
Research Institute for Advanced Computer Science

ANNUAL REPORT

October 1999 through September 2000

Cooperative Agreement: NCC 2-1006

Submitted to:

Contracting Office Technical Monitor:
Anthony R. Gross
Associate Director for Programs
Information Sciences & Technology Directorate
NASA Ames Research Center
Mail Stop 200-6

Submitted by:

Research Institute for Advanced Computer Science (RIACS)

Operated by:

Universities Space Research Association (USRA)

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

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I Introduction and Overview

The Research Institute for Advanced Computer Science (RIACS) carries out basic research and technology development in computer science, in support of the National Aeronautics and Space Administration's missions. RIACS is located at the NASA Ames Research Center. It currently operates under a multiple year grant/cooperative agreement that began on October 1, 1997 and is up for renewal in the year 2002.

Ames has been designated NASA's Center of Excellence in Information Technology. In this capacity, Ames is charged with the responsibility to build an Information Technology Research Program that is preeminent within NASA. RIACS serves as a bridge between NASA Ames and the academic community, and RIACS scientists and visitors work in close collaboration with NASA scientists. RIACS has the additional goal of broadening the base of researchers in these areas of importance to the nation's space and aeronautics enterprises.

RIACS research focuses on the three cornerstones of information technology research necessary to meet the future challenges of NASA missions:

- **Automated Reasoning for Autonomous Systems**
Techniques are being developed enabling spacecraft that will be self-guiding and self-correcting to the extent that they will require little or no human intervention. Such craft will be equipped to independently solve problems as they arise, and fulfill their missions with minimum direction from Earth.
- **Human-Centered Computing**
Many NASA missions require synergy between humans and computers, with sophisticated computational aids amplifying human cognitive and perceptual abilities.
- **High Performance Computing and Networking**
Advances in the performance of computing and networking continue to have major impact on a variety of NASA endeavors, ranging from modeling and simulation to data analysis of large datasets to collaborative engineering, planning and execution.

In addition, RIACS collaborates with NASA scientists to apply information technology research to a variety of NASA application domains. RIACS also engages in other activities, such as workshops, seminars, and visiting scientist programs, designed to encourage and facilitate collaboration between the university and NASA information technology research communities.

I.A Summary of FY2000 Activity

During the year October 1, 1999 through September 30, 2000, RIACS engaged in a number of research projects collaboratively with NASA scientists. Well over 120 publications and presentations

resulted from this work. Section II describes each of those projects along with a list of publications. In addition, RIACS continued to run a successful bi-weekly seminar series, augmented with special seminars, as well as support and participate in a number of workshops. The seminars and workshops are shown in Section III. Finally, RIACS initiated the Ames/RIACS Summer Student Research Program (SSRP), a competitive program in which selected students spent the summer at Ames working with Ames researchers.

Staffing at RIACS grew considerably during the year, from 20 scientists at the beginning of the year to 41 scientists at the end. This continued the growth in the prior year (from 12 scientists to 20). In addition, 24 visiting scientists and 18 visiting students spent time at RIACS during the year. Section IV provides more detail on the staffing.

II RIACS Projects During FY2000

NASA Ames has identified three cornerstones of information technology research necessary to meet the future challenges of NASA missions:

- Automated Reasoning for Autonomous Systems
- Human-Centered Computing
- High Performance Computing and Networking

RIACS research focuses on all three of these areas, as well as collaborating with NASA scientists to apply information technology research to a variety of NASA application domains. Research projects and the overall RIACS program are regularly reviewed by an eminent Science Council.

II.A Automated Reasoning for Autonomous Systems

Deep space exploration requires significant advances in artificial intelligence to support the needed capabilities for autonomous systems. RIACS scientists and visitors have been collaborating with NASA researchers in a number of areas, as described in the following sections.

II.A.i Automated Software Synthesis and Verification

II.A.i.a Task Summary

This research in automated software engineering is primarily concerned with the development of advanced tools for automated software synthesis and automated software verification & validation (V&V).

II.A.i.b RIACS Staff

Bernd Fischer
Dimitra Giannakopoulou
SeungJoon Park
Charles Pecheur
Grigore Rosu
Johann Schumann
Mahadevan Subramaniam
Willem Visser

Visiting Students

Flavio Lerda (Polytechnic of Torino, Italy)
Jeff Thompson (University of Minnesota)

Ralph Benzinger (Cornell University)
Corina Pasareanu (Kansas State University)

II.A.i.c Overview

Software is becoming a major enabling technology at NASA. The primary goals of this task are to reduce the cost of developing this software and improve the reliability of the software produced.

Researchers and Visiting Scientists primarily develop advanced tools for automated software synthesis and automated software V&V. This entails a spectrum of activities from fundamental research, case studies with NASA software systems in conjunction with NASA software development organizations, development of new algorithms, and tool implementation.

II.A.i.d Project Description

- Perform research to develop, design and implement techniques that will put verification tools into the hands of system designers.
- Investigate the application of model checking to find errors in software:
 - Verification of Autonomous systems
 - Verification of Avionics software
 - Program Verification
 - Abstraction techniques to reduce software complexity for model checking.
- Advanced research and development on software synthesis tools using deductive synthesis and other techniques from formal methods.
- Develop a system for the deductive synthesis of state-estimation software components based on Kalman filters.
- Develop a system for the deductive synthesis of data analysis software components from Bayesian networks.
- Develop techniques to allow machine assistance for software reuse
- High assurance software certification by proof logging and proof log checking.
- Close important gaps between different phases of the software development cycle.
- Implement and certify an adaptive neural network flight controller to be integrated and flight-tested in an F-15.

II.A.i.e Accomplishments

- Enhancement to the translation program allowing the verification of Livingstone models with the SMV symbolic model checker: new specification patterns, improved compatibility with Livingstone (in association with Carnegie Mellon University).
- Continued support to Livingstone users at Kennedy Space Center (KSC) in using the translator to improve the development of Livingstone models for the Mars exploration program.
- Development of a Livingstone Virtual Machine (VM) based on the original Livingstone program.

- Developed the Java PathFinder (JPF) model checker for Java. It is the first custom-made Java model checker available and is built on a JVM suitable for model checking.
- Applied the JPF model checker to a Java version of the DEOS system.
- Established our group's leadership in the field of software model checking by organizing 2 workshops on the topic (SPIN'00 and WAPATV'00) and also presented two tutorials (LFM'00 and ASE'00).
- Developed an automated prototype abstraction tool which implements the research idea performed last year, and application of the tool to the verification of real software systems.
- Solved abstraction problems on object-orientedness and dynamic creation of objects by having scalable abstraction predicates relating variables over multiple classes.
- Applied the automated abstraction tool for the verification of simplified JAVA code in the Remote Agent and DEOS.
- Extended a prototype system which applies deductive technology to synthesize efficient data analysis programs (e.g., classification, time series and image analysis) from high-level specifications in an extended Bayesian Network notation. Implemented back-ends for C/C++ environments. Applied the prototype successfully to a series of standard problems; current work is on shadowing the data analysis tasks for the Vulcan-project (finding extra-solar planets using a photometric approach).
- Development of explanation generation subsystem for Avionics Synthesis
- Design and development of a Java-based proof log checker prototype.
- Implemented data sampling module for program synthesis
- A prototype tool was developed which is capable of automatically synthesizing UML designs (statecharts) from sequence diagrams. Several smaller case studies (cruise-controller, ATM machine, autonomous agents) have been carried out; a large case study on shuttle-related software ("orbiter-in-a-box") has been started.
- A prototype system for the deductive synthesis of state-estimation software components based on Kalman filters has been developed. An elaborate explanation systems is capable of automatically generating design document and allows to interactively visualize the relationship between specification and synthesized code.
- Preliminary work on the verification of an on-line learning neural network flight controller.

II.A.i.f Publications and Presentations

Publications

1. Reid Simmons, Charles Pecheur. Automating Model Checking for Autonomous Systems. Proceedings of AAAI Spring Symposium on Real-Time Autonomous Systems, Stanford, March 20-22, 2000.
2. Charles Pecheur, Reid Simmons. From Livingstone to SMV: Formal Verification for Autonomous Spacecrafts. Proceedings of First Goddard Workshop on Formal Approaches to Agent-Based Systems, NASA Goddard, April 5-7, 2000. To appear in Lecture Notes in Computer Science, Springer Verlag.

3. Klaus Havelund, Mike Lowry, SeungJoon Park, Charles Pecheur, John Penix, Willem Visser, Jon L. White. Formal Analysis of the Remote Agent Before and After Flight. To appear in: Proceedings of 5th NASA Langley Formal Methods Workshop, Williamsburg, Virginia, 13-15 June 2000.
4. Reid Simmons, Charles Pecheur. Towards Automatic Verification of Autonomous Systems. Submitted to: International Conference on Intelligent Robots and Systems. Takamatsu, October 30-November 5, 2000.
5. Charles Pecheur. Verification and Validation of Autonomy Software at NASA. To be submitted. To appear as NASA Ames technical report
6. J. Penix, W. Visser, E. Engstrom, A. Larson and N. Weininger, Verification of Time Partitioning in the DEOS real-time Scheduling Kernel. 22nd International Conference on Software Engineering. June 2000.
7. W. Visser, S. Park and J. Penix. Applying Predicate Abstraction to Model Check Object-Oriented Programs. 3rd ACM SIGSOFT Workshop on Formal Methods in Software Practice. August 2000.
8. W. Visser and H. Barringer, CTL* Model Checking for SPIN. Journal Software Tools for Technology Transfer (STTT). Volume 2 Number 4. April 2000. Preliminary version appeared in proceedings of the 4th SPIN Workshop. Paris, France. November 1998.
9. W. Visser, K. Havelund, G. Brat and S. Park. Model Checking Programs. International Conference on Automated Software Engineering. September 2000.
10. G. Brat, K. Havelund, S. Park and W. Visser. Java PathFinder - A second generation of a Java model checker. Workshop on Advances in Verification. July 2000.
11. Karamanolis, C., Giannakopoulou, D., Magee, J., and Wheeler, S., Model Checking of Workflow Schemas. 4th International Enterprise Distributed Object Computing Conference (EDOC 2000), Makuhari, Japan, September 2000.
12. S. Park, S. Das, D. Dill. Automatic checking of aggregation abstractions through state enumeration. IEEE Transactions on Computer Aided Design of Integrated Circuits and Systems, volume 19(10), October 2000.
13. B. Fischer: Specification-Based Browsing of Software Component Libraries. Journal of Automated Software Engineering, Vol. 7, No. 2, 2000, pp. 179-200.
14. J. Penix, B. Fischer, J. Whittle, G. Pour, J. van Baalen, Automating Component Integration for Web-Based Data Analysis Applications. IEEE Aerospace Conference, Big Sky, Montana, March 2000.
15. B. Fischer, J. Whittle: An Integration of Deductive Retrieval into Deductive Synthesis. Proc. Automated Software Engineering (ASE-99), Cocoa Beach, FL, October 1999, pp. 52-61.
16. B. Fischer, J. Schumann, T. Pressburger, Generating Data Analysis Programs from Statistical Models (Position Paper). Proc. ICFP-Workshop on Semantics, Applications and Implementation of Program Generation, Montreal, September 19-20th, 2000. Lecture Notes in Computere Science 1924, pp. 212-229. Springer.
17. T. Kaiser, B. Fischer, W. Struckmann, MOPS: Verifying Modula-2 programs specified in VDM-SL. Proc. 4th Workshop on Tools for System Design and Verification, Reisingburg, July 2000. Ulmer Informatik Berichte Nr. 2000-07, pp. 163-167.

