerning the institutional resources of the Center for Advanced Computer Studies at USL, and Chapter 4 highlights the very substantial commitments that have already been made to the USL NASA Project, both from its primary sponsor - NASA - and from 110+ commercial computing organizations that are providing donated hardware and software to support the R&D activities of the USL NASA Project.

Chapter 5 of this document identifies a number of planned or proposed future R&D activities which are currently being examined by the USL NASA staff, and Chapter 6 highlights the major categories of benefits which we believe should accrue to NASA as a result of NASA's past grant sponsorship of these R&D efforts.

Finally, the 72 attachments to this Executive Summary represent the complete Final Report and integrated set of deliverables for this grant. As illustrated in these attachments, the USL NASA Project has been very successful to date in completing a large number of both high-quality research efforts and fully-operational product deliverables pursuant to our externally-funded R&D projects.

2. OVERVIEW OF USL NASA-SPONSORED R&D PROJECTS

Since December 1983, the Center for Advanced Computer Studies of the University of Southwestern Louisiana has been addressing a series of research and development activities under the sponsorship of the National Aeronautics and Space Administration (NASA) targeted at improving the effectiveness of scientific, engineering, economic, and educational professionals in utilizing a variety of computing capabilities. Certain of these activities have been performed in conjunction with Southern University, Baton Rouge, Louisiana.

The USL NASA/RECON Project represents a major, long-term program addressing innovative educational issues associated with the development, administration, evaluation, and widespread distribution of transportable educational programs for scientists and engineers to increase their knowledge of, and facilitate their utilization of automated scientific and technical information storage and retrieval systems (RECON is the major such information storage and retrieval system of NASA). These services are of truly broad scope, being targeted at Colleges of Engineering and Colleges of Physical Sciences at 234 colleges and universities throughout the United States. As well recognized by NASA, the provision of educational services of this magnitude is a joint responsibility of both the educational system and the information industry.

The second project, the USL NASA/JPL Project, represented a research and development effort to provide a wide range of computing capabilities for NASA Space Station pricing analyses. The scope of this project included computer system design, development, and implementation in areas such as statistical analysis, resource scheduling, graphical display facilities, computing environment analysis, and overall computer system life cycle management.

Our third project, the USL NASA PC R&D Project, represents a unified framework for addressing all of the PC-based research and developments activities being performed in support of either of the previous two projects.

Sections 2.1 through 2.3 of this document provide a more detailed overview of these three NASA-sponsored projects. Additionally, this Executive Summary is followed by an annotated table of contents of the documentation and deliverables that have been completed to date pursuant to the USL NASA/RECON Project.

2.1 The USL NASA/RECON Educational Project

The USL NASA/RECON Project represents a major, long-term project addressing the educational issues associated with the development, administration, evaluation, and widespread distribution of transportable, educational programs for scientists and engineers to increase their knowledge of, and facilitate their utilization of automated scientific and technical information storage and retrieval systems.

The primary objectives of the USL NASA/RECON Project include the following:

(1) The development of new information storage and retrieval (IS&R) system oriented educational programs for scientific and engineering disciplines; assumptions include non-computer-professional, non-IS&R-professional instructors (science and engineering faculty) and non-computer-professional, non-IS&R-professional audience (senior undergraduate students in *all* science and engineering disciplines, definitely not restricted only to computer science students).

(2) The development of a set of courses with varying degrees of emphasis on the principles and concepts of interactive information storage and retrieval systems and the specifics of effectively utilizing selected systems:

    (a) 18-week full semester course
    (b) 12-week full quarter course
    (c) 6-week mini-course
    (d) 1-2 day intensive workshops.

(3) The development of educational programs incorporating *extensive* hands-on interactive usage of multiple large-scale interactive information storage and retrieval systems and multiple data bases:

    (a) Under NASA-sponsorship, specific course modules incorporating NASA/RECON have been completely developed.

    (b) Current plans include establishing working relationships with other system vendors to incorporate course modules tailored to additional systems, such as DIALOG, DOE/RECON, SDC/ORBIT, BRS, DoD/DTIC/DROLS, and other similar systems.

(4) The development of fully transportable educational programs and course materials to facilitate wide distribution of the educational programs to colleges and universities throughout the United States:

    (a) Course material development philosophy is predicated on a set of system-independent, discipline-independent core materials, with hooks for incorporating system-specific modules and discipline-specific modules throughout.

    (b) Currently completed entries within the course material packages include:

        — Course outlines/syllabi
        — Lesson plans
        — Visuals
        — Instructor's manual
        — Additional supportive handouts/diagrams
        — All NASA/RECON system-specific educational materials
        — Bibliographies
        — Homework assignments with answer keys
        — Hands-on usage assignments with answer keys
        — Examinations with answer keys
        — Course evaluation documents.

(5) The development of an appropriate level of educational PC workstation functionality to complement and support the delivery and usage of the NASA/RECON educational course materials:

    (a) Software functionality addressing a common interface mechanism providing multi-level, casual user access to multiple, large-scale, remote information storage

and retrieval systems.

(b)   Software functionality addressing locally-PC-resident information system simulators and simulator generators for student usage.

(c)   Software functionality addressing instructor-controlled interactive presentation development and delivery systems.

(6)   Overall management of all phases of project activities:

(a)   Needs Analysis
(b)   Course development
(c)   Pilot course administration
(d)   Pilot evaluation
(e)   Development of distribution plan
(f)   Implementation of distribution plan
(g)   Conduct of regional seminars
(h)   Conduct of on-site seminars
(i)   Coordination of request processing/information dissemination
(j)   Course state-of-the-art enhancements
(k)   Additional system-oriented and data base-oriented enhancements
(l)   Institutional surveys/evaluations
(m)   Graduated student surveys/evaluations
(n)   Periodic statistical summary reporting.

During the initial stages of the preliminary work funded by NASA, a comprehensive needs analysis phase targeted at academic institutions was conducted and successfully completed. As part of this phase, a transportable information storage and retrieval system courses needs analysis questionnaire was developed and distributed to 237 colleges and universities throughout the United States. The questionnaire was completed and returned by 161 respondents (typically at the level of Academic Vice-Presidents, Deans of Colleges of Physical Sciences, and Deans of Colleges of Engineering).

A very brief overview of some of the major results of this needs analysis survey follows:

•   Computer usage is viewed as a very important or important educational objective in Engineering by 86.8% of the respondents and in Physical Sciences by 68.2% of the respondents.

[These results are highly complementary to our educational objectives.]

•   Availability of local computing access facilities is substantial; for example, responses indicate that substantial departmental computer terminals exist (86.7% in Engineering, 79.7% in Physical Sciences) and even substantial departmental personal computers exist (66.7% in Engineering, 59.3% in Physical Sciences).

[These results indicate that the availability of local computer access facilities will not be a problem in the local implementation of our online, hands-on oriented educational

programs.]

- A substantial number of colleges and universities do already have access to one or more IS&R systems (72.0%) and these systems are typically available to all Engineering departments (68.2%) and/or to all Physical Science departments (76.6%). However, while these systems are typically available to all faculty (98.3%), to all staff (90.4%), to all students for coursework (68.7%), and to all students for research (87.0%), they are typically being used almost exclusively by librarians (94.8%) and in only 8.6% of the colleges and universities responding were students reported as conducting searches themselves!

  [These results provide very strong justification for the need for our educational programs targeted at hands-on use of IS&R systems by the end-users themselves, e.g., students, faculty, and researchers, in contrast to library intermediaries.]

- With respect to college and university interest in offering Physical Science and Engineering students an opportunity to learn the principles and concepts of online IS&R systems and interact with such systems, only 2.5% of the respondents replied in the negative; 67.7% responded "YES", 21.7% undecided, and 7.5% responded that they are presently doing so.

  [These results indicate strong interest in the areas that our educational programs are addressing.]

- Funding was identified as the major obstacle to course implementation (82.1%).

  [Our PC R&D activities are addressing a number of potential solutions to the known high costs (vendor search time costs, telephone costs, telecommunications costs) of providing substantive, online, hands-on usage of large-scale IS&R systems.]

- An overwhelming majority (86.4%) of the colleges and universities responding indicated interest in incorporating a pre-packaged program (as we are developing) into their curriculum when such programs become available.

  [These results again represent very strong justification for our educational programs.]

- With respect to the types of educational material to be incorporated within the pre-packaged educational programs, respondents indicated their desire for virtually all of the types of educational material that we are planning to develop, including course syllabi (73.5%), hands-on usage assignments and keys (65.2%), support handouts (62.1%), workbooks (60.6%), overhead transparencies (55.3%), lesson plans (53.8%), textbooks (51.5%), homework assignments and keys (49.2%), videotapes/films (47.7%), and bibliographies

(43.2%). Only discussion topics (39.4%) and examinations and keys (38.6%) were requested by less than 40% of the respondents.

[Again, the results provide strong justification for the need for the types of educational materials that we are developing and incorporating within the educational programs.]

The above results clearly justify our educational program development efforts from the standpoint of colleges and universities throughout the United States (since the academic institutions providing the results represent precisely the target educational communities for our educational programs).

As a result of the course development efforts funded by NASA, the following transportable course materials have already been developed, pilot tested, evaluated, and are available for distribution:

- 18-week full semester course materials (system-independent and discipline-independent):

  - Course outlines/syllabi
  - Lesson plans
  - Visuals
  - Instructor's manual
  - Additional supportive handouts/diagrams
  - Bibliographies
  - Homework assignments with answer keys
  - Hands-on usage assignments with answer keys
  - Examinations with answer keys
  - Course evaluation documents.

- All NASA/RECON system-specific educational materials for the 18-week full semester course.

- 2-day NASA/RECON intensive workshop course materials (discipline-independent):

  - Workshop outlines/syllabi
  - Visuals
  - Additional supportive handouts/diagrams
  - Hands-on usage assignments with answer keys
  - Workshop evaluation documents.

2.2 The USL NASA/JPL Space Station Project

The USL NASA/JPL Project represented a research and development effort to provide a wide range of computing capabilities for NASA Space Station pricing analyses, including computer system design, development, and implementation in areas such as pricing auctions, economic modeling, statistical analysis, resource scheduling, graphical display facilities, computing environment analysis, and overall computer system life cycle management. These services were provided to NASA Headquarters, the NASA Space Station Program, and the Jet Propulsion Laboratory (JPL) to facilitate the conduct of quantifiable comparative analyses of alternatives and options associated with Space Station pricing activities.

The primary objectives of the USL NASA/JPL Project include the following:

(1)   Determination of the specific functionality required of computer systems to be developed for use in conjunction with the activities of the NASA JPL Space Station Pricing Workshop based on needs expressed by NASA Headquarters, the NASA Space Station Program, JPL, and other Workshop participants/participating agencies.

Categories of functionality include the following:

(a)   Computerized simulation/modeling capabilities, including discrete and continuous simulations, static and dynamic modeling, and parametric analysis of equation coefficients.

(b)   Computerized differential equations solution capabilities pursuant to theoretical pricing algorithm implementation.

(c)   Computerized economic forecasting capabilities.

(d)   Computerized resource scheduling and resource allocation capabilities.

(e)   Computerized queueing analysis capabilities.

(f)   Computerized pricing auction capabilities.

(g)   Computerized statistical data analysis capabilities for statistical analysis, summarization, and reporting of experiment results.

(h)   Computerized graphical display and analysis capabilities for graphical representation of the results from any of the foregoing capabilities and for interactive graphical analysis, manipulation, and experimentation with multi-variable relationships.

(2)   Analysis and recommendations of the most appropriate generic computing environment structure to serve as the structural foundation for the provision of all computing capabilities.

The candidate environments include the following:

(a)   Mini/mainframe (medium/large-scale, centralized computing facility) versus PC (personal computer - multiple microcomputer workstations, potentially distributed at remote geographic sites) environments.

(b)   Mini/mainframe together with PC environments, requiring:

> — Completely compatible mini/mainframe and PC operating systems, programming languages and programming language compilers, and all specific applications software packages.
> — Mini/mainframe-to-PC and PC-to-mini/mainframe downloading and uploading protocols.

(c) PC networking providing full computer communications networking capabilities across multiple PC's, potentially including both local area networking and long-distance, remote networking.

(3) Analysis and recommendations of the the most appropriate specific computing environment structure to serve as the development and implementation foundation for the provision of all computing capabilities.