18. B. Fischer: Automated Synthesis of Statistical Data Analysis Programs, Position paper for the AAAI-00-Workshop on Learning Statistical Models from Relational Data, Austin, TX, July 2000.
19. T. Kaiser, B. Fischer, W. Struckmann, The Modula-2 Proving System MOPS. Computer Science Report 2000-01, TU Braunschweig, June 2000.
20. Deepak Kapur and M.Subramaniam. Extending decision procedures with induction schemes. In Proc. of Conference on Automated Deduction CADE-17. July 2000.
21. Deepak Kapur and M. Subaramaniam. Verifying Arithmetic Circuits using a Rewrite-based Theorem Prover. To appear Intl. Journal of Software Technology and Tools.
22. J. Schumann. Automated Theorem Proving in Software Engineering. Habilitation, Technische Universitaet Muenchen. Feb. 2000.
23. J. Schumann. Automatic Debugging Support for UML Designs. In Proc. AADEBUG 2000, 2000.
24. J. Schumann and J. Whittle. Automatic Synthesis of Agent Designs in UML. In Proc. of Goddard Workshop on Agent-based Systems. Springer, 2000.
25. J. Whittle and J. Schumann. Generating Statechart Designs From Scenarios. In Proc. ICSE 2000, 2000.
26. Grigore Rosu and Joseph Goguen. On Equational Craig Interpolation Journal of Universal Computer Science, Volume 6, Issue 1, 2000, pages 194-200
27. Grigore Rosu. Equational Axiomatizability for Coalgebra accepted for publication in Theoretical Computer Science, to appear in Volume 260/1-2, 2000
28. Virgil Emil Cazanescu and Grigore Rosu. Weak Inclusion Systems; part 2 Journal of Universal Computer Science, Volume 6, Issue 1, 2000, pages 5-21
29. Grigore Rosu. Kan Extensions of Institutions. Journal of Universal Computer Science, Volume 5, Issue 8, 1999, pages 482-493
30. Joseph Goguen, Kai Lin, Grigore Rosu, Akira Mori, Bogdan Warinschi. An Overview of the Tatami Project. To appear in Cafe: An Industrial-Strength Algebraic Formal Method, Elsevier, 2000 accepted in December 1999.
31. Joseph Goguen, Kai Lin and Grigore Rosu. Circular Coinductive Rewriting Automated Software Engineering 2000 (ASE'00), Grenoble, France, 10-15 September 2000. IEEE
32. Samuel Buss and Grigore Rosu. Incompleteness of Behavioral Logics Coalgebraic Methods in Computer Science (CMCS'00), Berlin, Germany, 25-26 March 2000. Electronic Notes in Theoretical Computer Science, Volume 33, 2000
33. Grigore Rosu and Joseph Goguen. Hidden Congruent Deduction Lecture Notes in Computer Science, Volume 1761, 2000, pages 252-266

Presentations

1. Charles Pecheur. Advanced Modelling and Verification Techniques Applied to a Cluster File System. Presentation at ASE'99. Cocoa Beach, Florida, 15 October 1999.
2. Charles Pecheur, Formal Verification of Autonomous Systems. Florida Institute of Technology, 15 October 1999.

3. Charles Pecheur, Model Checking for Autonomy Software. Presentation for RIACS Seminar Series. NASA Ames, California, 4 November 1999.
4. Bernd Fischer, SeungJoon Park, Charles Pecheur, Willem Visser. Automated Software Engineering Group Presentation to RIACS Science Council. 11 February 2000.
5. Charles Pecheur, Issues: Verification of Autonomy. Invited panelist to AAAI Spring Symposium on Real-Time Autonomous Systems. Stanford, California, 21 March, 2000.
6. Peter Engrand and Charles Pecheur. Model Checking of Autonomy Models for an In-Situ Propellant Production System. Poster presentation at FAABS'00. NASA Goddard, Maryland, 6 April 2000.
7. Charles Pecheur. From Livingstone to SMV: Formal Verification for Autonomous Spacecrafts. Presentation at FAABS'00. NASA Goddard, Maryland, 6 April 2000.
8. Charles Pecheur. Future Directions: Verification of Autonomy. Invited panelist at FAABS'00. NASA Goddard, Maryland, 7 April 2000.
9. Klaus Havelund, Charles Pecheur, Reid Simmons, Willem Visser. Model Checking Tools and Trends. Tutorial for the 5th Langley Formal Methods Workshop, Williamsburg, Virginia, 13-15 June 2000.
10. Charles Pecheur. Presentation of the ASE group. Meeting with INRIA Rhône-Alpes and Polyspace, Montbonnot, France, 11 September 2000.
11. Charles Pecheur and Willem Visser. Model Checking for Software. Tutorial for the ASE'00 conference, Grenoble, France, 12 September 2000.
12. Willem Visser. Will Model Checking Scale to Software?. Invited Panelist. ASE99 Conference. 14 October 1999.
13. Willem Visser Analytic Verification at NASA Ames. Presentation and Demonstration. LUACTS Workshop. Johannesburg, South Africa. 6 December 1999.
14. Willem Visser. Picking Low-hanging Fruit. RIACS Seminar Series. NASA Ames, California, 13 April 2000.
15. Willem Visser. Java PathFinder - A second generation of a Java model checker. Presentation at WAVE'00 Workshop. July 2000.
16. Willem Visser. Java PathFinder Demonstration. Meeting with INRIA Rhône-Alpes and Polyspace, Montbonnot, France, 11 September 2000.
17. Willem Visser. Model Checking Programs. Presentation and demonstration at ASE'00 conference, Grenoble, France, 12 September 2000.
18. Dimitra Giannakopoulou. Model Checking of Workflow Schemas. Presentation at EDOC'00. Makuhari, Japan, September 2000.
19. B. Fischer, Generating Data Analysis Programs from Statistical Models. Talk and System Demonstration, ICFP-Workshop on Semantics, Applications and Implementation of Program Generation, Montreal, September 20th, 2000.
20. B. Fischer: AutoBayes System Demonstration, ICFP-Workshop on Rule-Based Programming, Montreal, September 19th, 2000.
21. B. Fischer and J. Schumann. Generating Data Analysis Programs from Statistical Models. Invited Talk and System Demonstration, Kestrel-Institute, Palo Alto, September 6th, 2000.
22. B. Fischer: Deduction-based Software Component Retrieval. Invited Talk, Computer Science Seminar, U Passau, Germany, July 21st, 2000.

23. M. Subramaniam. Extending Decision Procedures with Induction Schemes. Talk at NASA Ames and CADE-17.
24. M. Subramaniam. A Methodology for Designing Cache Coherence Protocols in Hardware. Talk at Dept. of CS Colloq. University of New Mexico and Hewlett Packard Labs at Palo Alto.
25. Johann Schumann. Tutorial on Automated First-order theorem proving in Software Engineering during the NASA Langley Formal Methods Workshop, June 14th, 2000.
26. Johann Schumann. Automatic Synthesis of UML Designs. Invited talk at the robotics lab at Xerox Parc May 2nd, 2000.
27. Johann Schumann. Proof Carrying Code. Formal invited scientific talk (Habilitation talk), Technische Universitaet Muenchen, Germany. Feb. 9th, 2000.
28. Grigore Rosu. Incompleteness of Behavioral Logics. Berlin, CMCS 2000 at ETAPS, March 2000
29. Grigore Rosu. Hidden Logic. University of Bucharest, Romania, August 2000

Other Professional Activities

- Charles Pecheur is part of the Program Committee of ASE'00.
- Charles Pecheur is Program Co-chair of the AAAI Spring 2001 symposium "Model-based Verification of Intelligence" (March 2001, with Lina Khatib).
- Willem Visser and Charles Pecheur are Program Co-chairs of the RIACS workshop on V&V of Autonomy (December 2000).
- Willem Visser, John Penix and Nigel Tracy. Organized the 1st International Workshop on Automated Program Analysis, Testing and Verification at ICSE'00 in Limerick, Ireland. June 2000.
- Klaus Havelund, Willem Visser and John Penix. Organized the 7th SPIN Workshop on Model Checking Software at Stanford, California, August/September 2000.
- Willem Visser is part of the Program Committee of SPIN'01.
- Bernd Fischer is part of the Program Committee of ASE'00.
- Bernd Fischer, Johann Schumann and Wray Buntine are organizers of the NIPS'00 Workshop on Software Support for Bayesian Analysis Systems. December 2000.

II.A.i.g Future Plans

- Development of a tool for closed-loop verification of Livingstone applications, based on the Generic Verification Environment and the Livingstone VM.
- Continue the support to verification activities in KSC Livingstone-based applications and the progressive transfer of tools and know-how to KSC engineers.
- To increase the scalability of automatic software verification by developing hierarchical and compositional techniques.
- Experiment with distributed and parallel search algorithms to extend the capabilities of the Java PathFinder Model Checker.

- Integrate static analysis techniques with the search algorithms within the Java PathFinder to allow larger systems to be validated.
- Continue research on the development of new techniques to reduce the cost and improve the behavioral coverage of the testing required by the FAA for the certification of flight software.
- Continue research on the V&V of DEOS and its application programs in conjunction with Honeywell Research Center.
- Application of the abstraction methods to software, hardware, and protocols used in NASA applications. (Depending on the funding situation, the candidate projects include AutoPilot from HCC, Ames Rover, New DIS protocol, abstract modeling of ISPP system, etc.)
- Find practical patterns in the verification using predicate abstraction, and to find a good metrics in the V&V process.
- Implement additional features to the abstraction tool such as function calls with abstracted data type.
- Develop a proof logging and proof log checking prototype. Primary focus on avionics synthesis application.
- Applications of Rewrite and Algebraic techniques in coming up with automatic abstractions.
- Integration of prototypical Sequence diagram to state-chart translation tool into commercial system
- Development of semantic foundations of UML transformations
- Extension of automatic debugging of UML designs
- Extend data analysis synthesis system by test data generator.
- Extend data analysis synthesis system to handle time series and image data.

II.A.i.h Problems Encountered

none

II.A.i.i Problem Resolution

N/A

II.A.ii Advanced Autonomous Planning and Scheduling

II.A.ii.a Task Summary

The goal of this task is to extend and improve autonomous planning and scheduling technology, to provide autonomous decision-making and decision-support capabilities for various NASA applications including spacecraft operations, rover control, satellite task scheduling, and airport surface movement systems. The core technology development is based on advanced constraint reasoning, in particular constraint-based planning. The task will extend the capabilities of the Remote Agent constraint-based planning techniques, which were flight validated on board the Deep Space One spacecraft in May 1999. Additionally, other constraint-based planning and scheduling techniques will be developed, with particular focus on plan optimization.

II.A.ii.b RIACS Staff

Ari Jonsson
Robert Morris

II.A.ii.c Overview

The high-level goal of this task is to continue the development of constraint-based planning and scheduling techniques, to support NASA mission operations. This includes autonomous operations on board spacecraft and rovers, on ground autonomous plan generation as part of mission operations, and the scheduling of air traffic operations. There are four main components of this task, which will be described briefly here and then in more details in the project description.

- Development of the core constraint-based planning system to provide a framework for both research and applications. Using this core, build a new version of the Remote Agent planner for spacecraft operations planning.
- Applying temporal and spatial scheduling to air traffic control operations. In particular, develop a framework and reasoning techniques for scheduling airport surface movement operations.
- Applying constraint-based techniques to the problem of scheduling Earth observing observation tasks on fleets of satellites.
- Continue development of advanced constraint reasoning techniques that support constraint-based planning and other constraint-based applications.

II.A.ii.d Project Description

Constraint-based planning for spacecraft ops

The main component of this task is the project on constraint-based planning. Within this project, there are roughly four main research thrusts, each of which addresses an important issue in planning with constrained interval tasks in complex domains.

The first is the development and implementation of a Next Generation Remote Agent planning framework. In particular, this involves a new design that can support advanced reasoning techniques, such as intelligent search methods. Just as importantly, it requires an implementation that is modular and well documented, to allow new techniques and approaches to be integrated and tested. The resulting system will serve both as a research tool and as a core for future applications of planning and scheduling.

The second is development and testing of different planning search techniques for constraint based planning. Of particular interest are methods based on repairing faulty plans and methods using intelligent backtracking to limit unnecessary search. Repair-based methods may be more efficient in many situations; additionally, they offer the possibility of repairing plans that have failed or are not applicable

in a new situations. Intelligent search techniques, such as those using dependency information, aim to identify the causes for failures to find a plan, and thus are often more effective than standard chronological backtracking methods. Another aspect of this is the development of techniques to gather and reason with dependency information, in a framework with highly dynamic constraint networks.

The third component addresses the issue of effectively finding plans by using automated techniques for guiding the planning process to examine likely paths and discarding impossible paths. These methods are often divided into two elements; one is the pruning of partial plans that can be proven not to lead to a complete plan, the other is the heuristic guidance of which possible partial plan candidates to examine. Recent results in the classical planning community have demonstrated that such methods can greatly improve the efficiency of a planning system; our goal is to develop methods that can achieve similar improvements on the more complex class of planning problems.

The fourth component concerns the capabilities of the framework for representing and handling more flexibility and uncertainty, e.g., by developing techniques to represent and reason about flexible aspects of a domain, while guaranteeing continued execution regardless of outcome. The results will be plans that are more likely to be executed successfully.

Autonomous decision support for SMS

At any large airport, operations are governed and affected by a number of different decision-makers, including airline operators, ramp controllers, airport management and air traffic controllers. The choices made by each decision-maker affects the eventual arrival, departure and takeoff time for flights operating in and out of the airport. The goal of this work is to develop autonomous planning and scheduling technology that can assist in the making of these decisions, with the goal of reducing delays, and thus costs, as well as pollution and congestion. Consider typical operations at a busy airport. After landing, ground control local control make decisions about how to get the flight to the appropriate ramp area. At that point, ramp controllers decide how to get the aircraft to its gate. During the turn-around process at the gate, airline operations make a number of decisions about how and when to accomplish the necessary tasks, and when to push back the flight. At that point, controllers will decide on how and when to move the flight out to the ramp and taxi areas, which runway to use, where in the takeoff queue to place it, and finally when to clear it for takeoff. Each of these decisions is influenced by a number of factors. These include arrival and departure delays, airline operations decisions, air traffic control decisions, gate assignments, runway choices, etc. Decisions and their outcomes for multiple flights interact in a number of different ways. For example, two aircraft cannot be at the same gate at the same time, and all landings and takeoffs using the same runway are separated by aircraft-dependent intervals. We propose to develop a framework for reasoning about decisions and interconnecting constraints.

The objective is threefold:

1. Provide up-to-date information of how operations are expected to go, given up-to-date information about event times, conditions, etc.

2. Provide advisory information for specified decisions, to assist with human decisions. This includes ``what-if" analysis.
3. Provide the capability for autonomous decision-making, based on up-to-date information and given optimization criteria.

An example of how this framework can be utilized to reason about airport surface operations involves a set of push back decisions being made by airline operations. The push back times are then denoted as optimization decisions, while all other operations are nominal. The nominal decisions include other airline push backs, ground control operations and takeoff times. The framework will calculate the optimal push back ordering, based on the available information, and display it as advice. The airline operations staff can also insert their own decisions and evaluate how these affect the expected departure times for the flights involved. Furthermore, the system will incorporate updated information about actual events, and suggest alternatives that would be better, based upon the new data. Finally, in a cooperative setting, multiple optimization criteria could be combined to provide an integrated system for reasoning about both push backs and ramp operations. The framework is required to be efficient enough to quickly incorporate additional information and update its estimates and optimization decisions. In the example above, information about a flight that is delayed at the gate will be incorporated into the database, and the advisory push back sequence can be reevaluated accordingly. More generally, the proposed framework will be required to integrate multiple heterogeneous sources of data relevant to the determination of surface movement in order to provide meaningful support to human decision-makers. The focus of the discussion in the remainder of this document will be on decision-making related to airport surface movement, but the conceptual framework can be extended to the whole airspace framework, including departure and arrival routes, and en-route airways.

Operations planning for multiple Earth-observing satellites

The purpose of this project is to provide decision-making support for planning and scheduling of activities for NASA's growing fleet of Earth-observing satellites. These satellites employ advanced sensing technology to assist scientists in the fields of meteorology, oceanography, biology, and atmospheric science to better understand how the Earth's systems of air, land, water and life interact with each other. Each satellite's limited resources of power, memory, and sensing instrumentation, as well as ground stations for communicating data and telemetry commands, must be efficiently allocated for the purpose of taking, storing, and downlinking high quality images of the earth. With fleets of satellites, there is the added need for planning for the coordination of satellites either in order to take multiple images of the same scene, or for taking individual elements of a mosaic image.

The planning problems in this domain consist of a set of satellites, each with sensing instruments, memory, resources for communicating data (antennae and transmitters), and a power source. The planner is given a set of requests for image data, as well as requests to perform non-imaging activities such as related to the calibration of instruments. A typical image request will specify the location and type of the data to be collected, the instruments to use, the resolution quality desired, the times at which

the images should be taken, and a priority that indicates its importance to the requester. The planner will also utilize current cloud cover prediction data, historical data indicating the last time the requested image has been taken (to ensure that the data is either current, or collected on a regular basis), as well as the list of scenes that each satellite will be able to scan during the planning period, and the set of ground stations that are available for downlinking data.

The planning model will describe temporal constraints on the orderings and durations of the activities of the satellite subsystems, in particular durations related to scanning, storing and downlinking data. It will also describe resource constraints such as the capacity of the various recording devices, warm-up times for the imaging equipment, constraints related to power consumption and the avoidance of instrument overheating, and the contact windows for, and capabilities of, the different ground stations.

A valid plan assigns a set of imaging and non-imaging tasks to each of the satellites, such that all the temporal, spatial, and resource constraints are satisfied. The goal of the planner is to find valid plans that optimize the science return value. The planning domain is highly dynamic, as weather, new requests, and targets of opportunity continuously combine to change the problem. This provides an excellent challenge task for replanning, constraint planning, and other techniques for taking execution into account during the planning process.

Constraint-based reasoning techniques

Finally, an general component of this task is the development of advanced constraint-based techniques for solving planning and scheduling problems. This exploration will be driven by the problems that arise from NASA applications, including constraint-based planning and scheduling, as described here above. Among the goals in this area are the development of more effective temporal reasoning techniques, the broadening of constraint reasoning techniques to more general classes of problems, the development of fast methods for approximate reasoning, and more.

II.A.ii.e Accomplishments

Constraint-based planner:

- The implementation of a uniform variable-based conditional subgoaling mechanism, capable of handling non-chronological changes, has been designed and implemented.
- The system has been extended to handle timeline constraints, including constraints containing variables.
- Support for the RAX domain description language (DDL) has been added, including automatic translation of And-Or structures into conditional subgoals, and extensions to the language for conditional subgoals.
- The system supports heuristic guidance for the search control, using both expressive descriptions of static heuristics and commonly used dynamic heuristics.
- Techniques for reducing search have been added to the system. These are based on identifying necessary decisions, such as those arising from symmetric subgoals and constraint propagation.