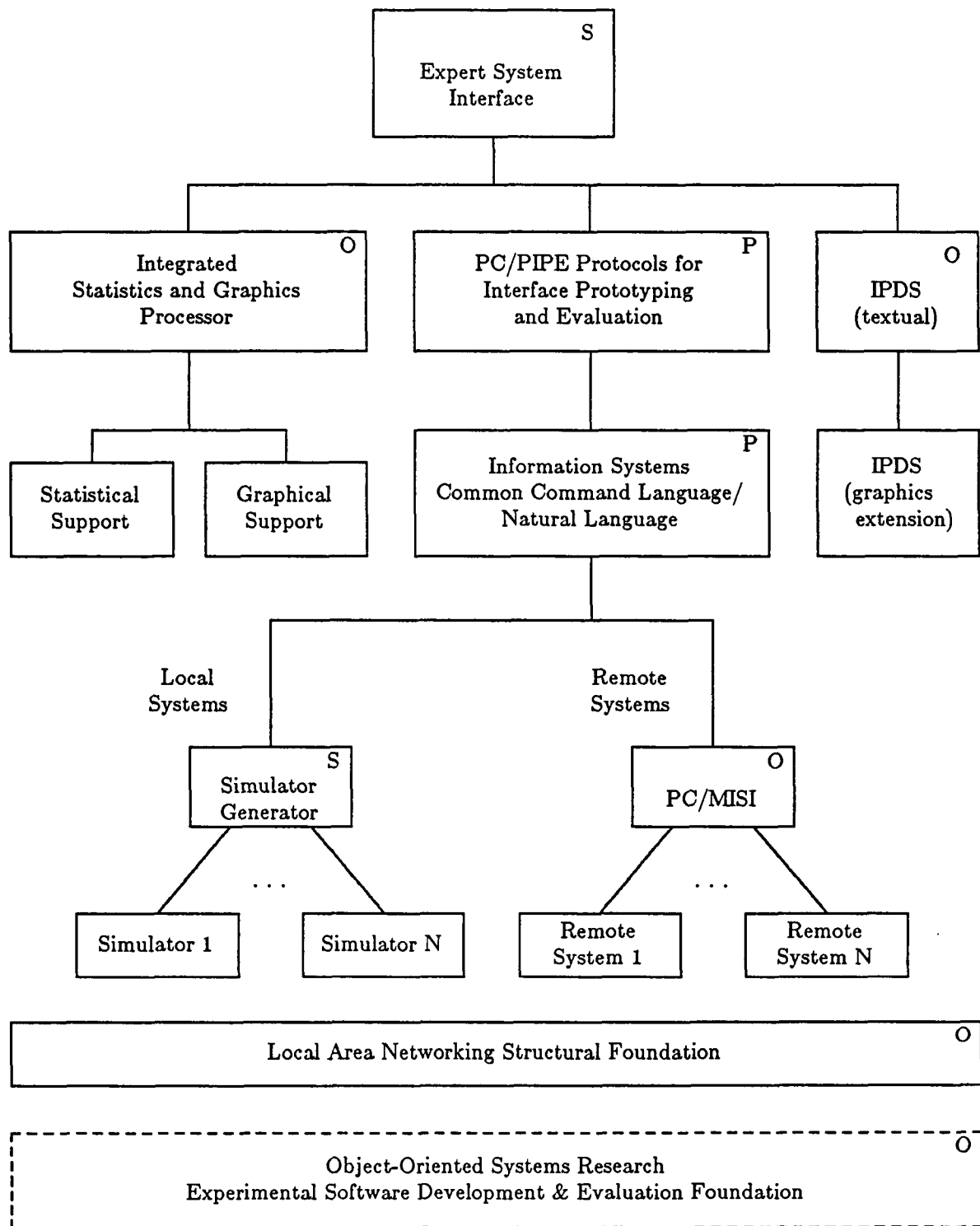The following types of specific computing environment analyses and recommendations are required:

(a) Computer hardware-related issues:

> — Hardware workstation functionality. Decision factors include projected computational processing time; projected required main and auxiliary storage capacities for developed software, for purchased packaged software, for data files, and so on; compatibility with existing and projected future NASA Headquarters, NASA Space Station Program, and JPL hardware configurations; and hardware extensibility over time.
> — Networking hardware to implement multiple machine networking capabilities.
> — Associated hardware peripherals (e.g., printers, plotters, etc.).

(b) Computer software-related issues:

> — Operating system functionality, including application software availability compatible with the operating system; compatibility with current, and extensibility into projected future NASA Headquarters, NASA Space Station Program, and JPL operating system and software configurations, e.g., compatibility with the NASA Space Station Information System 4-level workstation philosophy.
> — Specific analyses and recommendations for each of the software capabilities generically referenced in objective (1), items (a) through (h), namely:
>> — Simulation/modeling software.
>> — Differential equations solution software.
>> — Economic forecasting software.
>> — Resource scheduling and resource allocation software.
>> — Queueing analysis software.
>> — Pricing auction software.
>> — Statistical data analysis software.
>> — Graphical display and analysis software.

(4) Design and implementation of various pricing auction mechanisms for use within interactive, computer-based experimental environments (this NASA/JPL objective was addressed by Southern University, Baton Rouge, Louisiana):

(a) Smith auction prototype.

(b) Modified Smith auction and/or other auction mechanisms as determined appropriate for the Space Station pricing analysis environment.

(5) Design, implementation, and execution of appropriate statistical data analyses for the analysis of experimental data generated from experiments conducted utilizing the pricing

auction mechanisms implemented as a result of the completion of objective (4) above.

(6)   Provision of complete computer system life cycle management for all of the computing capabilities associated with each of the items referenced in objectives (1) through (5) above.

(7)   Provision of a complete quality assurance program to ensure formal assessment and evaluation of the quality of all of the products produced pursuant to the accomplishment of objectives (1) through (6) above.

2.3   The USL NASA PC R&D Project

In order to provide an integrated foundation and supportive computing environment for conducting the R&D activities associated with both the USL NASA/RECON Project and the USL NASA/JPL Project overviewed in the previous two sections, we have established the USL NASA PC R&D Project consisting of the following nine interrelated PC-based sub-projects (see Figure 1):

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                          ┌─────────────────┐ S
                          │ Expert System   │
                          │   Interface     │
                          └─────────────────┘
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Integrated Statistics and Graphics Processor	O
PC/PIPE Protocols for Interface Prototyping and Evaluation	P
IPDS (textual)	O

Statistical Support	
Graphical Support	
Information Systems Common Command Language/ Natural Language	P
IPDS (graphics extension)	

Local Systems

Remote Systems

Simulator Generator	S
PC/MISI	O

Simulator 1 ... Simulator N

Remote System 1 ... Remote System N

Local Area Networking Structural Foundation	O

Object-Oriented Systems Research Experimental Software Development & Evaluation Foundation	O

PROJECT STATUS LEGEND: S : Specification Stage   O : Operational Stage
                        P : Prototyping Stage

USL NASA/RECON & NASA/JPL PC Research Projects

(1)   *Expert System Interface Project:* a knowledge-assisted, front-end gateway to all required research support tools.

(2)   *Integrated Statistical/Graphical Processor:* statistical, graphical, and modeling research support tools.

(3)   *PC/Protocols for Interface Prototyping and Evaluation (PC/PIPE):* support for the rapid prototyping and evaluation of user/system interfaces.

(4)   *Information System Common Command Language/Natural Language Project:* top two levels of user/information system interface mechanism.

(5)   *PC/Multiple Information System Interface (PC/MISI):* bottom three levels (direct system invocation, individual system command language, common menu language driver) of user/information system interface mechanism.

(6)   *Information System Simulator/Simulator Generator Project:* information system and database simulator generator and simulator support tools.

(7)   *Interactive Presentation Development System Project:* PC-controlled video projection/presentation support tools.

(8)   *Object-Oriented Systems/Metrics Project:* research addressing object-oriented systems prototyping, development, experimental metrics analysis, and validation.

(9)   *Local Area Networking Structural Foundation Project:* the USL NASA net consists of an ETHERNET-based LAN of IBM PC, XT, AT, and 3270 PC/G machines, plus AT&T 3B2/400, 6300, and 7300 UNIX PCs dedicated to these NASA projects.

The following nine sub-sections provide brief overviews of these nine PC-based sub-projects.

2.3.1 Expert System Interface Project

The ultimate goal of the Expert System Interface Project is to construct an expert system to serve as a knowledge-assisted gateway between the (potentially) computing-naive end-user communities and the totality of computing capabilities being represented within all of the other component sub-projects of these NASA R&D programs. This project is only in an initial specifications stage at the present time.

2.3.2 Integrated Statistical/Graphical Processor

The fully-operational Integrated Statistical/Graphical Processor Project represents the development of a highly integrated and highly extensible PC workstation processor for statistically analyzing and graphically displaying either empirical results from actual experiments of public good pricing mechanism implementations or results from simulations of theoretical economic

auction models in support of NASA JPL Space Station pricing analyses.

2.3.3 PC/Protocols for Interface Prototyping and Evaluation Project

The PC/PIPE system, selected components of which are in a preliminary prototyping stage, represents a set of tools to facilitate the design, rapid prototyping, and implementation of user interfaces, coupled with a set of run-time support tools which provide extensive facilities for the monitoring and evaluation of user/system interaction protocols and the prototyped interfaces themselves.

2.3.4 Information System Common Command Language/Natural Language Project

This project represents a major planned extension to the PC/MISI Project (see Section 2.3.5), intended to superimpose two additional language processing levels on top of the existing three interface levels of PC/MISI in order to provide complete support for a command language truly "common" across all major interactive information storage and retrieval systems (e.g., NASA/RECON, DOE/RECON, DIALOG, BRS, ORBIT, etc.) and further to provide a natural language front-end to this common command language.

2.3.5 PC/Multiple Information System Interface Project

The fully-operational PC/MISI project represents the design, implementation, and operational use of a mechanism for providing multi-level casual user access to multiple, large-scale, remote information storage and retrieval systems. By implementing all required long distance communications network access protocols, host system login protocols, host system command interpreter protocols, and PC/host uploading and downloading protocols, PC/MISI provides a highly consistent and simplified user view of multiple, functionally-different information systems, eliminating the tremendous learning and usage burden from the user who requires access to multiple, remote information systems and databases.

2.3.6 Information System Simulator/Simulator Generator Project

This project, in advanced specifications stage, represents an attempt to address the very high cost of providing extensive online access to major information storage and retrieval systems (typically ranging between $50 and $250 per online connect time hour). In order to eliminate long

distance telephone and communications network charges and host system online connect time charges, this project focuses on the development of mechanisms for generating simulators of such systems and their databases to reside in local PC workstations. While such simulators would not, of course, be used by researchers requiring access to complete and current databases, they would provide extremely cost-effective mechanisms for use within the NASA/RECON education and training programs introduced in Section 2.1.

2.3.7 Interactive Presentation Development System Project

The fully-operational Interactive Presentation Development System (IPDS) represents a highly interactive, PC-based system for creating, editing, and displaying video presentation sequences as a dynamically-modifiable and graphically-enhanced replacement for traditional overhead transparency or slide presentations. This system, providing total PC control over large-screen video projection equipment, has also been developed primarily for support of the NASA/RECON education and training programs.

2.3.8 Object-Oriented Systems/Metrics Project

This project is concerned with investigating the impact of object-oriented systems design and implementation methodologies on software systems in distributed and highly heterogeneous computing environments. The primary issues addressed include the extension of object-oriented systems to support distributed and highly parallel computing, the evaluation of object-oriented systems performance for the development, modification, and maintenance of software systems in distributed environments, and the development and validation of software metrics appropriate to object-oriented systems. Our research in this area will initially emphasize the development and validation of software metrics for design and implementation using commercially available object-oriented development environments. This activity is intended to provide objective, quantitative, and extensible results in the near term. These results will be of immediate value to commercial concerns with an interest in object-oriented systems technology. Additionally, a long-term, four-phase research plan has been formulated to address prototype systems design and implementation, evaluation criteria specification, experimental application selection, and evaluation.

2.3.9 Local Area Networking Structural Foundation Project

This fully-operational project represents a combined theoretical and experimental analysis of heterogeneous node configurations, local area network topologies, information system and

database distribution policies, and associated performance metrics targeted at determining the optimal local area network structure for supporting all of the PC workstation R&D being addressed within the other eight sub-projects overviewed above.

2.4 USL NASA Project Future Directions

The research and development activities overviewed within this document do not represent the efforts of a small group of researchers operating in isolation from either our own internal university community or from the external research and academic communities and commercial marketplace. Rather, we have consistently viewed these R&D projects as a mechanism for both enhancing the traditional university curricula by incorporating advanced research techniques and formal, large-scale project development methodologies into that curricula, and for enhancing the relationships and technology transfer between academic and commercial concerns.

To date, these NASA projects have involved the concerted efforts of approximately 95 graduate and undergraduate students, conducting serious research and development activities under the auspices of graduate research seminars and senior undergraduate special projects. These NASA R&D activities have resulted in over 80 publications and reports. The NASA/RECON educational programs and the NASA microcomputer R&D environment developed pursuant to these projects have been utilized by over 1,200 students as part of formal, full-semester courses (at both the senior undergraduate level and the graduate level).

Additionally, the results of USL NASA Project activities have received considerable attention within the commercial computing marketplace. In particular, over 110 software vendors have made significant software donations to our NASA development work and maintain regular liaison with our PC R&D staff.