- The development and use of module and system tests has improved the stability of the implemented system.
- Initial optimization efforts have yielded a significant speedup for the system; many other optimization opportunities have been identified.

Theoretical work

- Domain analysis work; projected state spaces.
- Formalization of RA planning framework.
- Work on relating constraint-based planning to other efforts in planning and scheduling.
- Dynamic constraint reasoning framework.
- Planning as dynamic constraint satisfaction work

EOS scheduling

- Study of existing satellite operations, with particular focus on Landsat 7.
- Initial outline of task modeling

SMS scheduling

- Study of airport operations, ATC issues, etc.
- Completed a framework describing a principled approach to reasoning about airport surface movement, based on combining temporal constraint reasoning with resource conflict resolution methods.

II.A.ii.f Publications and Presentations

1. Denise Draper, Ari K. Jonsson, David Clements, and David Joslin, "Cyclic Scheduling", in Proceedings of the 16th International Joint Conference on Artificial Intelligence (IJCAI99), 1999.
2. Ari K. Jonsson, and Jeremy Frank, "A Framework for Dynamic Constraint Reasoning using Procedural Constraints", in Workshop on Constraints in Control, held in conjunction with the Fifth International Conference on Principles and Practices of Constraint Programming (CP99), 1999.
3. Ari K. Jonsson, Paul H. Morris, Nicola Muscettola, Kanna Rajan, and Ben Smith, "Planning in Interplanetary Space: Theory and Practice", in Proceedings of the 2nd NASA International Workshop on Planning and Scheduling for Space, 2000.
4. David E. Smith, Jeremy Frank, and Ari K. Jonsson, "Bridging the Gap Between Planning and Scheduling", Knowledge Engineering Review, 15(1), 2000.
5. Ari K. Jonsson, Paul H. Morris, Nicola Muscettola, Kanna Rajan, and Ben Smith, "Planning in Interplanetary Space: Theory and Practice", in Proceedings of the Fifth International Conference on Artificial Intelligence Planning Systems (AIPS), 2000.

6. Jeremy Frank, Ari K. Jonsson, and Paul H. Morris, "On Reformulating Planning as Dynamic Constraint Satisfaction", to appear in Proceedings of Symposium on Abstraction, Reformulation and Approximation (SARA), 2000.
7. Ari K. Jonsson, and Jeremy Frank, "A Framework for Dynamic Constraint Reasoning using Procedural Constraints", to appear in Proceedings of the Fourteenth European Conference on Artificial Intelligence (ECAI), 2000.
8. Robert Morris and Paul Morris, "On the Complexity of Reasoning about Repeating Events". Proceedings of the International Conference on Knowledge Representation and Reasoning (KR-2000).
9. Robert Morris and Lina Khatib, "General Temporal Knowledge for Planning and Data Mining", Forthcoming in the Annals of Mathematics for Artificial Intelligence.

II.A.ii.g Future Plans

Continuing the research and development in each of the focus areas.

II.A.ii.h Problems Encountered

None

II.A.ii.i Problem Resolution

N/A

II.A.iii Bayesian Inference and Image Analysis

II.A.iii.a Task Summary

NASA's EOS program, as well as other data collecting government agencies (such as NOAA, USGS, NIMA, etc.) and industry generate vast sets of observational data of the earth. This data is a basic resource, that can help answer such basic scientific questions as global warming, changing land use, ocean circulation and so on. In addition this data provides the raw material for answering broad policy questions, such as crop assessment, forestry planning, urban planning, etc. Also, individual users may find this data helpful in providing information about their particular farm or community. Also, NASA has image processing needs for planetary rovers and for integrating information from multiple images of planetary surfaces. Given this range of users, this raises the question how can NASA best meet the information needs of these users?

Bayesian model-based data integration in principle solves the problem of how to integrate information from multiple sensors. However, there are many practical problems in constructing computationally efficient models, especially in view of the huge amounts of data involved. In the long run, it should be possible to integrate all satellite (or other) data into one global model as the data is received. This updated model can then be used to project particular information required by particular users. It is also

very useful for spotting changes, because these are where there is a larger than expected difference between what the model expects and what is observed. The model can also be used to compress the data, since only the differences between expected and observed need to be stored. In the short term, this technology potential can be tested in much more limited demonstrations of data integration, such as integrating the images from the same satellite on different passes. This limited case is what the Bayesian Inference group is investigating.

II.A.iii.b RIACS Staff

Peter Cheeseman

Robin Morris

Vadim Smelyanskiy (now a civil servant)

David Maluf

II.A.iii.c Overview

This problem of integrating information from different sensors to answer particular questions is a familiar one in remote sensing and other fields, and often is referred to as "data fusion". "Data fusion", as sometimes envisioned, is a fundamental misconception. Data should ****never**** be tampered with, let alone "fused". Data is what was observed, and as such cannot be changed after the event. What basic theory says is possible is to construct geophysical models of the surface and atmosphere that "best" predict the observed data. For example, a geophysical ground model would include a point-by-point description of the topography, ground cover types and spectral characteristics, soil types, moisture content, etc. From such a geophysical model, it is possible to project what a particular patch of ground would look like from a particular viewing angle, under particular lighting conditions, with a particular camera etc. That is, given the model, one can probabilistically predict what would be observed (the expected data). The difference between what is actually observed (the data) and the expected data can be used to update the model. Thus the model acts as the central repository of all the real information in the data and is constructed from our prior knowledge of geophysical processes and how radiation interacts with the geophysical system. This central model could loosely be described as the result of "fusing" the data, but it is not itself "data" or a "data product". The Bayesian probabilistic estimation approach not only allows estimation of the most probable model given prior domain knowledge and the data, but it also estimates the uncertainty associated with the model. In particular, if this model uncertainty is high, it means that there is insufficient data/prior knowledge to pin down which model actually applies.

II.A.iii.d Project Description

The basic theory behind our approach is that of inverse graphics. That is, if we knew what the ground is like, the lighting conditions, and the camera orientation and characteristics, etc., then we could predict what the camera would see (an image). This is the standard computer graphics problem. However, we have the inverse problem--we know what the images are, and we want to find the most probable ground truth (surface) that would have generated them, assuming we know the lighting conditions and

camera characteristics. The most important (and difficult) part of this process is recovering the camera orientation and position for each image. To do this, we must register all the images with respect to each other to an accuracy of a small fraction of a pixel; this registration tells us how an image maps onto the ground truth model we are building.

Our initial ground model is formed by letting each pixel "vote" on what the corresponding ground position should be depending on how much that ground position contributed to that pixel. This initial ground model is then used to project what each image should be (i.e., predict each pixel value). The differences between the predicted pixel value and the observed value are used to update the ground model until it cannot be further improved. This procedure produces an increase in both spatial resolution and gray-scale resolution (super-resolution). We are now able to generate images from a high-resolution ground model, and then reconstruct the surface from these images at a resolution much higher than the input images. We are currently trying to extend the system so that it can learn the camera parameters and lighting conditions while simultaneously inferring the unknown surface.

II.A.iii.e Accomplishments

We have been successful in reconstructing unknown surfaces from synthesized low-resolution images of that surface, even though the images are taken from different viewpoints and under different lighting conditions. The surface is reconstructed at much higher resolution than the input images (super-resolution). This is the first time this has been achieved to our knowledge. The results of this super-resolution can be seen on our web page:

<http://ic-www.arc.nasa.gov/ic/projects/bayes-group/people/rdm/>

II.A.iii.f Publications and Presentations

1. "A Bayesian Approach to High Resolution 3D Surface Reconstruction from Multiple Images", by R. Morris, P. Cheeseman, V. Smelyanskiy and D. Maluf.

II.A.iii.g Problems Encountered:

Instability of NASA Funding (from the 632 program). This caused much stress for FY00, and is likely to cause similar stress for FY01.

II.A.iii.h Problem Resolution

Proposal writing to mainly NASA funding sources may generate sufficient funds to cover this research for FY01.

II.A.iv Reinforcement Learning Techniques

II.A.iv.a Task Summary

The research conducted under this task supports the development of advanced onboard autonomous planning and control architectures and algorithms which enable current and future NASA planetary exploration missions.

II.A.iv.b RIACS Staff

John Loch

II.A.iv.c Overview

Future exploration missions require new methods of commanding and controlling robotic agents on distant planetary and asteroid surfaces. Communication with robotic agents operating on distant planetary surfaces is constrained by bandwidth, opportunity, and time delay. Bandwidth and opportunity constraints can be improved by building additional communication infrastructure, but the time delay imposed by the limited speed of light is here to stay.

What this means for the operation of planetary surface rovers is that at a minimum they must be capable of autonomously executing human designated command sequences on the order of tens of minutes between command cycles for operation on Mars and nearby asteroids. Rover operations on the moons of Jupiter, such as Europa, will require robust execution of command sequences on the order of hours between command cycles.

The objective of the research conducted under this task is to develop robust, fault-tolerant autonomous control architectures capable of executing human designated command sequences. The research conducted under this task is being applied to two NASA projects: the Personal Satellite Assistant (PSA) project and the Robust Task Execution project.

The Personal Satellite Assistant (PSA) project is a NASA project to develop a free-flying robot that will serve as a virtual astronaut assistant onboard the International Space Station. The PSA robot will be used to monitor environmental conditions, assist astronauts in performing experiments and serve as a telepresence device for ground-based operators via an onboard videoconferencing system.

The Robust Task Execution project is a recently funded NASA activity that is exploring the use of reinforcement learning methods to improve the performance of autonomous rover navigation in natural terrain. The successful application of the research conducted under this task can lead to enhanced autonomous navigation algorithms, which will enable long-range Mars rover operations, planned for the 2003 Mars rover missions.

II.A.iv.d Project Description

- Development of a reinforcement learning architecture for robust navigation of mobile robots in both 3-dimensional spaces (PSA) and natural terrain.

- Research methods for handling large state space exploration for learning optimal navigation strategies.
- Research methods for automatic discretization of robotic sensors for optimal performance.
- Research methods for incremental learning of tasks.
- Research methods for transferring learned strategies between tasks.

II.A.iv.e Accomplishments

- Completed design and testing of PSA motion control software.
- Completed design and testing of PSA position and velocity estimation software.
- Completed rover-terrain simulator software.
- Design and testing of reinforcement learning architecture for rover control was verified using rover-terrain simulator.
- Formulated research plan to investigate effects of sensor and actuator configurations on reinforcement learning performance.
- Reinforcement learning algorithms verified to find optimal action selection policy using the rover-terrain simulator.

II.A.iv.f Publications and Presentations

None.

II.A.iv.g Future Plans

- Enhance fidelity of rover-terrain simulator to include complex rover-terrain interactions.
- Performed detailed testing of reinforcement learning algorithms with varying sensor and actuator configurations.
- Port the reinforcement learning architecture to the K-9 hardware rover testbed.
- Test performance of learned policy from simulation on K-9 rover testbed.
- Test improved performance from additional learning using K-9 rover testbed.

II.A.iv.h Problems Encountered

None.

II.A.iv.i Problem Resolution

N/A

II.A.v Model-Based Autonomy and Integrated Vehicle Health Management

II.A.v.a Task Summary

This task focuses on the formalization and development of model-based autonomous systems for controlling complex systems operating in harsh environments, including deep space probes, next generation reusable launch vehicles, biological life support systems, Mars rovers and other complex physical devices. Currently, the research is focusing on the task of assessing and managing the health of these devices using both qualitative and quantitative models. Through the use of a model that describes the underlying processes and components that are active within the system, a model-based system is able to reason generatively about the behavior of the system to detect, isolate and respond to failures.

Currently, technology being developed under this task is being demonstrated within a number of domains. Under this task, work is being done on two flight experiments on experimental reusable launch vehicles – the X-34 and the X-37 vehicles. These flight experiments will demonstrate the use of a model-based health management system that reasons broadly about system-level interactions to detect and isolate off-nominal conditions.

II.A.v.b RIACS Staff

Daniel Clancy
Richard Dearden
Anupa Bajwa

II.A.v.c Overview

Over the past year, this task has focused on maturing and extending the Livingstone model-based health management system initially demonstrated as part of the Remote Agent Experiment. Livingstone uses a functional/structural model-based upon first-principles to describe the nominal and faulty behavior of the components of a device and the interactions that occur between the components. Currently, Livingstone uses a discrete or “qualitative” model that describes the behavior of the components at an abstract level. This simplifies the modeling process and allows coverage over a broad range of artifacts. In our experience, this level of modeling is adequate for a majority of the failures that must be detected.

This task has currently been focusing in three areas:

- porting and maturing the existing technology demonstrated as part of the Remote Agent experiment so that it can be used to support the X-34 and X-37 flight experiments,
- extending the capabilities of this technology to reason about both the discrete and continuous dynamics of a complex physical device, and
- Applying this technology to the X-34 flight experiment.

In addition, work has been done under this task to assist NASA in the formulation and management of both the Intelligent Systems program as well as the Design for Safety program.

Links

- <http://ic-www.arc.nasa.gov/ic/projects/mba/index.html> Model-based autonomy home page
- http://www.ksc.nasa.gov/shuttle/upgrades/ksc/ivhm/data_depot/x34/vti_bin/nitex1.htm NITEX experiment page

II.A.v.d Project Description

Autonomous control of complex physical devices is critical to achieving many of the goals identified in NASA's current goal of "faster, better and cheaper." Existing techniques within the area of model-based reasoning have focused on modeling the system using a set of high-level, qualitative models that focus on a discrete characterization of the system's behavior. Often, however, to accurately monitor and diagnose the system it is necessary to use a quantitative characterization of the expected behavior of individual components or subsystems that include continuous behaviors. We call a mix of discrete and continuous behaviors a hybrid model. This task has been developing a set of techniques for monitoring and diagnosis of complex physical devices using hybrid models. The product of this proposal is a hybrid monitoring and diagnosis architecture that is able to reason about system-level interactions as well as detailed component behavior by combining the computational benefits of a high-level discrete model with the precision provided by lower level continuous models of individual components or sub-systems.

This task is also applying these techniques within a flight experiment. This experiment will fly on Orbital Sciences X-34 vehicle that will fly in FY 2002. The experiment will monitor the health of the main propulsion system and the reaction control system throughout the entire mission. Health status will be downlinked to the ground and displayed to the ground control team through an advanced ground station.

II.A.v.e Accomplishments

- Hired Richard Dearden to complement the existing staff on this project.
- Completed a port of the Livingstone system to C++ along with significant enhancements to the underlying core algorithms used within the system. Specifically, we added the ability to reason about multiple hypothesis and to track these hypothesis over time.
- Have developed a detailed design for the X-34 flight experiment and begun the model development task. In addition to developing the design, a requirement specification has been completed along with the project plan. We have begun implementing portions of the design and have developed a number of models for the X-34 experiment. We also have acquired domain knowledge and have identified the failure scenarios that will be tested and demonstrated. An initial demonstration of a restricted model is expected at the end of October.
- Collaborated with Stanford on developing Bayesian model selection techniques when reasoning about the behavior of a hybrid discrete/continuous system.
- Supervised two summer students who performed research in the area of hybrid systems. Both summer students laid the ground work for defining their PhD thesis. We expect to continue collaborations with both students as they continue their research.

- Assisted in defining the Design for Safety program. This program is expected to have an FY02 start in the order of 50 to 80 million dollars a year. Significant support was provided to assist in defining the technical vision for this program.

II.A.v.f Publications and Presentations

1. Daniel J. Clancy, "Model-based System-level Health Management for Reusable Launch Vehicles", AIAA Space 2000, Long Beach, Ca 2000
2. Tony Gross, Butler Hines, Daniel J. Clancy, "The Critical Role of Information Technology in Human Space Exploration", AIAA Space 2000, Long Beach, CA, 2000.
3. McIlraith, S., Biswas, G., Clancy, D., and Gupta, V., "Towards Diagnosing Hybrid Systems". In the *Proceedings of the Hybrid Systems Workshop*, Pittsburgh, PA, March 2000.
4. A. Bajwa and D. Kulkarni, "Engine Data Analysis Using Decision Trees" AIAA-2000-3627, 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Huntsville, Alabama, 19 July 2000

II.A.v.g Future Plans

- Continue to support the development of the X-34 experiment. We expect a full scale demonstration to be ready in early 2001.
- Develop techniques for applying particle filtering to the diagnosis of failures in hybrid systems.
- Extend Livingstone to enable it to reason about the discrete and continuous behavior of a complex physical device.

II.A.v.h Problems Encountered:

None

II.A.v.i Problem Resolution

N/A

II.A.vi Spacecraft Autonomy

II.A.vi.a Task Summary

The goal of this task is to conduct research aimed at furthering the state of the art in constraint-based planning, scheduling and execution, with particular focus on efficient handling of temporal constraints in the presence of uncertain activity outcomes. The theories and algorithms resulting from this research will be directly applicable to planning and scheduling systems currently under development, such as the HSTS 2.0 planning framework, and will support advances in the state of the art in plan execution. This work will be performed in close collaboration with other researchers at NASA Ames and RIACS.

II.A.vi.b RIACS Staff

Kanna Rajan
Paul Morris
Greg Dorais
Rich Washington

II.A.vi.c Overview

The primary objective of this research has been to support the Autonomy and Robotics area's (ARA) aggressive charter to support NASA missions with closed-loop autonomy. This involves not just research, but also design, implementation and integration of the software products generated by the in-house research activities. In this context our primary efforts have been focused on Planning and Scheduling activities specifically in domain modeling, search control and knowledge representation within the HSTS planning framework. The most prominent research effort is the 632-CETDP funded effort on Intelligent Deployable Execution Agents (the next step in the development of the original Remote Agent architecture).

II.A.vi.d Project Description

One primary objective has been to build connections outside ARC to be able to 'export' ARA technologies into other NASA entities and potentially missions on the ground. These connections required building bridges with both commercial and academic contacts relevant to the long term strategic needs of ARA and ARC at large. Specific institutions that were involved were:

- JPL (D. Bernard, S.Krasner, D. Dvorak, C.Raymond, R.Rasmussen et.al)
- NASA Goddard (P. Hughes, H.Murray, P.Hempel)
- NASA JSC (D.Scherckenghost, D.Kortenkamp)
- Johns Hopkins/APL (K.Heeres, M. Holdridge, E.Reynolds, J.Appleby)
- ESA, Holland (E. Bornshlegl)
- Axlog, France (C. Guttier)
- CMU (R. Simmons)
- UPitt (M. Pollack)
- U.Durham, UK (M. Fox)
- SRI (K. Myers, M. deJardin, D. Wilkins)
- USC/ISI (M. Tambe)
- United Space Alliance (M. Barry, A. Nowlting)
- Lockheed Martin (M. Gersh, C. Orogo, D. Suri)
- CSOC (M. Skudlarek)

In each of the above instances, substantial communication has been established to build technical or programmatic bridges.