Based on the results of this substantial usage of our NASA educational resources and our NASA PC hardware and software resources, and based on our extensive interactions with the 110+ commercial computing organizations which have provided hardware and/or software resources to these project, a number of directions for future research have evolved:

(1)   Analytical models of user interfaces.

Within the current state of research in human engineering and user interface design, there are a massive number of unsupported, often conflicting, design principles that have been proposed. Many of these guidelines are based on the intuition and limited experience of particular designers with particular systems. The field seriously needs analytical models of user behavior (e.g., cognitive models, conceptual models, etc.), analytical models of user/system interaction protocols, and formal specifications of user interfaces. These issues are an integral component of future planned phases of both the NASA Object-Oriented Systems Project and the NASA PC/PIPE (Protocols for Interface Prototyping

and Evaluation) Project.

(2) *Automated user/system interaction monitors.*

The utilization of transparent, automated user/system interaction monitors is proving to be absolutely essential for conducting serious and objective evaluations of alternative user/system interface prototypes and designs. Without the availability of such monitored data, assessments of interface effectiveness become subjective conjectures, rather than statistically defensible results derived from objectively measurable phenomena.

(3) *Human factors experimental designs.*

With significant diversity in the backgrounds, experience, motivation, and needs of different components of our user communities, very careful attention to the design, conduct, and verification of both controlled and uncontrolled human factors experiments is clearly needed. Experimental researchers need to be able to quantify a variety of human factors issues in order to be able to generalize user/system interaction results beyond specific systems, applications, and user communities.

(4) *Object-oriented design philosophy.*

As we are experiencing within our own very robust NASA PC hardware and software configurations, computing environments are becoming increasingly distributed collections of highly heterogeneous computing components requiring dynamic reconfigurability in response to technological evolution. Object-oriented systems provide strong encapsulation, in that objects use private methods to manipulate private data exclusively in response to typed messages from other objects. This minimizes inter-module dependencies and provides for very flexible problem decomposition strategies. The late binding of messages to target objects, in object-oriented systems, provides the flexibility to reconfigure software systems dynamically without re-compilation, supporting both the adaptability of the overall system and the ability to aggregate existing modules into new objects on the fly. Very rapid incremental development and modification are directly supported by the object-oriented class/inheritance mechanisms. Such design philosophies are becoming critical within highly dynamic R&D environments, and are currently under serious investigation within the USL NASA PC graphics research area and the USL NASA expert systems research area.

3. OVERVIEW OF USL CACS INSTITUTIONAL RESOURCES

The Center for Advanced Computer Studies (CACS) at the University of Southwestern Louisiana was established in October 1984 by combining existing graduate programs in Computer Science and Computer Engineering. Graduate degrees have been offered by the University in Computer Science for 22 years (MS-1964, PhD-1968) and in Computer Engineering for five years (MS-1981, PhD-1986). Undergraduate degrees in Computer Science and Computer Engineering are offered by the Departments of Computer Science and Electrical and Computer Engineering, respectively.

As of the 1986-1987 Academic Year, CACS has 20 full-time graduate faculty members, 96 PhD students, and 182 MS students.

CACS is extremely active in advanced research and development activities, having received numerous research grants and contracts from organizations such as the National Science Foundation, the National Aeronautics and Space Administration, the Army Research Office, the Army Corps of Engineers, the Office of Naval Research, the North Atlantic Treaty Organization, and many others. All R&D activities in the information systems area are coordinated through the DBMS (Data Base Management System) Project, a large-scale R&D project founded in October 1975 by the Principal Investigator for this proposed project, and administered under the auspices of the Center for Advanced Computer Studies at USL.

Computing facilities available to all CACS researchers include two DEC VAX-11/780s (one UNIX, one VMS) and approximately 40 PCs, plus access to the University's central Computing Center which includes an IBM 3090/200 (VM and MVS; acquired in 1986), a three-processor Pyramid 90X system (all UNIX), and the University's Honeywell Multics system (in the process of being phased-out over a two-year period and replaced by the IBM 3090).

Additionally, the USL NASA Project has its own computing environment, consisting of 19 computer hardware machines (AT&T 3B2/400, AT&T 6300, AT&T 7300 UNIX PC, IBM PC, XT, AT, 3270/G, ZENITH Z-100, Z-150, Z-248 systems) and over 195 different software systems.

4. CURRENT USL NASA PROJECT FUNDING SUPPORT

As of July 1987, the current levels of funding support for the USL NASA Project, *excluding* direct grant/contract dollars provided by NASA funding, are as depicted in the following table:

USL NASA Project Funding Support

(excluding direct grant/contract dollars provided by NASA funding)

1.	All NASA/RECON System Usage Time/Cost (NASA Headquarters Donated)	$ 239,000.
2.	All TELENET Communications Network Time/Cost (NASA Headquarters Donated)	$ 63,000.
3.	IBM PC-Compatible Software Donation Program (102 Different Donor Organizations)	$1,080,000.
4.	AT&T Hardware/Software Donation Grant	$ 100,000.
5.	AT&T-Compatible Software Donation Program (16 Different Donor Organizations)	$ 99,800.
6.	Other Software Donations (NASA Project-Compatible IBM 3090 Software)	$ 151,200.
7.	Other Hardware Donations and Miscellaneous Project Support	$ 34,700.

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TOTAL PROJECT FUNDING $ 1,767,700.

In the above table, one of the most notable items of widespread recognition of the USL NASA Project is evidenced in the large number of different organizations providing software grant support to this project. The USL NASA Project's PC software environment (and the majority of its hardware environment) has been established almost completely through outright donations of PC software (and hardware) to the USL NASA Project. Recognizing both the past successes and current potential of our R&D activities, the following major PC software vendors are currently participating donor organizations in the USL NASA PC Software Donation Programs:

1. International Business Machines Corporation
2. Lifeboat Associates
3. SPSS, Incorporated
4. Phoenix Computer Products Corporation
5. Applied Technical Systems
6. Wiley Professional Software
7. Rational Systems, Inc.
8. Arity Corporation
9. Central Point Software Incorporated
10. Spruce Technology Corporation
11. Gold Hill Computers
12. UniPress Software
13. The Software Link, Incorporated
14. Oracle Corporation
15. Relational Database Systems, Inc.
16. Computer Innovations, Inc.
17. Greenleaf Software, Inc.
18. Emerging Technology Consultants, Inc.
19. Microrim, Inc.
20. WELCOM Software Technology
21. Spartacus, Inc.
22. FTG Data Systems
23. Strategic Software Planning Corporation
24. Penton Software, Inc.
25. Zanthe Information, Inc.
26. Expertware, Inc.
27. Productivity Products International, Inc.
28. Production Systems Technologies, Inc.
29. Network Software Associates, Inc.
30. The Lisp Company
31. IMSL Incorporated
32. MacMillan Software Company
33. Simulation Software, Ltd.
34. Alloy Computer Products, Inc.
35. Texas Instruments, Incorporated
36. Microsoft Corporation
37. Lotus Development Corporation
38. FTP Software, Inc.

39.	Foresight Resources Corporation
40.	Micrografx, Inc.
41.	Gimpel Software
42.	Lugaru Software, Ltd.
43.	Enertronics Research, Inc.
44.	Prospero Software
45.	American Small Business Computers
46.	McDermott Corporation
47.	WordPerfect Corporation
48.	Software Architecture & Engineering, Inc.
49.	AT&T Information Systems, Inc.
50.	Locus Computing Corporation
51.	UNIFY Corporation
52.	Touchstone Software Corporation
53.	Rhodnius Incorporated
54.	The Pilot Group, Intelligent CourseWare, Inc.
55.	BRS Information Technologies
56.	Conetic Systems, Inc.
57.	Aker Corporation
58.	Prior Data Sciences Product Sales, Inc.
59.	Systems Compatibility Corporation
60.	HavenTree Software Limited
61.	Paul Mace Software, Inc.
62.	InstaPlan Corporation
63.	The Whitewater Group
64.	Datalight
65.	MathSoft, Inc.
66.	Personal TEX, Inc.
67.	Kemp-Carraway Heart Institute
68.	MicroPro International Corporation
69.	POWER-BASE Systems, Inc.
70.	mbp Software and Systems Technology, Inc.
71.	Gazelle Systems
72.	Software Publishing Corporation
73.	MicroControl Systems, Inc.
74.	Scientific Endeavors Corporation
75.	Persoft, Inc.
76.	Expert Systems International
77	AT&T Bell Laboratories (Murray Hill Labs)
78.	AT&T Bell Laboratories (Morristown Labs)
79.	Datastorm Technologies, Inc.
80.	Catspaw, Inc.
81.	Micro Data Base Systems, Inc.
82.	Ron Turley Computer Associates
83.	Peachtree Software
84.	EXSYS, Inc.
85.	Universal Technical Systems, Inc.

86.   CalComp
87.   Image Network
88.   The Santa Cruz Operation
89.   Symantec Corporation
90.   R.R. Software, Inc.
91.   Custom Software Systems
92.   DataEase International
93.   True BASIC, Inc.
94.   JMI Software Consultants, Inc.
95.   Automata Design Associates
96.   The Wollongong Group
97.   MIX Software
98.   The Small Computer Company, Inc.
99.   Generic Software, Inc.
100. UniPress Software
101. Data Language Corporation
102. Integral Quality, Inc.
103. Communications Research Group
104. STSC, Inc.
105. Mouse Systems Corporation
106. MicroProducts, Inc.
107. Access Technology, Inc.
108. Ashton-Tate
109. General Research Corporation
110. Campbell Services, Inc.
111. Meridian Software Systems, Inc.
112. Interactive Systems, Inc.
113. Nastec Corporation

The number of different participating organizations and the magnitude of their donations are yet another indication of the level of respect that our PC R&D activities are receiving within the professional computing community and within the commercial computing marketplace.

5. OVERVIEW OF RESEARCH & DEVELOPMENT ACTIVITIES

This chapter describes a number of major computer science R&D activities and capabilities that are highly relevant to the educational curriculum development work that was performed pursuant to NASA Grant NGT-19-010-900.

Since its inception, the USL NASA Project has maintained a strong interest in evolving technologies applicable to the support of the computing needs of scientific and engineering personnel. The USL NASA Project has significant, proven expertise in a variety of computer systems research and development areas, including, in essence, each of the R&D areas identified in Section 2.3 of this document (for example, object-oriented systems and their associated evaluation methodologies, interactive user interfaces, expert and knowledge-based systems, graphical information systems, distributed resource integration, programming and prototyping environments, distributed database management systems, and information storage and retrieval systems). Additionally, we have special interests in certain research activities that have potential generalizability across all application domains (for example, objective and analytical productivity/complexity criteria, metrics, and evaluation methodologies for development in, and utilization of object-oriented systems, regardless of the particular application domain).

The following sections of this chapter highlight R&D projects in the four primary areas which represent the focal points of our current and future planned R&D activities. These four areas are:

- **Object-Oriented Systems**
- **Expert Systems**
- **Database Management Systems**
- **Graphics.**

The chapter concludes with a brief identification of the USL NASA Project's computing resources that are currently available for supporting these R&D activities.

5.1 Object-Oriented Systems R&D Activities

Object-oriented systems technology has recently been used in the development of a large variety of complex software systems including database management systems, expert and knowledge-based systems, operating systems, programming environments, prototyping systems, and simulation systems. The resulting systems, developed utilizing the object-oriented paradigm, are often characterized as providing better productivity, flexibility, reliability, maintainability, and extensibility than similar systems developed using more traditional software technologies. Initial success in achieving these design goals using this technology has prompted several major commercial concerns, including, for example, AT&T, Hewlett-Packard, Tektronix, and Xerox, to

establish substantial long-term commitments to object-oriented systems technology for both internal and commercial product development.

However, despite the significant recent research and development activity in this area, very little research and associated experimentation has been performed in an attempt to quantify and characterize experimentally the apparent leverage provided by object-oriented systems in the software development, utilization, and evolution processes.

As one example of our thrusts in one of these R&D areas, the major objectives of our metrics research project for object-oriented systems are as follows:

(1)   The establishment of a robust, multi-vendor hardware/software experimental environment for supporting generalizable research into object-oriented systems measurement and evaluation.

(2)   The formulation of objective, analytical criteria and metrics to characterize both object-oriented development systems and specific object-oriented applications.

(3)   The conduct of carefully controlled comparative evaluations of experimental applications with respect to their development and utilization under both object-oriented and traditional design methodologies.

(4)   The experimental validation of quantitative and extensible complexity metrics appropriate to object-oriented development activities.

These objectives are motivated by the inadequacy of existing metrics to address aspects unique to object-oriented systems, including the issues of hard encapsulation of data-centered objects (this minimizes inter-module data coupling), inheritance lattice organization, and inheritance mechanisms.