II.A.vi.e Accomplishments

- Lead the Spacecraft Autonomy group within ARA to foster these connections and to build on efforts to 'fly' ARA software either on the ground or on board. The group leads are also instrumental in helping shape the vision of ARA and to look 'beyond the horizon' on our research goals and strategic vision concomitant with the goals and needs of the agency and specifically of the Information Directorate at ARC.
- Organized and led the Program and Organizing committees for a successful 2nd NASA International Planning/Scheduling workshop on Space in San Francisco. This workshop is the focal point of presenting research and problem sets for the NASA P&S community and is bi-annual. We had 22 high-quality plenary papers and 10 posters. We were innovating in getting a commentary from on each plenary paper from a member of either the research/mission or technologists community, which was well received. I am now the Chair of the permanent P&S Executive committee which will steer how future workshops will be executed. The committee includes representatives from NASA, APL, USA, ESA and well established academics from the US, Japan and Europe.
- Took over efforts to push the area towards Distributed Control of multiple spacecraft, a thrust area the agency as a whole is moving towards and which require substantial autonomy for large fleets of spacecraft in constellations or formations. I led an ARC effort in conjunction with M. Tambe (USC/ISI) to propose a 3yr \$1.8M proposal for the AIST program which unfortunately was not funded. However, in conjunction with B. Clancey (HCC Chief Scientist) we have proposed a \$2M/per year effort in cross-cutting HCC and autonomy areas for GSFC and APL missions.
- Took over as the chair of the ARA Selection Committee which will aggressively market and get top notch researchers necessary to sustain the core competency of the area.
- Morris continued work on the New Remote Agent Planner (NRAP). This included enhancements needed to support interfacing to an execution module being developed by the IDEA group. The dispatchability code developed for RAX was ported from Lisp to C++. The ported code was then optimized. Its speed was increased by a factor of 8 from 2 hours to 15 min., which is faster than the Lisp version (35 min). In this process, some bugs in the existing NRAP were discovered and fixed. The enhancements also included modifying the temporal network to maintain timepoint equivalence classes (TEQs), and to compute enabling conditions for TEQs.
- Morris participated in the AIPS Conference which took place April 14-18 in Breckenridge, CO.
- Morris reviewed an AI Journal paper for a special issue on Heuristic Search and also reviewed a paper for Annals Of Mathematics And Artificial Intelligence Journal.
- Morris wrote a draft of mathematical results concerning a general strategy for dynamic controllability, and also developed a prototype Lisp implementation of an algorithm for dynamic controllability. This will form the basis of a paper to be submitted to IJCAI-01 in collaboration with N. Muscettola and T. Vidal.
- Morris assisted K. Rajan in preparing a presentation given by Rajan to RIACS Science board.
- Morris prepared and submitted a Step 1 proposal for the IS NRA in collaboration with K. Rajan and others.

Title: Temporal Plan Merging For An Astronaut Activity Organizer. Total Funds: \$1219K (over 3 years). Personnel: Paul Morris (Technical P.I.), Kanna Rajan, Martha Pollack (U.Mich.), William Clancey, John O'Neill, Mark Shirley (Administrative P.I.). Submitted to Automated Reasoning (TA-1) through NASA ARC.

- Morris participated in the AAAI-2000 Conference in Austin, Texas, July 30 to Aug 3.

II.A.vi.f Publications and Presentations

Publications:

1. P. Morris and N. Muscettola, "Execution of Temporal Plans with Uncertainty" , Seventeenth National Conference on Artificial Intelligence (AAAI-2000), Austin, Texas, Jul/Aug, 2000.
2. A. Jonsson, J. Frank, and P. Morris, "On the Representation of Mutual Exclusion Constraints for Planning", Symposium on Abstraction, Reformulation, and Approximation (SARA-2000), Austin, Texas, July, 2000.
3. A. Jonsson, Paul Morris, Nicola Muscettola, Kanna Rajan, and Ben Smith, "Planning in interplanetary space: Theory and practice", In Proceedings of the 5th International Conference on AI Planning Systems, Breckenridge, CO, April, 2000.
4. Robert Morris and Paul Morris, "On the Complexity of Reasoning about Repeated Events", KR-2000 Conference, Breckenridge, CO, April, 2000.
5. K. Rajan, A. Jonsson, R. Washington, G. Dorais, P. Morris, Presentation to RIACS Science Council (Presented by K. Rajan). NASA Ames, June, 2000.
6. RA Experiment Team, "DS1 Remote Agent Experiment" in the DS1 Symposium, Pasadena.
7. K. Rajan, M. Shirley, W. Taylor and B. Kanefsky , "Ground Tools for the 21st Century" in IEEE Aero 2000.
8. K.Rajan et.al, "The Remote Agent: An Autonomous Control System for the New Millennium" at Applications of AI track of the European Conf. on AI, Berlin, Germany, Aug 2000.

Presentations:

1. NASA Planning/Scheduling workshop, March 2000
2. AAAI Constraints Workshop, invited talk, July 2000
3. European Conf. on AI, August 2000
4. European Space Agency, invited talk September 2000
5. Design for Safety Workshop, October 2000

II.A.vi.g Future Plans

Proposed goals/assignment for next review period:

- Continue with research efforts to do scientific exploration of ideas in P&S and execution of plans.
- Push on developing a modular and unified language for building domain models of complex systems.
- Build a credible research effort in Distributed Control in cooperation with researchers at ARC and outside specifically Goddard, JPL and USC/ISI.
- Continue efforts in building connections with academia and industry. developers despite the booming internet economy.

II.A.vi.h Problems Encountered:

None.

II.A.vi.i Problem Resolution

N/A

II.B Human-Centered Computing

Many NASA missions require synergy between humans and computers, with sophisticated computational aids amplifying human cognitive and perceptual abilities. Areas of collaboration between RIACS and NASA scientists are described in the following sections.

II.B.i Work Practice Analysis

II.B.i.a Task Summary

The focus of this research is on understanding how people and systems are interconnected in practice. To accomplish this, research is conducting in the areas of work systems analysis and evaluation and the development of computational modeling tools for simulating how people collaborate, communicate, and work within their environment.

II.B.i.b RIACS Staff

Maarten Sierhuis
John O'Neill

II.B.i.c Overview

The research conducted under this task is an integral part of the Work Systems Analysis and Evaluation group in Code-IC. The group's research philosophy is based on the view that Human-Centered Computing is a software engineering methodology. This methodology is based on the scientific study of cognition in people and machines, especially understanding the differences between perceptual-motor/cognitive/social aspects of people and present-day computer systems with the objective of developing computer systems that fit human capabilities and practices by exploiting and improving AI programming methods.

II.B.i.d Project Description

The following projects were conducted under this task during FY00:

Brahms

The objective of the Brahms project is to research how we can model the work practices of people and systems as an integral part of a human-centered system engineering approach. Brahms is a multi-agent modeling and simulation environment for simulating the situated work processes and activities of organizations, including people and systems.

Information Environments for Mission Control

Information system applications in Mission Control have traditionally been designed using functional approaches resulting in problems integrating data across systems, duplication of data, and problems with the currency and updating of data. Work practice studies are being conducted in Mission Control to describe the total information environment. The information environment includes the data models used by information system applications, and all the information required by the flight controllers to perform their work. An output of the information environment study will be an enterprise data model for Mission Control. This project is a collaboration with the Mission Operations Directorate at JSC and the Work Systems Design and Evaluation Group at NASA Ames.

Studying Delays at United Airlines

A major objective of NASA's Aviation Program is to improve the efficiency of the U.S. Airspace system. A major contributor to the efficiency of the U.S. airspace system are the airlines, particularly with respect to their scheduling of flights in delay situations. The Work Systems Design and Evaluation Group at NASA Ames is working in partnership with the SMS Technical Area at NASA Ames and United Airlines to study how airlines identify delay situations, and how they respond to delay situations.

II.B.i.e Accomplishments

Brahms

- Release of a Java-based multi-agent production system (Virtual Machine) on top of the Java Language. The Java-based Virtual Machine is more than 100-times faster than the old prototype simulation engine, developed in G2™ (from the Gensym Corporation).
- Developed a third Brahms model as an experiment for researching the expressiveness of the Brahms language and the ability for Brahms to *predict* work activities, collaboration and communication of people and systems in actual NASA domains. Models that have been developed are: A *predictive* model of the activities and communications for Heat Flow Instrument Deployment on the Moon, based on analysis of the work practices of the Heat Flow Deployment activity of the Apollo astronauts, during the Apollo Lunar Surface Experiment Package deployment.
- Developed a model of new Missions Operations practices for autonomous rover missions to the Moon. The Victoria mission is proposed by Dr. Michael Sims, NASA ARC to the NASA Discovery Program. The objective of this effort is to develop a design tool for the Victoria Mission Operations, based on a design model of the work practices of the Science Team and Rover, specifically focusing on human-rover collaboration. The model relates the human and rover activities, systems, instruments, and communication with the hard constraints of rover power consumption and data transmission volume. The objective is to develop simulation tools for mission designers to perform what-if scenarios for work processes, -procedures and mission activities of the science teams, as well as the rover.

Information Environments for Mission Control

- Conducted ethnographic observations of the work practices of Orbital Flight Dynamics flight controllers in Shuttle Mission Control.
- Specified a preliminary data model for Orbital Flight Dynamics.
- Initiated a program of work to leverage Oracle's expertise and products in aiding Mission Control to evolve their information systems infrastructure.
- Initiated a series of presentations to Harry McDonald, George Abbey, and John Young to establish a cross-agency jointly funded program of work to evolve Mission Control's information systems infrastructure.

Studying Delays at United Airlines

- Conducted ethnographic observations of the aircraft turnaround processes at San Francisco airport.
- Wrote a report analyzing the aircraft turnaround process from a delay perspective.
- Conducted ethnographic observations of delays from a customer perspective.
- Wrote a report analyzing how the airline's operation needs to be redesigned to better serve customers in delay situations.

II.B.i.f Publications and Presentations

1. Bradshaw, J. M., Sierhuis, M., Gawdiak, Y., Thomas, H., Greaves, M. and Clancey, W. J. (2000). "Human-Centered Design for the Personal Satellite Assistant", In International Conference on Human-Computer Interaction in Aeronautics 2000Toulouse, France.
2. Sierhuis, M. (2000). "Modeling and Simulation of Work Practices on the Moon, In Computational Analysis of Social and Organizational Systems" 2000http://www.ices.cmu.edu/casos/papers_content.html, Carnegie Mellon University, Pittsburgh, PA.
3. Sierhuis, M., Clancey, W. J., Hoof, R. v. and Hoog, R. d. (2000a). "Modeling and Simulating Human Activity", In Autonomous Agents 2000 workshop on Intelligent Agents for Computer Supported Co-operative Work: Technology and Risks(Ed, Petsch, M.) Barcelona. Spain.
4. Sierhuis, M., Clancey, W. J., Hoof, R. v. and Hoog, R. d. (2000b). "Modeling and simulating work practices from Apollo12", In International Workshop on Simulation for European Space ProgrammesESTEC, Noordwijk, The Netherlands.
5. Sierhuis, M., Sims, M. H., Clancey, W. J. and Lee, P. (2000c). "Applying multiagent simulation to planetary surface operations", In COOP'2000 workshop on Modelling Human Activity(Ed, Chaudron, L.) Sophia Antipolis, France, pp. 19-28.
6. O'Neill, J. "Creating Classification Systems that Support the "Real" Work of Large Organizations", Classification Schemes in Cooperative Work Workshop at CSCW 2000.
7. O'Neill, J. & Wales, R. "The Myths of Reliability and The Perfect Air Travel Experience: Designing an Airline to Pro-actively Manage Delay Situations", report submitted to NASA and United Airlines, 2000.