5.2   Expert Systems R&D Activities

The primary thrust of the USL NASA Project in the area of expert systems research and development is the NASA Expert System Interface Project as identified in Section 2.3.1 of this document. As illustrated in Figure 1 of Section 2.3, this project represents the very highest level user/system interface area within the entire scope of the USL NASA Project's research and development activities.

The ultimate goal of this long-term R&D project is to construct an expert system which will serve as a knowledge-assisted gateway between the potentially computing-naive end-user communities and the totality of computing capabilities and resources associated with all of the other component sub-projects of the USL NASA R&D programs described within this document.

Within this context, this specific project has the potential for serving as the R&D foundation for addressing significant strides in expert systems research, since this project addresses the front-ending of expert systems hardware and software technology to a large number of other types of computer-based systems and associated application domains. In particular, as defined within the scope of Section 2.3, the NASA Expert System Interface Project will address each of the following categories of target systems/applications:

(1) *Statistical, graphical, and modeling research support tools* (via the Integrated Statistical/Graphical Processor Project of Section 2.3.2).

(2) *Tools for the rapid prototyping and evaluation of user/system interfaces* (via the PC/Protocols for Interface Prototyping and Evaluation (PC/PIPE) Project of Section 2.3.3).

(3) *Common command language and natural language interface facilities* (via the Information System Common Command Language/Natural Language Project of Section 2.3.4).

(4) *Both local and remote database management systems and information storage and retrieval systems* (via the PC/Multiple Information System Interface (PC/MISI) Project of Section 2.3.5).

(5) *Simulator and simulator generator systems* (via the Information System Simulator/Simulator Generator Project of Section 2.3.6).

(6) *Educational and training workstation facilities* (via the Interactive Presentation Development System Project of Section 2.3.7).

(7) *Object-oriented system prototyping, experimentation, and evaluation tools* (via the Object-Oriented Systems/Metrics Project of Section 2.3.8).

(8) *Workstation interconnection tools* (via the Local Area Networking Structural Foundation Project of Section 2.3.9).

By the very nature of its scope of coverage, this project holds tremendous potential for supporting very high visibility research in a wide variety of expert systems application domains.

5.3 Database Management Systems R&D Activities

Within the scope of computer science research at the University of Southwestern Louisiana, the area of database management systems has represented one of the most longstanding, formally-established R&D projects at this University.

Founded in October 1975 by the author of this Executive Summary, the USL DBMS Project has served, for the past 11 years, as the primary research and development foundation for supporting the USL Computer Science Department's and the Center for Advanced Computer Studies' graduate-level area of emphasis in Management Information Systems, producing, during this time period, 4 completed Ph.D. dissertations and over 30 completed M.S. Theses/Projects

specifically addressing the DBMS area.

Prior to 1984, the primary R&D directions of DBMS activities at USL were focused in the following area: multi-level user language support for generalized database management systems, comparative models of database design philosophies (relational, network, hierarchical), both imbedded and external software monitoring mechanisms for information systems, and generalized measurement and evaluation facilities for both database systems and information storage and retrieval systems.

Since the initiation of the USL NASA Project in December 1983 under the direction of the same principal investigator (Dominick), the goals and directions of the USL DBMS Project have been realigned to coincide with the information systems-related R&D components of the USL NASA Project. This current set of integrated R&D goals and directions include the following primary thrusts:

(1) *Rapid prototyping of user/system interfaces for information systems.* Predicated on both cognitive and conceptual analytical models of user interfaces (see future direction (1) in Section 2.4), this R&D direction focuses on the development of a comprehensive set of automated tools for the initial prototyping, experimental evaluation, and subsequent re-design/re-evaluation of user/system interfaces for both database management systems and information storage and retrieval systems. The primary NASA Project supporting this research is the PC/PIPE Project of Section 2.3.3 and a secondary supportive project is the PC/MISI Project of Section 2.3.5.

(2) *Automated interaction monitoring within experimental designs.* Based on extensive DBMS Project research and development expertise in the areas of software monitoring and user interface evaluation, this R&D direction focuses on the use of automated user/system interaction monitors (see future direction (2) in Section 2.4) within carefully-controlled human factors experimental designs (see future direction (3) in Section 2.4) to establish an integrated R&D environment for the automated collection of empirical user/system interaction protocol data, the automatic and dynamic analysis of such data, and the interpretation of experimental results as feedback into information system self-tuning processes. The primary NASA projects supporting this research are the aforementioned PC/PIPE Project and the NASA Object-Oriented Systems/Metrics Project of Sections 2.3.8 and 5.1.

(3) *Educational curricula and supportive workstations for information systems.* In essence, this R&D direction subsumes the entire NASA/RECON Educational Project of Section 2.1. Serving as one of our three primary governing directions for the entire USL NASA Project, this R&D thrust has been described in detail in previous sections of this capabilities document, and will not be reiterated here. It is, however, important to note that our approach to educational program development and usage is strongly supported by innovative educational PC workstation functionality provided by R&D activities such as the NASA Interactive Presentation Development System of Section 2.3.7 and the NASA

5.4 Graphics R&D Activities

The rapidly decreasing cost and rapidly increasing capability of workstation-based graphics systems have made possible the incorporation of sophisticated interactive graphics functionality into a wide variety of complex system designs. The widely recognized impact of this technology has been a significant increase in user productivity, provided that appropriate consideration is given to human factors design issues, system performance constraints, and graphical software development support.

The USL NASA Project has actively pursued graphical systems research in several areas which represent the principal focal points of our continuing graphical information systems research. These areas include:

(1) *Graphical software development methodologies.* This research effort is aimed at investigating design methodologies appropriate to effectively supporting the development of interactive graphical applications. Current activities include a comparative evaluation of procedural, functional, and object-oriented design decomposition strategies for graphical information systems.

(2) *Graphics standards.* This activity addresses investigating the design of graphics standards and the impact of those standards on systems development in various applications domains. Standards under investigation at various levels of functionality include: GKS, CGI, CORE, DGIS, NAPLPS, and PHIGS.

(3) *Interactive graphical tools integration.* The goal of this effort is to develop integration strategies that permit the effective coordinated use of multiple graphical tools in distributed workstation environments. Major issues include consistent user interface design, sharability of information between tools, and application design generality. Project activity in this area has included the Interactive Presentation Development System, The USL NASA/JPL Graphical Analysis System, and the USL Document Preview/Preparation System.

(4) *Distributed graphics systems.* Making effective use of computing resources in a distributed environment depends upon the ability to coordinate those resources in addressing problems. This effort focuses on the investigation of design strategies for graphical information systems in distributed environments. Major considerations of this research effort are distributed resource models, resource interaction protocols, reconfiguration strategies, and device independence mechanisms.

(5) *Image processing.* The focus of this research direction is the innovative incorporation of image processing techniques into graphical information systems. Current interests include

image compression, classification, enhancement, and representation structures.

(6)   *Realistic image rendering.* This research focus will concentrate on designing and developing highly efficient strategies for producing realistic images. Current areas of exploration include integral ray-tracing, oct-tree algorithms, surface representation and manipulation techniques, and lighting models.

5.5   Supportive Computing Resources Currently Available

The USL NASA Project has made a substantial commitment to each of the previously identified R&D areas as pivotal to our future R&D activities.

This commitment includes the virtual dedication of our recently-acquired (October 1986) AT&T computing environment, including 7 workstations, for extended periods to the support of controlled usage experiments, with associated automated data collection and evaluation, related to object-oriented versus traditional systems development and usage.

Our initial expert systems development work has been conducted utilizing our substantial IBM PC-based environment, currently supporting Software Architecture & Engineering's *KES Knowledge Engineering System*, Texas Instruments' *Personal Consultant*, Production Systems Technologies' *OPS83*, Kemp-Carraway's *FLOPS*, Expert Systems International's *ES/P Advisor*, EXSYS, Inc.'s *EXSYS Expert System Development Package*, General Research Corporations's *TIMM-PC* with *EXONLY*, and a variety of LISP and PROLOG systems (including the major such products from Gold Hill Computers, Arity Corporation, and The Lisp Company). Similarly, our initial object-oriented systems development work has been conducted utilizing the same IBM PC-based environment, currently supporting Xerox's *Smalltalk*, Texas Instruments' *Scheme*, AT&T's *C++*, The Whitewater Group's *ACTOR*, and Productivity Products International's *Objective-C*.

As an extension to our already extremely successful software donation programs for our PC environments (see Chapter 4), efforts are currently underway to establish a comprehensive software experimental environment for our AT&T workstations. Toward that end, the USL NASA Project has initiated contact with, and received preliminary commitments from a number of organization for the donation of AT&T-compatible object-oriented development products, including *C++* (recently received in Beta test mode for our AT&T 7300 Unix PC's from AT&T Bell Laboratories), *Objective C* from Productivity Products International, and *Gemstone* (an object-oriented distributed database management system) from Servio-Logic Development Corporation.

The USL NASA Project currently has installed 35 major database system software products for supporting the R&D activities identified in Section 6.3 above. These include some of the most powerful and most well-respected relational database management systems and associated query language and application development systems available today for PC environments, including, for example, Oracle Corporation's *ORACLE* database system, *SQL* query interface, and

SQL-DSS CALC integrated spreadsheet system, Relational Database Systems' *INFORMIX/SQL* and *ESQL/C* systems, Microrim's *RBASE:5000*, Zanthe's *ZIM Application Development System*, Unify Corporation's *UNIFY* relational database management system, Rhodnius' *Empress/32* relational database system environments, Conetic Systems' *C/BASE* database system and database utilities environments, Micro Data Base Systems' *Knowledge Man/2* relational database system, including its major natural language, communications, graphics, report generator, text processing and forms generator interfaces, The Small Computer Company's *filePro 16 Plus* relational database system, Data Language Corporation's *PROGRESS* relational database and applications development system, and Ashton-Tate's *dBASE III Plus*. Additionally, the we have access to Cullinet's *IDMS/R* database system and its associated applications development environments on the University's mainframe IBM 3090/200.

The USL NASA Project also has a reasonably comprehensive graphical systems development environment for supporting the R&D activities identified in Section 5.4 above. Graphics development software includes IBM's *GKS/CGI* scientific programming support series, Media Cybernetics' *Multi-Halo* programming support library, Metagraphics' *MetaWindows Plus* object-oriented graphics development environment, Prior Data Sciences' *C/GKS*, Scientific Endeavors' *Publication Quality Scientific Graphics*, HavenTree Software's *Interactive Easy Flow*, Paul Mace Software's *GRASP*, MathSoft's *MathCAD*, MicroControl Systems' *CADKEY*, Calcomp's *CADVANCE/3D*, Generic Software's *GenericCADD*, and STSC's *ATLAS-GRAPHICS* and *STATGRAPHICS* packages. Additionally, we have access to IBM's *GDDM* graphics system on the University's IBM 3090/200, Honeywell's *MGS* hierarchical graphics system on the University's Honeywell Multics system, and various graphics support systems on both CACS and NASA Unix machines.

All of the above identified, existing facilities are totally under the control of the USL NASA Project and hence available for serious and immediate dedication to the research and development activities identified earlier within this chapter.

6. EXPECTED BENEFITS TO NASA

Pursuant to NASA Grant NGT-19-010-900, NASA is, of course, receiving the full set of product deliverables associated with this project (72 attached documents).

As an additional result of having established this grant relationship with the Center for Advanced Computer Studies at USL, NASA has been receiving all of the benefits associated with the significant positive visibility that the research and development and educational programs overviewed within this document are, and will continue to be receiving within academic, governmental, and commercial scientific and engineering communities throughout the United States.

As one of the agencies providing support for these programs, NASA has been prominently acknowledged within all USL NASA/RECON project-related open literature publications, conference presentations and panel sessions, the projects' four formal working paper series', and similar information dissemination activities. This should unquestionnably result in a considerable amount of positive public relations for NASA since these programs are targeted at very widespread information dissemination and distribution.

For example, within the USL NASA/RECON Project, we are, at the present time, in communication with approximately 230 colleges and universities with respect to soliciting their input into these NASA-sponsored educational programs, and plans are in preparation for conducting needs analysis surveys of governmental and commercial organizations of similar magnitude. Furthermore, after the implementation of the educational program distribution plan, the actual administration of these educational programs at colleges and universities throughout the United States will bring very widespread exposure of this project's supportive funding agencies to faculty, researchers, staff, and students at those colleges and universities.

As just one example of the impact that these projects have had at one university, since the NASA Project was initiated at USL in December 1983, this R&D project has supported 10 funded Computer Science Research Assistants and 99 different USL graduate and undergraduate student R&D team members. Additionally, the USL NASA Project has been responsible for providing online, hands-on usage of the very large scale NASA RECON information system to over 280 USL senior and graduate students, and USL NASA Project-developed software systems have been utilized by over 1,200 USL students within full-semester courses at USL.

Furthermore, the USL NASA Project has gained tremendous additional exposure within this university community via the provision by its staff of microcomputer consultation services and/or operational computer software systems to a variety of departments and units within the University, including the each of the following units at USL:

1. Center for Advanced Computer Studies
2. Computer Science Department
3. Mathematics Department
4. Geology Department
5. Statistics Department

6.   Industrial Technology Department

7.   Chemistry Department

8.   Psychology Department

9.   College of Nursing

10.   College of Business Administration

11.   University Library

12.   University Computing Center

13.   University Office of Information Services

14.   University Campus Network Office

15.   University Media Center

16.   Office of the President

17.   Office of the Academic Vice-President

We believe that comparable levels of exposure at the other colleges and universities throughout the United States who also adopt these NASA/RECON educational programs are not at all unrealistic.

Each of these activities should yield significant positive visibility within both current and potential future NASA scientific, engineering, and educational environments and user communities.

7. SUMMARY

After a brief introduction in Chapter 1, Chapter 2 of this document provided an overview of the three primary NASA-sponsored projects being conducted by the Center for Advanced Computer Studies of the University of Southwestern Louisiana. Each of these projects represents very extensive research and development activities with a serious commitment of both NASA and USL resources and a very significant useful lifetime. For example, the USL NASA/RECON Educational Project serves as the primary foundation for a major educational program that is being developed specifically to be implanted into, and utilized within the curricula of a very large number of colleges and universities throughout the United States for many years to come.

Chapter 3 presented additional generic information concerning the institutional resources of the Center for Advanced Computer Studies at USL, and Chapter 4 highlighted the substantial commitments that have already been made to the USL NASA Project, both from its primary sponsor - NASA - and from the 110+ commercial computing organizations that are providing donated hardware and software to the USL NASA Project.

Chapter 5 of the document identified a number of planned or proposed future R&D activities which are currently being examined by the NASA staff of the Center for Advanced Computer Studies, and Chapter 6 highlighted the major categories of benefits which should accrue to NASA as a result of NASA's grant sponsorship of these R&D efforts.

Finally, the 72 attachments to this Executive Summary represent the complete Final Report and integrated set of deliverables for this grant. As illustrated in these attachments, the USL NASA Project has been very successful to date in completing a large number of both high-quality research efforts and fully-operational product deliverables pursuant to our externally-funded R&D projects. Each of these 72 deliverables is also available in machine-readable format and all referenced supportive computer programs are also available in both source and object machine-readable format.

The NASA Project of the Center for Advanced Computer Studies at the University of Southwestern Louisiana looks forward to a favorable review of this Final Grant Report and to future R&D activities with NASA.

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This document represents an annotated table of contents of reports representing results of activities being conducted by the Center for Advanced Computer Studies of the University of Southwestern Louisiana pursuant to the specifications of National Aeronautics and Space Administration Contract Number NASW-3846 and Training Grant Number NGT-19-010-900. This work is being performed jointly by the University of Southwestern Louisiana and Southern University.

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NASA CONTRACT NASW-3846

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NASA TRAINING GRANT NGT-19-010-900

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OF

DOCUMENTATION/DELIVERABLES COMPLETED TO DATE

(UPDATED: 10/02/87)

PART I.   PROJECT MANAGEMENT AND CONTROL DOCUMENTS

1.1   USL NASA TASKS/STATUS PROJECT MANAGEMENT AND CONTROL
REPORT, REVISED: SEPTEMBER 29, 1987, 59p.

The primary project management and control report being utilized at USL for project task/status
assignment, monitoring, and management. Report identifies tasks and status via task number, task
status, responsible party, date identified, date completed, milestone date, and task description.

PART II.   NEEDS ANALYSIS PHASE DOCUMENTS

2.1   NEEDS ANALYSIS PHASE: LIST OF TARGETED INSTITUTIONS, 28p.

The list of the institutions that were targeted for surveying via distribution of the first college and university needs analysis questionnaire. Questionnaires were distributed to all entries identified on this list.

2.2   NEEDS ANALYSIS PHASE: QUESTIONNAIRE COVER LETTER TO TARGETED INSTITUTIONS, 2p.

The cover letter distributed to the targeted institutions together with the first college and university needs analysis questionnaire itself in order to overview the intent of the needs analysis phase of the contract and introduce the questionnaire to the surveyed community.

2.3   NEEDS ANALYSIS PHASE: NEEDS ANALYSIS QUESTIONNAIRE, 6p.

The first college and university needs analysis questionnaire distributed to the targeted institutions. The questionnaire addressed information about the universities, information storage and retrieval system usage, information storage and retrieval system educational needs, information storage and retrieval system educational courses, and comments sections.

2.4   NEEDS ANALYSIS PHASE: NEEDS ANALYSIS QUESTIONNAIRE RESULTS, 24p.

The results of the first college and university needs analysis questionnaire. This document contains all descriptive statistics for all questions, basic correlation analysis, all respondents' comments, and results interpretation sections.

PART III.   COURSE DEVELOPMENT PHASE DOCUMENTS AND
            COURSE DEVELOPMENT WORKING PAPER SERIES
            DOCUMENTS

3.1   "COURSE DEVELOPMENT PHASE: STANDARDIZED COURSE MATERIAL
      DOCUMENTATION TEMPLATES," WAYNE D. DOMINICK, USL/DBMS
      NASA/COURSES WORKING PAPER SERIES REPORT NUMBER
      DBMS.NASA/COURSES-1, MAY, 1983, 5p.

      This Course Development Series entry contains the set of standardized course material documenta-
      tion templates for each of the following course materials: course syllabi, lesson plans, homework
      assignments, homework assignment answer keys, usage assignments, usage assignment answer keys,
      examinations, and examination answer keys.

3.2   "COURSE DEVELOPMENT PHASE: COURSE DEVELOPMENT STANDARDS
      FOR VISUALS OUTLINES," FRANK Y. CHUM, USL/DBMS NASA/COURSES
      WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-2,
      MARCH 27, 1984, 6p.

      This Course Development Series entry contains the set of development and documentation stan-
      dards for preparing outlines for course visuals.

3.3   "COURSE DEVELOPMENT PHASE: COURSE DEVELOPMENT STANDARDS
      FOR VISUALS," FRANK Y. CHUM AND SUZY GALLAGHER, USL/DBMS
      NASA/COURSES WORKING PAPER SERIES REPORT NUMBER
      DBMS.NASA/COURSES-3, MARCH 27, 1984, 18p.

      This Course Development Series entry contains the set of development and documentation stan-
      dards for preparing course visuals.

3.4   "COURSE DEVELOPMENT PHASE: INTEGRATED OUTLINE OF COURSE VISU-
      ALS," WAYNE D. DOMINICK, FRANK Y. CHUM, AND SUZY GALLAGHER,
      USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER
      DBMS.NASA/COURSES-4, AUGUST 14, 1984, REVISED: MAY 22, 1986, REVISED:
      APRIL 10, 1987, 18p.

This Course Development Series entry contains the integrated outline of the system-independent course visuals associated with a full semester course offering.

3.5   "COURSE DEVELOPMENT PHASE: COURSE VISUALS," SUZY GALLAGHER, MARTIN GRANIER, PHILIP P. HALL, SHERIEF EL-MOUGY, SRINU KAVI, I-HSIUNG LIU, AND KIL-HYUN NAM, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-5, MAY 14, 1985, REVISED: MAY 29, 1986, REVISED: JANUARY 7, 1987, REVISED: APRIL 5, 1987, 566p.

This Course Development Series entry contains the system-independent course visuals associated with a full semester course offering.

3.6   "COURSE DEVELOPMENT PHASE: COURSE LESSON PLANS," SUSAN KNELLER, MARTIN GRANIER, SUZY GALLAGHER, AND DESIREE MATTA, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-6, MAY 14, 1985, REVISED: MAY 23, 1986, REVISED: JANUARY 12, 1987, 152p.

This Course Development Series entry contains the course lesson plans associated with a full semester course offering.

3.7   "COURSE DEVELOPMENT PHASE: COURSE HOMEWORK ASSIGNMENTS AND ANSWER KEYS," MARTIN GRANIER, SUSAN KNELLER, AND KIL-HYUN NAM, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-7, MAY 14, 1985, REVISED: JUNE 3, 1986, REVISED: DECEMBER 12, 1986, 68p.

This Course Development Series entry contains the course homework assignments and answer keys associated with a full semester course offering.

3.8   "COURSE DEVELOPMENT PHASE: COURSE NASA RECON USAGE ASSIGN-MENTS AND ANSWER KEYS," MARTIN GRANIER AND KIL-HYUN NAM, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-8, MAY 14, 1985, REVISED: MAY 24, 1986, REVISED: MARCH 19, 1987, 77p.

This Course Development Series entry contains the course NASA RECON usage assignments associated with a full semester course offering.

3.9 "COURSE DEVELOPMENT PHASE: COURSE EXAMINATIONS AND ANSWER KEYS," MARTIN GRANIER, SUSAN KNELLER, AND VALENTINE U. IHEBUZOR, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-9, MAY 14, 1985, REVISED: MAY 22, 1986, REVISED: APRIL 10, 1987, 22p.

This Course Development Series entry contains the course examinations and answer keys associated with a full semester course offering.

3.10 "COURSE DEVELOPMENT PHASE: COURSE INSTRUCTOR'S MANUAL," SUZY GALLAGHER, MARTIN GRANIER, SHERIEF EL-MOUGY, AND I-HSIUNG LIU, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-10, MAY 14, 1985, REVISED: MAY 29, 1986, REVISED: JANUARY 7, 1987, REVISED: APRIL 5, 1987, 566p.

This Course Development Series entry contains the course instructor's manual associated with a full semester course offering.

3.11 "COURSE DEVELOPMENT PHASE: COURSE NASA/RECON SPECIFIC HOOKS AND VISUALS", JOSE P. DIAZ. USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-11, MAY 14, 1985, REVISED: MAY 21, 1986, 44p.

This Course Development Series entry contains the NASA/RECON specific hooks and visuals associated with a full semester course offering.

3.12 "COURSE DEVELOPMENT PHASE: EDUCATIONAL RESEARCH ON THE APPLICATION OF MEASUREMENT TOOLS TO THE NASA COURSE HOMEWORK ASSIGNMENTS AND EXAMINATIONS", M. SUSAN KNELLER, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-12, FEBRUARY 6, 1985, 22p.

This Course Development Series entry represents the research of educational theory and its application in the construction of the course deliverables, specifically homework assignments and tests, pursuant to the specifications of National Aeronautics and Space Administration Contract Number NASW-3846. The theories of Benjamin S. Bloom were incorporated in the construction and

evaluation of homework and test items in an attempt to accurately develop and then test the various levels of learning of students enrolled in a NASA/RECON course. In addition, a system for coding questions which allows for the identification of content area as well as cognitive level was developed for use in all assignments and tests. A simple key for understanding the code was provided.

3.13 "COURSE DEVELOPMENT PHASE: AN OVERVIEW OF NEEDS ANALYSIS QUESTIONNAIRE DEVELOPMENT AS RELATED TO THE NASA COURSE DEVELOPMENT PROJECT," GUIDO A. RIJO, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-13, FEBRUARY 28, 1985, 27p.

This Course Development Entry reports on a survey of public opinion and market research techniques to facilitate the design and construction of survey tools for the evaluation of the NASA/RECON course. This work gives an overall view of questionnaire design, analysis, and evaluation. It also identifies features which help increase the number of responses to a questionnaire.

3.14 "COURSE DEVELOPMENT PHASE: COURSE BIBLIOGRAPHY," BEE LEE LIM, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-14, MAY 2, 1985, REVISED: MARCH 28, 1987, 10p.

This Course Development Series entry contains the course bibliography, listing books used by the research team in the development of the system-independent course material and recommended as references for instructors presenting the course.

3.15 "COURSE DEVELOPMENT PHASE: COURSE HANDOUTS," VALENTINE U. IHEBUZOR, MARTIN R. GRANIER, MOUNIR E. BSAIBIS, KATHY A. CAVANAUGH, AND CHI-SHING HONG, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-15, DECEMBER 5, 1985, REVISED: MAY 24, 1986, REVISED: DECEMBER 4, 1986, 134p.

This Course Development Series entry contains the supportive handouts associated with a full semester course offering.

3.16 "COURSE DEVELOPMENT PHASE: COURSE DIAGRAMS," MAHAMMED A. BAKKOUR AND VALENTINE U. IHEBUZOR, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-16, JUNE 17, 1986, 41p.

This Course Development Series entry contains the supportive diagrams associated with a full semester course offering.

3.17 "COURSE DEVELOPMENT PHASE: COURSE LESSON PLAN METHODOLOGY," DESIREE J. MATTA AND VALENTINE U. IHEBUZOR, USL/DBMS NASA/COURSES WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/COURSES-17, JANUARY 22, 1987, 135p.

This Course Development Series entry presents the methodology for constructing and timing the lesson plans associated with a full semester course offering.