8. O'Neill, J. "A Preliminary Data Model for Orbital Flight Dynamics", RIACS Technical Report, 2000.
9. O'Neill, J. "A "Middle-Out" Perspective of Organizational Learning", Proceedings of the Theorizing Organizational Learning as Situated Practice Symposium, Academy of Management Conference, 2000
10. O'Neill, J. & O'Brien, F. "The Relational Nature of Organizational Knowledge" to appear in the Journal of Cognitive Technology.
11. O'Neill, J. & O'Brien, F. "The Effects of Outsourcing on C2", Proceedings of the 2000 Command and Control Research and Technology Symposium, 2000.
12. Wales, R. & O'Neill, J. "Distributed Communication, Technology and Work Systems on the International Space Station", Proceedings of the Computers and Communication in the Workplace Workshop, Global and Local Histories: Applied Anthropology Across the Centuries Conference, 2000.
13. O'Neill, J. & Wales, R. "A Human-Centered Computing Study of Delays at United Airline's San Francisco Operation: Initial Findings from Shuttle Operations" report submitted to NASA and United Airlines, 2000.

II.B.i.g Future Plans

Brahms

- Develop a user-friendly Brahms model-builders environment.
- Develop a Java-language application interface to Brahms.
- Apply Brahms as a multi-agent planning and execution system for intelligent agent systems.
- Extend Brahms with Virtual Reality Display capabilities for end-user interaction.
- Apply Brahms as a knowledge-based requirements engineering tool for human-centered design.

Current Brahms proposals

- Multi-Agent Software Design and Engineering for Human-Centered Collaborative Autonomous Space Systems (funding awarded by NRA 99-OS-05 - Cross Enterprise Technology Development Program).
- Teamwork in Practice: Design for Collaboration in Mixed Human-Robotic Teams. (proposed by UWF to NRA 2-37143 - Intelligent Systems Program)
- Work Practice Simulation Environment for Habitat Design and Scheduling (proposed by NASA to NRA 2-37143 - Intelligent Systems Program)
- Agent-Assisted Training Based on Models of Team Activity (proposed by USC/ISI to NRA 2-37143 - Intelligent Systems Program)
- Mobile Agent Architecture (proposed by NASA to NRA 2-37143 - Intelligent Systems Program)

Studying Delays at United Airlines

- Create models of United Airline's ground operations, identifying communication and information flow "gaps" and the effects of rework caused by delays.
- Work with United Airlines in rethinking their operations from a customer perspective.

Information Environments for Mission Control

- Continue studying and describing the information environment in Mission Control with the aim of identifying new opportunities for intelligent systems.

II.B.i.h Problems Encountered:

The Brahms project lost a Brahms software developer in August '00.

II.B.i.i Problem Resolution

We were able to hire an appropriate replacement using a QSS contractor.

II.B.ii Spoken Language Interface to Complex Systems

II.B.ii.a Task Summary

The group's primary focus is on Spoken Dialogue Natural Language Interfaces (SDNLIs) to semi-autonomous agents and complex software systems. We address three major areas in which significant breakthroughs need to be made in order to have the type of spoken language interfaces envisioned for the variety of applications relevant to NASA :

- (1) Portability
- (2) Flexible, Robust Dialogue Capabilities
- (3) Language Modeling.

Our group is actively exploring ways to integrate spoken dialogue interfaces into current and future NASA missions.

II.B.ii.b RIACS Staff

Beth Ann Hockey
Manny Rayner
John Dowding
Frankie James

II.B.ii.c Overview

A major issue for NASA in this age of Faster, Better, Cheaper is the need for increased productivity by key personnel. As NASA launches more Shuttle missions to service the ISS, astronauts and mission controllers will have more tasks to perform and less time for training. It is clear that personnel working in the field of Air Traffic Control are under similar pressure. An important part of creating performance enhancing systems to address these problems is to have interfaces that do not in themselves create additional work or cognitive burden. Imagine how much easier it would be to use a computer system

that you could simply converse with in the way you would when delegating to a human assistant or as you would when collaborating with a colleague.

Not only will research in spoken dialogue systems result in superior interfaces, it will also address broader issues of communication between humans and computer systems. At the heart of the work is the question of understanding and modeling how people communicate, of exploring what representations can facilitate that communication either with other humans or with computer and robotic systems. Our approach is based on empirical study of what people say to each other, what people say to actual systems and what they say to simulations of possible future systems. We believe that one of the benefits of a spoken dialogue interface is that the closer it is to handling the types of conversations that people would have with each other, the more the interface provides a reduction in required training and in cognitive load.

Speech recognition and natural language processing have been identified as growth areas for NASA Ames. NASA's needs in this area differ from the commercial sector in at least two ways:

- 1) NASA requires interfaces for many quite diverse applications. The number and diversity of NASA applications drives the need for research in portability, that is the ability to use and /or adapt language resources and system components to multiple applications
- 2) Many NASA applications, such as collaborative rovers will require dialogue capabilities that are likely to be beyond the state of the art for commercial systems for the foreseeable future.

Part of our approach to addressing NASA's needs in the area of spoken language dialogue interfaces is to leveraging off state of the art commercial and research software and develop the portability and advance capabilities on top of that base.

II.B.ii.d Project Description

The thrust of our project is to investigate near and longer term applications of spoken dialogue interfaces for NASA and to research areas that are crucial to developing the more advanced interfaces. The Surface Movement Advisor system for Ramp tower controllers is an example application that could benefit immediately from a spoken interface. Longer term applications are in robotics and complex systems such as the Personal Satellite Assistant, collaborative rovers or smart instrumentation. The major research issues we have been investigating are: Language Modeling, Portability and Advanced Dialogue capabilities.

Language Modeling

Language Modeling is important for both portability and for mixed initiative dialogue. In order to be able to port from one application to another one needs to be able to build a domain specific language model to guide speech recognition. Mixed initiative dialogue put an added burden on language modeling because the user is free to produce a wider variety of utterances. We have been doing initial work on domain specialization and on improving language models using sparse or noisy data.

Portability:

Methods are needed for specializing from general resources such as grammar and vocabulary to particular domains. This year we have been emphasizing techniques for specializing language models while considering how the domain specific and domain independent aspects of other dialogue system components can be separated. For the language modeling we have been testing Explanation Based Learning (EBL) as a technique for domain specialization.

Advanced Dialogue Capabilities:

Most current dialogue systems assume strict turn taking between user and system. Asynchronous dialogue management loosens this assumption. We have been working on some initial aspects of asynchronous dialogue management, in particular interrupting actions and being able to subsequently resume or abandon those actions. The problem of asynchronous dialogue management has only just started being addressed in the research community so there is much more leading edge work to be done.

Failures can happen at any stage of processing in a spoken dialogue system. We have been developing an architecture for handling these "errors" uniformly and as a integral part of the processing. By carrying along information about failures and other aspects of the processing we have a ready resource at every stage of processing for querying the user to get needed information or for deciding between alternative interpretations.

There are typically other potential sources of information in a dialogue besides the speech. We have been investigating using information such as eye-tracking to improve the performance of spoken dialogue system components. Our investigation thus far has concentrated on using eye-tracking information in reference resolution. The obvious extensions of this works would be to make use of eye-tracking information in other parts of the dialogue system and/or to look at other modalities.

User Testing and Iterative Design

A key part of our methodology for this project is to gather information from user interactions with our systems. We have been using both informal user interactions and structured user tests to test and extend our interfaces. Feedback from users shows us where to extend vocabulary, grammar, and dialogue responses and suggests what new capabilities would be productive to explore.

II.B.ii.e Accomplishments

- Developed a set of base components for testing and development of spoken dialogue systems.
- Built three demonstration systems based on these components: Science Desk, Surface Movement Advisor and The Simulated Personal Satellite Assistant (PSA) Interface. The Simulated PSA is the most advanced and has served as our research and development test bed.
- Research on portability (EBL) and advanced dialogue capabilities such as asynchronous dialogue management, integrated failure handling through maintaining meta-outputs and using multiple sources

of information such as eye-tracking with the dialogue. We have also investigated methods for improved language modeling to support mixed initiative dialogue.

- Carried out a moderate sized, controlled user study which produced a corpus of interactions with the Simulated PSA system. This corpus supplied the data for experiments reported in our publications this year.
- Developed methods and components for integrating multimodal information with the dialogue system. Demonstrated integration of simulated eye-tracking events with the dialogue system under IS program funding for FY00 from Lee Stone.
- Integrated the Simulated PSA interface with a 6-degree of freedom simulation under funding from the PSA project.
- Developed collaborations with:
 - Lee Stone and Roger Remington (Code IH, NASA Ames)
 - David Miller (University of Oklahoma)
 - Yuri Gawdiak, Greg Dorais, Adam Sweet (Code IC, NASA Ames, PSA project)
 - Rich Keller (Code IC, NASA Ames)
 - Ted Berger (University of Southern California)
 - Pete Bonnasso (JSC)
 - EU D'Homme Project (U. Edinburgh, SRI International, netdecisions [UK]; Telia, U. Gothenburg [Sweden]; University of Seville[Spain])
- Submitted 5 proposals to 632 Thinking Systems NRA, 5 proposals to the IS program and 1 NSF proposal as either PIs or CoIs.
- Recruited and hired two senior researchers.

II.B.ii.f Publications and Presentations

1. Boye, J., Hockey, B.A. and Rayner, M. "Asynchronous Dialogue management: Two Case-Studies". Gotalog 2000: Fourth Workshop on the Semantics and Pragmatics of Dialogue, June 2000.
2. Rayner, M., Hockey, B.A., James, F., Bratt, E.O., Goldwater, S., Gawron, J.M. "Compiling language models from a linguistically motivated unification grammar". COLING 2000. August 2000.
3. Hockey, B.A., Rayner, M. and James, F. "A comparison of the XTAG and CLE grammars for English." In Proceedings of TAG+5: International Workshop on Tree Adjoining Grammars and Related Formalisms. Paris France, May 25-27 2000.
4. Rayner, M., Hockey, B.A. and James, F. "A Compact Architecture for Dialogue Management Based on Scripts and Meta-Outputs". Proceedings of Applied Natural Language Processing 2000, Seattle, April 29-May 3 2000.
5. Rayner, M., Hockey, B.A. and James, F. "Turning speech into scripts". In AAAI Spring Symposium on Natural Dialogues with Practical Robotic Devices. Stanford CA, April 2000.