PART IV. WORKING PAPER SERIES DOCUMENTS

4.1 USL/DBMS NASA/RECON WORKING PAPER SERIES STANDARDS, REVISED MARCH 29, 1984, 36p.

The full set of standards for the development, formatting, reviewing, and issuance of entries within the USL/DBMS NASA/RECON Working Paper Series.

4.2 "OVERVIEW OF THE NASA/RECON EDUCATIONAL, RESEARCH, AND DEVELOPMENT ACTIVITIES OF THE COMPUTER SCIENCE DEPARTMENTS OF THE UNIVERSITY OF SOUTHWESTERN LOUISIANA AND SOUTHERN UNIVERSITY," WAYNE D. DOMINICK, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-1, REVISED MAY 31, 1984, 9p.

An introduction to the USL/DBMS NASA/RECON Working Paper Series which has been established to provide a foundation for a formal information dissemination mechanism concerning activities being performed pursuant to the NASA/RECON contract. This entry also serves as an index into the collection of Working Paper Series reports.

4.3 "NASA RECON: COURSE DEVELOPMENT, ADMINISTRATION, AND EVALUATION," WAYNE D. DOMINICK AND LEROY ROQUEMORE, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-2, MAY, 1983, 65p.

Working Paper Series entry representing the scope of the initial contract proposal to NASA.

4.4 "TRANSPORTABLE, UNIVERSITY-LEVEL EDUCATIONAL PROGRAMS IN INTERACTIVE INFORMATION STORAGE AND RETRIEVAL SYSTEMS," WAYNE D. DOMINICK AND LEROY ROQUEMORE, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-3, JANUARY 27, 1984, 16p.

Working Paper Series entry representing the abstract and visuals associated with the above named presentation delivered at the 11th Annual Conference of the Mid-South Association for Educational Data Systems. This presentation overviewed the educational aspects of the NASA contract activities.

4.5 "THE MAN/MACHINE INTERFACE IN INFORMATION RETRIEVAL: PROVIDING ACCESS TO THE CASUAL USER," MARTIN GRANIER, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-4, MAY 16, 1984, 69p.

Working paper series report surveying the state-of-the-art in high level man/machine interfaces for supporting casual user access to interactive information storage and retrieval systems. Additionally, capabilities and characteristics of selected specific systems are addressed within the report, including LEXIS, CONIT, IIDA, CITE, and CCL.

4.6 "KNOWLEDGE-BASED SYSTEMS: A PRELIMINARY SURVEY OF SELECTED ISSUES AND TECHNIQUES," SRINU KAVI, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-5, MAY 31, 1984, 102p.

Working Paper Series report surveying the state-of-the-art in knowledge-based systems (expert systems), including issues related to knowledge representation, knowledge bases, cognitive engine strategies, user interfaces for knowledge-based systems, and application considerations.

4.7 "CONCEPTS AND IMPLEMENTATIONS OF NATURAL LANGUAGE QUERY SYSTEMS," I-HSIUNG LIU, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-6, JUNE 1, 1984, 46p.

Working paper series report surveying the state-of-the-art in natural language query systems for information systems, including issues related to hierarchies of user languages, query language analyzers, dialog controllers, and synthesizers, and implementation considerations for natural language query systems.

4.8 "A REPORT ON THE USL NASA/RECON PROJECT: PART I. THE DEVELOPMENT OF A TRANSPORTABLE, UNIVERSITY LEVEL, IS&R EDUCATIONAL PROGRAM," SUZY GALLAGHER AND MARTIN GRANIER, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-7, OCTOBER 4, 1984, 30p.

This Working Paper Series entry describes a project which has as its goal the production of a set of system-independent, discipline-independent transportable college level courses to educate science and engineering students in the use of large-scale information storage and retrieval systems. This project is being conducted with the cooperation and sponsorship of NASA (National Aeronautics and Space Administration) by research and development teams at the University of Southwestern Louisiana and Southern University. Chapter I is an introduction which provides an overview of the project and a listing of the management phases. Chapter II furnishes general information regarding

current accomplishments in all areas under development at present. Chapter III deals specifically with the development of the course materials by presenting a series of diagrams and keys to clearly depict the progress and interrelationships of various tasks and sub-tasks. Chapter IV presents plans for activities to be conducted to accomplish the completion of delivery of all course materials. The final chapter constitutes a summary of the project objectives, methods, plans, and accomplishments.

4.9 "A REPORT ON THE USL NASA/RECON PROJECT: PART II. PC-BASED R&D IN SUPPORT OF IS&R APPLICATIONS," FRANK Y. CHUM, PHILIP P. HALL, DENNIS R. MOREAU, AND SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-8, OCTOBER 4, 1984, 20p.

This Working Paper Series entry describes the PC R&D development effort initiated as part of the NASA/RECON Project at the University of Southwestern Louisiana. This effort involves the development of a PC-based environment for the prototyping and evaluation of various tools designed to enhance the interaction between scientists and engineers and remote information systems. The design of PC-based tools for the enhancement of the NASA/RECON university level courses is described as well as the design of a multi-functional PC-based workstation to support access to and processing of information from local, distributed, and remote sources. Course preparation activities are described in a companion report entitled "A Report on the USL NASA/RECON Project: Part I. The Development of a Transportable, University-Level, IS&R Educational Program", by Suzy Gallagher and Martin Granier, USL/DBMS NASA/RECON Working Paper Series report number DBMS.NASA/RECON-7.

4.10 "KNOWLEDGE BASED SYSTEMS: A CRITICAL SURVEY OF MAJOR CONCEPTS, ISSUES, AND TECHNIQUES," SRINU KAVI, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-9, DECEMBER 11, 1984, 306p.

This Working Paper Series entry presents a detailed critical survey of knowledge based systems. After being in a relatively dormant state for many years, only recently is artificial intelligence (AI) - that branch of computer science that attempts to have machines emulate intelligent behavior - accomplishing practical results. Most of these results can be attributed to the design and use of Knowledge-Based Systems, KBSs (or expert systems) - problem solving computer programs that can reach a level of performance comparable to that of a human expert in some specialized problem domain. These systems can act as a consultant for various requirements like medical diagnosis, military threat analysis, project risk assessment, etc. These systems possess knowledge to enable them to make intelligent decisions. They are, however, not meant to replace the human specialists in any particular domain. In this thesis, a critical survey of recent work in interactive KBSs is reported, KBSs are identified. A case study (MYCIN) of a KBS, a list of existing KBSs, and an introduction to the Japanese Fifth Generation Computer Project are provided as appendices. Finally, an extensive set of KBS-related references are provided at the end of this report.

4.11 "KNOWLEDGE BASED SYSTEMS: A CRITICAL SURVEY OF MAJOR CON-
CEPTS, ISSUES, AND TECHNIQUES: VISUALS," SRINU KAVI, USL/DBMS
NASA/RECON WORKING PAPER SERIES REPORT NUMBER
DBMS.NASA/RECON-10, DECEMBER 11, 1984, 84p.

This Working Paper Series entry represents a collection of presentation visuals associated with the
companion report entitled "Knowledge Based Systems: A Critical Survey of Major Concepts, Issues,
and Techniques", USL/DBMS NASA/RECON Working Paper Series report number
DBMS.NASA/RECON-9.

4.12 "AN OVERVIEW OF SELECTED INFORMATION STORAGE AND RETRIEVAL
ISSUES IN COMPUTERIZED DOCUMENT PROCESSING", VALENTINE U. IHE-
BUZOR, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT
NUMBER DBMS.NASA/RECON-11, DECEMBER 29, 1984, 49p.

The rapid development of computerized information storage and retrieval techniques has intro-
duced the possibility of extending the word processing concept to document processing. A major
advantage of computerized document processing is the relief of the tedious task of manual editing
and composition usually encountered by traditional publishers through the immense speed and
storage capacity of computers. Furthermore, computerized document processing provides an author
with centralized control, the lack of which is a handicap of the traditional publishing operation. A
survey of some computerized document processing techniques is presented with emphasis on related
information storage and retrieval issues. String matching algorithms are considered central to
document information storage and retrieval and are also discussed.

4.13 "AN INNOVATIVE, MULTIDISCIPLINARY EDUCATIONAL PROGRAM IN
INTERACTIVE INFORMATION STORAGE AND RETRIEVAL", MARY C. GAL-
LAGHER, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT
NUMBER DBMS.NASA/RECON-12, FEBRUARY 7, 1985, 146p.

There exists a number of large-scale bibliographic Information Storage and Retrieval Systems
which contain vast amounts of valuable data of interest in a wide variety of research applications.
These systems are not used to capacity because the end users, that is the researchers themselves,
have not been trained in the techniques of accessing such systems and their associated data. This
thesis describes the development of a transportable, university-level course in methods of querying
online interactive Information Storage and Retrieval systems as a solution to this problem. This
course was designed to instruct upper division science and engineering students to enable these end
users to directly access such systems. The course is designed to be taught by instructors who are
not specialists in either computer science or research skills. It is independent of any particular
IS&R system or computer hardware. This project was sponsored by the National Aeronautics and
Space Administration and conducted by the University of Southwestern Louisiana and Southern
University.

4.14 "AN INNOVATIVE, MULTIDISCIPLINARY EDUCATIONAL PROGRAM IN INTERACTIVE INFORMATION STORAGE AND RETRIEVAL: PRESENTATION VISUALS", MARY C. GALLAGHER, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-13, FEBRUARY 7, 1985, 33p.

This Working Paper Series entry represents a collection of presentation visuals associated with the companion report entitled "An Innovative, Multidisciplinary Educational Program in Interactive Information Storage and Retrieval", USL/DBMS NASA/RECON Working Paper Series report number DBMS.NASA/RECON-12.

4.15 "USL NASA/RECON PROJECT PRESENTATIONS AT THE 1985 ACM COMPUTER SCIENCE CONFERENCE: ABSTRACTS AND VISUALS," FRANK Y. CHUM, SUZY GALLAGHER, MARTIN GRANIER, PHILIP HALL, DENNIS MOREAU, AND SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-14, MARCH 10, 1985, 80p.

This Working Paper Series entry represents the abstracts and visuals associated with presentations delivered by six USL NASA/RECON research team members at the above named conference. The presentations highlight various aspects of NASA contract activities pursued by the participants as they relate to individual research projects. The titles of the six presentations are as follows:

(1) "The Specification and Design of a Distributed Workstation,"
(2) "An Innovative, Multidisciplinary Educational Program in Interactive Information Storage and Retrieval,"
(3) "Critical Comparative Analysis of the Major Commercial IS&R Systems,"
(4) "Design Criteria for a PC-Based Common User Interface to Remote Information Systems,"
(5) "The Design of an Object-Oriented Graphics Interface," and
(6) "Knowledge-Based Information Retrieval: Techniques and Applications."

4.16 "THE DESIGN OF PC/MISI, A PC-BASED COMMON USER INTERFACE TO REMOTE INFORMATION STORAGE AND RETRIEVAL SYSTEMS," PHILIP P. HALL, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-15, APRIL 24, 1985, 87p.

The amount of information contained in the data bases of large-scale information storage and retrieval systems is very large and growing at a rapid rate. The methods currently available for accessing this information have not been successful in making the information easily available to the people who have the greatest need for it. This thesis describes the design of a personal computer based system which will provide a means for these individuals to retrieve this information through one standardized interface. The thesis identifies each of the major problems associated with providing access to casual users of information storage and retrieval systems and describes the manner in which these problems are to be solved by the utilization of the local processing power of

a personal computer. Additional capabilities, not available with standard access methods, are also provided to improve the user's ability to make use of this information. The design of PC/MISI is intended to facilitate its use as a research vehicle. Evaluation mechanisms and possible areas of future research are described in this thesis. The PC/MISI development effort is part of a larger research effort directed at improving access to remote IS&R systems. This research effort, supported in part by the National Aeronautics and Space Administration, is also overviewed in this thesis.

4.17 **"THE DESIGN OF PC/MISI, A PC BASED COMMON USER INTERFACE TO REMOTE INFORMATION STORAGE AND RETRIEVAL SYSTEMS: PRESENTATION VISUALS," PHILIP P. HALL, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-16, APRIL 24, 1985, 29p.**

This Working Paper Series entry represents a collection of presentation visuals associated with the companion report entitled "The Design of PC/MISI, A PC-Based Common User Interface to Remote Information Storage and Retrieval Systems," USL/DBMS NASA/RECON Working Paper Series report number DBMS.NASA/RECON-15.

4.18 **"NATURAL LANGUAGE QUERY SYSTEM DESIGN FOR INTERACTIVE INFORMATION STORAGE AND RETRIEVAL SYSTEMS," I-HSIUNG LIU, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-17, APRIL 22, 1985, 164p.**

The currently developed multi-level language interfaces of information systems are generally designed for experienced users. These interfaces commonly ignore the nature and needs of the largest user group, namely, casual users. This research identifies the importance of natural language query system research within information storage and retrieval system development; addresses the topics of developing such a query system; and finally, proposes a framework for the development of natural language query systems in order to facilitate the communication between casual users and information storage and retrieval systems.

4.19 **"NATURAL LANGUAGE QUERY SYSTEM DESIGN FOR INTERACTIVE INFORMATION STORAGE AND RETRIEVAL SYSTEMS: PRESENTATION VISUALS," I-HSIUNG LIU, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-18, APRIL 22, 1985, 52p.**

This Working Paper Series entry represents a collection of presentation visuals associated with the companion report entitled "Natural Language Query System Design for Interactive Information Storage and Retrieval Systems," USL/DBMS NASA/RECON Working Paper Series report number DBMS.NASA/RECON-17.

4.20 "AN HIERARCHICAL APPROACH TO PERFORMANCE EVALUATION OF EXPERT SYSTEMS," SRINU KAVI, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-19, MAY 8, 1985, 40p.

The number and size of expert systems is growing rapidly. Formal evaluation of these systems - which is not performed for many systems - increases the acceptability by the user community and hence their success. Hierarchical evaluation that had been conducted for computer systems is applied for expert system performance evaluation. Expert systems are also evaluated by treating them as software systems (or programs). This paper reports many of the basic concepts and ideas in the Performance Evaluation of Expert Systems Study that is being conducted at the University of Southwestern Louisiana.

4.21 "SOME ISSUES IN DATA MODEL MAPPING," JAMAL R. ALSABBAGH, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-20, MAY 10, 1985, 27p.

Numerous data models have been reported in the literature since the early 1970's. They have been used as database interfaces and as conceptual design tools. The mapping between schemas expressed according to the same data model or according to different models is interesting for theoretical and practical purposes. This paper addresses some of the issues involved in such a mapping. Of special interest are the identification of the mapping parameters and some current approaches for handling the various situations that require a mapping.

4.22 "KARL: A KNOWLEDGE-ASSISTED RETRIEVAL LANGUAGE," SPIROS TRIAN-TAFYLLOPOULOS, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-21, OCTOBER 31, 1985, 146p.

Data classification and storage are tasks typically performed by application specialists. In contrast, information users are primarily non-computer specialists who use information in their decision-making and other activities. Interaction efficiency between such users and the computer is often reduced by machine requirements and resulting user reluctance to use the system. This thesis examines the problems associated with information retrieval for non-computer specialist users, and proposes a method for communicating in restricted English that uses knowledge of the entities involved, relationships between entities, and basic English language syntax and semantics to translate the user requests into formal queries. The proposed method includes an intelligent diction-ary, syntax and semantic verifiers, and a formal query generator. In addition, the proposed system has a learning capability that can improve portability and performance. With the increasing demand for efficient human-machine communication, the significance of this thesis becomes apparent. As human resources become more valuable, software systems that will assist in improving the human-machine interface will be needed and research addressing new solutions will be of utmost importance. This thesis presents an initial design and implementation as a foundation for further research and development into the emerging field of natural language database query systems.

4.23 "KARL: A KNOWLEDGE-ASSISTED RETRIEVAL LANGUAGE: PRESENTATION VISUALS," SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-22, OCTOBER 31, 1985, 54p.

This Working Paper Series entry represents a collection of presentation visuals associated with the companion report entitled "KARL: A Knowledge-Assisted Retrieval Language," USL/DBMS NASA/RECON Working Paper Series report number DBMS.NASA/RECON-21.

4.24 "A SURVEY OF CHEMICAL INFORMATION SYSTEMS," ANEESA BASHIR SHAIKH, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-23, DECEMBER 5, 1985, 160p.

This Working Paper Series entry represents a survey of the features, functions, and characteristics provided by a fairly wide variety of chemical information storage and retrieval systems currently in operation. The types of systems (together with an identification of the specific systems) addressed within this survey are as follows: Patents and Bibliographies (Derwent's Patent System; IFI Comprehensive Database; PULSAR); Pharmacology and Toxicology (Chemfile; PAGODE; CBF; HEEDA; NAPRALERT; MAACS); Networks - The Chemical Information System (CAS Chemical Registry System; SANSS; MSSS; CSEARCH; GINA; NMRLIT; CRYST; XTAL; PDSM; CAISF; RTECS Search System; AQUATOX; WDROP; OHMTADS; MLAB; Chemlab); Spectra (OCETH; ASTM); Crystals (CRYSRC); and Physical Properties (DETHERM). Summary characteristics and current trends in chemical information systems development are also examined within the report.

4.25 "A METHODOLOGY FOR THE DESIGN AND EVALUATION OF USER INTERFACES FOR INTERACTIVE INFORMATION SYSTEMS," MOHAMMAD U. FAROOQ, USL/DBMS NASA/RECON WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/RECON-24, JANUARY 22, 1986, 103p.

This Working Paper Series entry represents the definition of proposed research addressing the development and validation of a methodology for the design and evaluation of user interfaces for interactive information systems. The major objectives of this research are: the development of a comprehensive, objective, and generalizable methodology for the design and evaluation of user interfaces for information systems; the development of equations and/or analytical models to characterize user behavior and the performance of a designed interface; the design of a prototype system for the development and administration of user interfaces; and the design and use of controlled experiments to support the research and test/validate the proposed methodology. The proposed design methodology views the user interface as a virtual machine composed of three layers: an interactive layer, a dialogue manager layer, and an application interface layer. A command language model of user system interactions is presented because of its inherent simplicity and structured approach based on interaction events. All interaction events have a common structure based on common generic elements necessary for a successful dialogue. It is shown that, using this model, various types of interfaces could be designed and implemented to accommodate various categories of users. The implementation methodology is discussed in terms of how to represent the various

types of information pertaining to an interaction event, and how to store and organize the information. A generalized evaluation methodology is also proposed for the evaluation of user interfaces. The methodology will allow interface developers to evaluate user interfaces from the viewpoint of the performance of their users. A Personal Computer-based Protocols for Interface Prototyping and Evaluation (PC/PIPE) system is proposed. The system will be composed of two main components. The first component will be a set of tools to support the design and implementation of a user interface. The second component will be a set of run-time support tools which will handle interaction between the user and the system, and will provide facilities for monitoring user interactions for conducting serious evaluations of user interfaces.

PART V.   PC R&D SPECIFICATIONS DOCUMENTS AND
PC R&D WORKING PAPER SERIES DOCUMENTS

5.1   "AN OVERVIEW OF THE USL/DBMS NASA/PC R&D PROJECT WORKING PAPER SERIES," WAYNE D. DOMINICK, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-1, REVISED AUGUST 15, 1984, 6p.

An introduction to the USL/DBMS NASA/PC R&D Working Paper Series which has been established to provide a foundation for both a formal and informal information dissemination mechanism concerning PC-based research and development activities being performed pursuant to the NASA contract. This entry also serves as an index into the collection of Working Paper Series reports.

5.2   "THE USL NASA PC R&D PROJECT: GENERAL SPECIFICATIONS OF OBJECTIVES," WAYNE D. DOMINICK, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-2, JUNE 6, 1984, 6p.

The general specifications of the objectives of the USL/DBMS NASA PC R&D Project, a Research and Development Project initiated at USL in order to address future R&D issues related to the PC-based processing environments acquired pursuant to the NASA contract work, namely, the IBM PC/XT systems.

5.3   "THE USL NASA PC R&D DEVELOPMENT ENVIRONMENT STANDARDS," DENNIS R. MOREAU, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-3, JULY 31, 1984, 8p.

The development environment standards which have been established in order to control usage of the IBM PC/XT development systems and to prevent interference between projects being concurrently developed on the PC's. The standards address the following areas: scheduling PC resources; login/logout procedures; training; file naming conventions; hard disk organization; diskette care; backup procedures; and copying policies.

5.4   "GENERAL SPECIFICATIONS FOR THE DEVELOPMENT OF A PC-BASED SIMULATOR OF THE NASA RECON SYSTEM," SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-4, AUGUST 2, 1984, 21p.

The general specifications for the design and implementation of an IBM PC/XT-based simulator of the NASA RECON system, including record designs, file structure designs, command language analysis, program design issues, error recovery considerations, and usage monitoring facilities. Once implemented, such a simulator will be utilized to evaluate the effectiveness of simulated information system access in addition to actual system usage as part of the total educational programs being developed within the NASA contract.

5.5 **"GENERAL SPECIFICATIONS FOR THE DEVELOPMENT OF A USL NASA PC R&D STATISTICAL ANALYSIS SUPPORT PACKAGE," JINOUS BASSARI AND SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-5, AUGUST 2, 1984, 14p.**

The USL NASA PC R&D statistical analysis support package is designed to be a three level package to allow statistical analysis for a variety of applications within the USL DBMS NASA Contract work. The design addresses usage of the statistical facilities as a library package, as an interactive statistical analysis system, and as a batch processing package.

5.6 **"GENERAL SPECIFICATIONS FOR THE DEVELOPMENT OF A USL NASA PC R&D DISTRIBUTED WORKSTATION," FRANK Y. CHUM, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-6, AUGUST 15, 1984, 10p.**

This document defines the general specifications for the development of a PC-Based distributed workstation (PCDWS) for an information storage and retrieval systems environment. This research proposes the development of a PCDWS prototype as part of the USL/DBMS NASA/PC R&D project in the PC-Based workstation environment.

5.7 **"THE USL NASA PC R&D INTERACTIVE PRESENTATION DEVELOPMENT SYSTEM," DENNIS R. MOREAU, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-7, AUGUST 2, 1984, 8p.**

The Interactive Presentation Development System (IPDS) is a highly interactive system for creating, editing, and displaying video presentation sequences, e.g., for developing and presenting displays of instructional material similar to overhead transparency or slide presentations. However, since this system is PC-based, users (e.g., instructors) can step through sequences forward or backward, focusing attention to areas of the display with special cursor pointers. Additionally, screen displays may be dynamically modified during the presentation to show assignments or to answer questions, much like a traditional blackboard. This system is now implemented at USL for use within the piloting phases of the NASA contract work.

5.8 "THE USL NASA PC R&D PROJECT: DETAILED SPECIFICATIONS OF OBJEC-
TIVES," FRANK Y. CHUM, PHILIP P. HALL, DENNIS R. MOREAU, AND SPIROS
TRIANTAFYLLOPOULOS, USL/DBMS NASA/PC R&D WORKING PAPER
SERIES REPORT NUMBER DBMS.NASA/PC R&D-8, AUGUST 15, 1984, 21p.

This document represents the specifications for a number of projects which are to be implemented
within the USL NASA PC R&D Project. The goals and objectives of the PC development project
and the interrelationships of the various components are discussed. Six individual projects are
described. They are a NASA/RECON simulator, a user interface to multiple remote information
systems, evaluation of various personal computer systems, statistical analysis software develop-
ment, interactive presentation system development, and the development of a distributed process-
ing environment. The relationships of these projects to each other and to the goals and objectives
of the overall project are also discussed.

5.9 "DESIGN CRITERIA FOR A PC-BASED COMMON USER INTERFACE TO
REMOTE INFORMATION SYSTEMS," PHILIP P. HALL, USL/DBMS NASA/PC
R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-9,
AUGUST 13, 1984, 21p.

A set of design criteria are presented which will allow the implementation of an interface to multi-
ple remote information systems on a microcomputer. The focus of the design description is on pro-
viding the user with the functionality required to retrieve, store and manipulate data residing in
remote information systems through the utilization of a standardized interface system. The intent
is to spare the user from learning the details of retrieval from specific systems while retaining the
full capabilities of each system. The system design includes multi-level capabilities to enhance usa-
bility by a wide range of users and utilizes microcomputer graphics capabilities where applicable. A
data collection subsystem for evaluation purposes is also described.

5.10 "A PERFORMANCE EVALUATION OF THE IBM 370/XT PERSONAL COM-
PUTER," SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/PC R&D WORK-
ING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-10, OCTOBER 5,
1984, 47p.

This Working Paper Series entry addresses an evaluation of the IBM 370/XT personal computer.
The evaluation focuses primarily on the use of the 370/XT for scientific and technical applications
and applications development. A measurement of the capabilities of the 370/XT was performed by
means of test programs which are presented in appendices to the report. Also included is a review
of the facilities provided by the operating system (VM/PC), along with comments on the IBM
370/XT hardware configuration.

5.11 "USL/DBMS NASA/PC R&D PROJECT 'C' PROGRAMMING STANDARDS," DENNIS R. MOREAU, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-11, OCTOBER 5, 1984, 11p.

This Working Paper Series entry establishes a set of programming standards intended to promote reliability, readability, and portability of "C" programs written for PC R&D development projects. These standards must be adhered to except where reasons for deviation are clearly identified and approved by the PC R&D team. Application for approval is made by completing the USL/DBMS NASA/PC R&D Form Number DBMS.NASA/PC FORM-1, "Request for Deviation from C Programming Standards". Any approved deviation from these standards must also be clearly documented in the pertinent source code. Two companion Working Paper Series entries address other system development aspects: (1) "NASA/PC R&D System Design Standards," USL/DBMS NASA/PC R&D Working Paper Series Report Number DBMS.NASA/PC R&D-12, October 12, 1984; and (2) "NASA/PC R&D System Testing Standards," USL/DBMS NASA/RECON Working Paper Series Report Number DBMS.NASA/PC R&D-13, October 12, 1984.

5.12 "USL/DBMS NASA/PC R&D PROJECT SYSTEM DESIGN STANDARDS," DENNIS R. MOREAU, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-12, OCTOBER 12, 1984, 5p.

This Working Paper Series entry establishes a set of system design standards intended to assure the completeness and quality of designs developed for PC R&D projects. The standards presented within this document include the areas of problem definition, initial design plan, design specification, and re-evaluation.

5.13 "USL/DBMS NASA/PC R&D PROJECT SYSTEM TESTING STANDARDS," SRINU KAVI, DENNIS R. MOREAU, AND LIN YAN, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-13, OCTOBER 12, 1984, 5p.

This Working Paper Series entry establishes a set of system testing standards to be used in the development of all "C" software within the NASA/PC R&D Project. Testing will be considered in two phases, namely, the program testing phase and the system testing phase. The objective of these standards is to provide guidelines for the planning and conduct of program and software system testing.

5.14 "IBM PC/IX OPERATING SYSTEM EVALUATION PLAN," MARTIN GRANIER, PHILIP P. HALL, AND SPIROS TRIANTAFYLLOPOULOS, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-14, NOVEMBER 28, 1984, 9p.

This Working Paper Series entry contains an evaluation plan for the IBM PC/IX Operating System designed for IBM PC/XT computers. The evaluation plan covers the areas of performance measurement and evaluation, software facilities available, man-machine interface considerations, networking, and suitability of PC/IX as a development environment within the USL NASA PC/R&D project. In order to compare and evaluate the PC/IX system, comparisons with other UNIX*-based systems available are also included. * UNIX is a trademark of AT&T Bell Laboratories.

5.15 ”PC-BASED MULTIPLE INFORMATION SYSTEM INTERFACE (PC/MISI) DESIGN PLAN,” PHILIP P. HALL, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-15, JANUARY 13, 1985, 13p.

This Working Paper Series entry presents the general design plan for the implementation of a common user interface to multiple remote information systems within a microcomputer-based environment. The intent is to provide a framework for the development of detailed specifications which will be used as guidelines for the actual implementation of this system.

5.16 ”PC-BASED MULTIPLE INFORMATION SYSTEM INTERFACE (PC/MISI) DETAILED DESIGN AND IMPLEMENTATION PLAN,” PHILIP P. HALL, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-16, APRIL 10, 1985, 69p.

This Working Paper Series entry represents the design plan for the personal computer multiple information system interface (PC/MISI) project. The document is intended to be used as a blueprint for the implementation of the system and each component is described in the detail necessary to allow programmers to implement the system. A description is included of the system data flow and the system file structures.

5.17 ”AN OVERVIEW OF THE EVALUATION PLAN FOR PC/MISI - PC-BASED MULTIPLE INFORMATION SYSTEM INTERFACE,” BEE LEE LIM AND PHILIP P. HALL, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-17, APRIL 24, 1985, 27p.

This Working Paper Series entry represents an initial evaluation plan for the personal computer multiple information system interface (PC/MISI) project. The document is intended to be used as a blueprint for the evaluation of this system and each objective of the design project is discussed along with the evaluation parameters and methodology to be used in the evaluation of the implementation's achievement of those objectives. The potential of the system for research activities related to more general aspects of information retrieval is also discussed.

5.18 "THE NASA PC SOFTWARE EVALUATION PROJECT," JULIE C. KUAN, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-18, JANUARY 24, 1986, 29p.

The USL NASA PC software evaluation project is intended to provide a structured framework for facilitating the development of quality NASA PC software products. The project will assist NASA PC development staff to understand the characteristics and functions of NASA PC software products. Based on the results of the project teams' evaluations and recommendations, users can judge the reliability, usability, acceptability, maintainability and customizability of all the PC software products. The objective of this report is to provide initial, high-level specifications and guidelines for NASA PC software evaluation. The primary tasks to be addressed in this project are as follows: to gain a strong understanding of what software evaluation entails and how to organize a structured software evaluation process; to define a structured methodology for conducting the software evaluation process; to develop a set of PC software evaluation criteria and evaluation rating scales; and to conduct PC software evaluations in accordance with the identified methodology. The categories of PC software to be evaluated within the scope of this project are as follows: Database/File Management Systems, Operating Systems, Programming Languages, Statistical Data Analysis Systems, Document Processing Systems, Communication Packages, Network System Software, Graphics Support Software, Environment Management Software, General Utilities.

5.19 "OBJECT-ORIENTED SYSTEMS: AN ANNOTATED BIBLIOGRAPHY," CHERIE T. POWELL AND DENNIS R. MOREAU, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-19, DECEMBER 10, 1986, 26p.

This Working Paper Series entry represents a comprehensive annotated bibliography of journal publications, conference publications, and books related to object-oriented systems. This is an evolving document and will be updated periodically to reflect the current state of research literature in this area.

5.20 "A PROGRAMMING ENVIRONMENT EVALUATION METHODOLOGY FOR OBJECT-ORIENTED SYSTEMS," DENNIS R. MOREAU, USL/DBMS NASA/PC R&D WORKING PAPER SERIES REPORT NUMBER DBMS.NASA/PC R&D-20, SEPTEMBER, 1987, 168p.

This Working Paper Series entry represents the final Ph.D. Dissertation of Dennis R. Moreau, Senior USL NASA Research Assistant. The abstract of this research follows.

The object-oriented design strategy as both a problem decomposition and system development paradigm has made impressive inroads into the various areas of the computing sciences. Substantial development productivity improvements have been demonstrated in areas ranging from artificial intelligence to user interface design. However, there has been very little progress in the formal characterization of these productivity improvements and in the identification of the underlying cognitive mechanisms. The development and validation of models and metrics of this sort require large

amounts of systematically-gathered structural and productivity data. There has, however, been a notable lack of systematically-gathered information on these development environments. A large part of this problem is attributable to the lack of a systematic programming environment evaluation methodology that is appropriate to the evaluation of object-oriented systems.

Consequently, the research presented in this document addresses the design, development, and evaluation of a systematic, extensible, and environment-independent methodology for the comparative evaluation of object-oriented programming environments. This methodology is intended to serve as a foundational element for supporting research into the impact of object-oriented software development environments and design strategies on the software development process and resultant software products. A systematic approach is defined for conducting the methodology with respect to the particular object-oriented programming environment under investigation. The evaluation of each environment is based on user performance of representative and well-specified development tasks on well-characterized applications within the environment. Primary metrics needed to characterize the software applications under examination are also defined and monitored for subsequent use in the analysis and evaluation of the environments.

The major contributions of this work are as follows:

1. This research has formally established the primary metric data definitions that completely characterize the unique aspects of object-oriented software systems, including the inheritance lattice and messaging graph.

2. This research has established language-independent procedures for automatically capturing this primary metric data during an evaluation. These procedures have been shown to be instantiable in a representative set of object-oriented languages.

3. This research has established the fundamental characteristics of object-oriented software that indicate consistent applications of object-oriented design techniques, namely, that common capabilities are factored throughout the inheritance lattice and that individual objects focus on providing specific capabilities.

4. This research has defined a language-independent application domain-specific development paradigm based on these fundamental characteristics for highly interactive graphical applications.

5. This research has identified design principles for a programming environment evaluation methodology (PEEM) that ensure its applicability to object-oriented development environments. The PEEM design principles unique to this work include the following: the requirement for primary metric data definitions that completely characterize the object-oriented characteristics of the software under evaluation, the requirement for the identification of relevant applications domain-specific development paradigms to support the validity and comparability of evaluative results, and the requirement for automatic capture of performance and primary metric data to ensure consistency and eliminate human bias.

6. Finally, this research has produced a systematic, extensible, and environment-independent programming environment evaluation methodology capable of supporting research into complexity models and metrics for object-oriented systems. The design principles, identified in contribution 5 above, establish the basis of the fundamental distinctions between exiting PEEMs and the PEEM developed as part of this research.

PART VI. WORKSHOP DEVELOPMENT PHASE DOCUMENTS AND WORKSHOP WORKING PAPER SERIES DOCUMENTS

6.1   "NASA/RECON WORKSHOP: OUTLINE OF WORKSHOP VISUALS," JULIE C. KUAN AND VALENTINE U. IHEBUZOR, USL NASA/WORKSHOP WORKING PAPER SERIES REPORT NUMBER USL.NASA/WORKSHOP-1, JULY 28, 1985, 12p.

This Workshop Development Series entry contains the integrated outline of the NASA/RECON visuals associated with a two-day intensive NASA/RECON workshop.

6.2   "NASA/RECON WORKSHOP: WORKSHOP VISUALS," WAYNE D. DOMINICK, MARTIN R. GRANIER, VALENTINE U. IHEBUZOR, PRASAD R. YENDLURI, JULIE C. KUAN, K. S. LEUNG, AND CHEE KONG SUN, USL NASA/WORKSHOP WORKING PAPER SERIES REPORT NUMBER USL.NASA/WORKSHOP-2, JULY 28, 1985, REVISED: MAY 18, 1986, REVISED: MARCH 28, 1987, 227p.

This Workshop Development Series entry contains the NASA/RECON visuals associated with a two-day intensive NASA/RECON workshop.

6.3   "NASA/RECON WORKSHOP: WORKSHOP NASA/RECON USAGE ASSIGN-MENTS AND ANSWER KEYS," MARTIN R. GRANIER, KIL-HYUN NAM, AND SUSAN KNELLER, USL NASA/WORKSHOP WORKING PAPER SERIES REPORT NUMBER USL.NASA/WORKSHOP-3, JULY 28, 1985, REVISED: APRIL 13, 1987, 42p.

This Workshop Development Series entry contains the NASA/RECON usage assignments and answer keys associated with a two-day intensive NASA/RECON workshop.

6.4   "NASA/RECON WORKSHOP: WORKSHOP ADDITIONAL SUPPORTIVE HAN-DOUTS," VALENTINE U. IHEBUZOR, USL NASA/WORKSHOP WORKING PAPER SERIES REPORT NUMBER USL.NASA/WORKSHOP-4, JULY 28, 1985, 56p.

This Workshop Development Series contains the NASA/RECON-related additional supportive handouts associated with a two-day intensive NASA/RECON workshop. Additional handouts include material such as the workshop daily schedule, list of participants, TELENET access signon and direct dial signon information, NASA/RECON user's command guide information for the NASA

Library Network, miscellaneous NASA/RECON access series and related information, miscellaneous NASA/RECON sample sessions documents, and related additional supportive handout material.

6.5   "NASA/RECON WORKSHOP: WORKSHOP EVALUATION QUESTIONNAIRE, SUMMARY RESULTS, AND ANALYSES FROM USL NASA/RECON WORKSHOP OF JULY 16-17, 1985," VALENTINE U. IHEBUZOR, MARTIN R. GRANIER, PRASAD R. YENDLURI, AND CHEE KONG SUN, USL NASA/WORKSHOP WORKING PAPER SERIES REPORT NUMBER USL.NASA/WORKSHOP-5, JULY 28, 1985, 7p.

This Workshop Development Series contains complete documentation associated with the participants' evaluation of the July 16-17, 1985 USL NASA/RECON workshop. Such material includes the workshop evaluation questionnaire, statistical summary results of all participants' evaluations, and the complete text of all participants' specific and general comments concerning the workshop.

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16. Abstract

This grant final report executive summary documents a major, long-term program addressing innovative educational issues associated with the development, administration, evaluation, and widespread distribution of transportable educational programs for scientists and engineers to increase their knowledge of, and facilitate their utilization of automated scientific and technical information storage and retrieval systems. This educational program is of very broad scope, being targeted at Colleges of Engineering and Colleges of Physical Sciences at a large number of colleges and universities throughout the United States. The educational program is designed to incorporate extensive hands-on, interactive usage of the NASA RECON system and is supported by a number of microcomputer-based software systems to facilitate the delivery and usage of the educational course materials developed as part of the program.

The grant final report consists of this executive summary and 72 attached reports representing completed research reports, curriculum materials, and software deliverables and documentation in the following six areas:

(1)   Overall Project Management and Control (1 Report)
(2)   Needs Analysis Phase Documents (4 Reports)
(3)   Course Development Phase Documents (17 Reports)
(4)   Research Working Paper Series Documents (25 Reports)
(5)   PC R&D Working Paper Series Documents (20 Reports)
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