8. James, F., M. Rayner, and B.A. Hockey. 2000. "Accuracy, coverage, and speed: What do they mean to users?" In CHI 2000 Workshop on Natural-Language Interaction.

II.B.ii.g Future Plans

Goal: Creating natural spoken dialogue interfaces to robots and spacecraft systems which are flexible and model human behavior

Advanced Dialogue Management

Current spoken dialogue systems are capable of taking dialogue initiative but rarely take task initiative. We will explore designing systems that can take task initiative, which will necessarily require building an interface in a domain or application in which a large amount of task-specific knowledge is available. Closely modeling human behavior will make a system seem very natural for the users to use and let it respond in ways which the users expect. For example, if the user asks a question, then the user can answer the question, ask a clarification question, answer another question relevant to the task, or abandon the present task and start another. Mechanisms for treating all of these cases are available in the Information State Processing. We will continue to explore the problem of asynchronous dialogue management, where the traditional assumption of strict turn-taking between user and computer does not apply. Issues that arise in asynchronous dialogue management include overlapping speech, where the user and computer speak simultaneously, and time-critical speech, where the computer will need to modify its responses depending on the amount of time available to interact with the user.

Advanced Dialogue Language Modeling

The language modeling research that we will pursue is related to the issues of portability and robustness when building spoken dialogue systems in a new domain. State-of-the-art statistical language models require a large amount of training data. This leads to good performance, but can be very expensive to collect, and inhibits porting to new domains. We are exploring methods to take advantage of a large broad coverage grammar of English, and use only a very small collection of data to specialize this to a new domain. This will require advances in the grammar specialization process, but also advances in the compilation process that converts a grammar-based language model to a speech recognition language model.

Advanced Speech Features in Dialogue Systems

The prosody, i.e.: intonation, loudness and duration, of words in a dialogue signal major phrase boundaries, focus words and the distinction between questions and statements. We will be marking words in the lattices with intonational meanings, which will help the parser to accurately find the correct analysis of the utterance.

Since the system knows the meaning of the statements it wishes to generate, the intonation of the synthesis can be forced to reflect the correct meaning. When a person hears a question with the wrong intonation, they end up confused. For example, if the system says: Where do YOU want to go? The person wonders who else the person might refer to. The correct intonation is WHERE do you want to go?

Advanced Multimodal Dialogues

The power of integrating eye and speech information into a single, cooperative interface is that the multiple independent sources of information about operator intent will greatly reduce both low and higher-level speech interface problems, and thereby allow more reliable, as well as more powerful, human-computer communication. While there have been psycholinguistic studies of eye-movement behaviors with respect to listeners there has been no investigation of eye movement of speakers. There is no data on correlation of eye-movement events with what is being spoken. However, we believe that, if a correlation exists between a speaker's eye movements and his speech, the eye movements can be extremely useful in disambiguating a speech signal to produce an interpretation. For example, if the speech system is able to understand part of a user utterance ("open the door at the..."), and the user is looking at the door to the crew hatch, the system should be able to use that information to decide that the command was "open the door at the crew hatch." Similarly, if none of the utterance was understood, but the eye movements led the system to believe that the user was interested in the flight deck, it could ask a clarification question to the effect of "what do you want me to do at the flight deck?" We could also use eye movement data of this type to resolve deictic (and possibly other) references, which would allow the dialogue between the human and computer to be more natural (e.g., "go to that door"). Data will need to be collected to verify that speakers do indeed use eye movements that correlate with their speech, as well as to determine the time at which the relevant eye movements occur in relation to the speech.

Another multimodal area we are interested in exploring is the integration of avatars with the spoken dialogue interface.

II.B.ii.h Problems Encountered:

Staffing:

One major problem for the group this year has been loss of personnel. At three researchers the group was very small for this area of research so Manny Rayner's departure left us below critical mass. This also meant that much of Beth Ann Hockey's time had to be spent presenting papers at conferences and recruiting.

Office/Lab space

We have not had suitable space to do our research since the group moved to building 262 in April. Our success in hiring has made the problem of having suitable space even more acute. We still have no appropriate space for conducting user testing or other system testing activities so have had to abandon doing most of those testing and data collection activities since moving to building 262. We are also having trouble accommodating our equipment in our current space, and have additional equipment on order.

European collaborations and Export control:

The Speech and Natural Language Processing research communities are global. Some of our most promising potential collaborations are with European projects such as D'Homme and SIRIDUS. We have been impeded in joining these collaborations by lack of accurate information about export control

procedures and by various export control requirements. Particularly problematic has been the State Department requirement for a TAA in order to actually engage in any useful discussion with our collaborators.

II.B.ii.i Problem Resolution

Staffing

The problem of insufficient personnel has been greatly improved by recruiting two excellent researchers: John Dowding and Jim Hieronymus.

Office/Lab space

We have prepared and circulated a document outlining the basic requirements for a speech and natural language testing and development lab. We have discussed potential solutions to the office/lab space problem with RIACS director Barry Leiner and will continue to pursue possible solutions with him.

European collaborations and Export control:

The problem of getting accurate information on procedures has improved through discussion with USRA headquarters. The problem of getting through the process in a timely way so that we can participate in collaborative projects is still a problem. For example, we will be able to license software to our collaborators on the D'Homme project which starts in January but not be able to discuss many crucial aspects of that software with them until we receive permission from the State Department in the form of a TAA. The TAA could take as long as March to process; in the worst case scenario we could miss participating in 1/4 of this 1 year project.

II.B.iii Frameworks for Distributed Computing

II.B.iii.a Task Summary

The primary activity of this task is the development of a framework to simplify the creation of distributed applications. Key ideas include applying aspect-oriented programming technology to separate the specification of systematic policies from underlying functional code and developing richer mechanisms for event-based publish-and-subscribe services. This work is applicable to the development of distributed applications as the DARWIN wind-tunnel data reporting system and the NASA-wide Intelligent Synthesis Environment virtual design system.

II.B.iii.b RIACS Staff

Robert Filman

II.B.iii.c Overview

A critical issue in developing component-based and distributed systems is getting the assembled set of components to follow the policies of the overall system. To achieve *ilities* such as reliability, availability,

responsiveness, performance, security, and manageability, all system components must consistently perform certain actions.

We have been developing the Object Infrastructure Framework (OIF), a CORBA centered system for achievingilities in distributed systems. OIF realized the following key ideas:

- **Intercepting communications.** OIF intercepted and manipulated communications among functional components, invoking appropriate “services” on these calls.
- **Discrete injectors.** Our communication interceptors, *injectors*, are first class objects:
- **Injection by object/method.** Each instance and each method on that object can have a distinct sequence of injectors.
- **Dynamic injection.** The injectors on an object/method are maintained dynamically and can, with the appropriate privileges, be added and removed.
- **Annotations.** Injectors can communicate among themselves by adding annotations to the underlying requests of the procedure call mechanism.
- **Thread contexts.** To allow clients and servers to communicate with the injector mechanism, the system maintains a “thread context” of annotations for threads, and copies between this context and the annotation context of requests.
- **High-level specification compiler,** a compiler from high-level specification of desired properties and ways to achieve these properties to default injector initializations.

OIF injectors on CORBA-wrapped tools and services can be used to enforce and perform systematic services such as:

- Maintain the annotations of artifacts created by running design tools.
- Enforce complex, not-yet-anticipated access control rules on data, particularly as contractors form federations to deal with design sub-problems.
- Enforce automatic data set transformations to translate between representations.
- Supply alternative servers of the same service.
- Report on the status of jobs to distributed managers and debuggers.
- Support “session” environments reflecting user privileges downstream and carrying the user environment.
- Support “long-lived” transactions needed by the design process, (in contrast “database” transactions, such as bank account updates and airline reservations.)
- Obtain and assure the appropriate versions of datasets.
- Provide software redundancy and mobility, enabling moving computations and data for increased efficiency.

II.B.iii.d Project Description

- Extend the OIF system to work in additional environments (e.g., VisiBroker 3.4 and Java 2).

- Extend the OIF system developed in the prior work to include additional policy mechanisms for configuration management, agent-based computing, futures, and choice-based problem solving mechanisms.
- Extend the OIF specification system to allow segmented specifications and to provide “wizards” to simplify policy-injector creation.
- Develop the theoretical framework for injector-based aspect-oriented programming
- Apply the OIF mechanisms to domains such as DARWIN and ISE.

II.B.iii.e Accomplishments

- Upgraded OIF to VisiBroker 3.4, Java 2, and Orbacus 3.2.
- Extended the publish-and-subscribe event mechanism to include embedded events and marshalling object references.
- Designed an overall ISE application layer architecture centered on OIF and repository/annotation behaviors

II.B.iii.f Publications and Presentations

1. Robert E. Filman, Stu Barrett, Diana Lee, and Ted Linden, "Inserting Ilities by Controlling Communications," Communications of the ACM, in press.
<http://ic-www.arc.nasa.gov/ic/darwin/oif/leo/filman/text/oif/oif-cacm-final.pdf>
2. Robert E. Filman, David J. Korsmeyer, and Diana D. Lee, "A CORBA Extension for Intelligent Software Environments," Advances in Engineering Software, Vol 31, in press, 2000. (Also appeared in National Aeronautics and Space Administration, 5th National Symposium on Large-Scale Analysis, Design and Intelligent Synthesis Environments, Williamsburg, VA, October 1999.)
<http://ic-www.arc.nasa.gov/ic/darwin/oif/leo/filman/text/oif/williamsburg-print-final.pdf>
3. Robert E. Filman and Diana D. Lee, "Managing Distributed Systems with Smart Subscriptions," Proc. 2000 International Conference on Parallel and Distributed Processing Techniques and Applications (PDPTA'2000), Las Vegas, June 2000, pp. 853-860.
<http://ic-www.arc.nasa.gov/ic/darwin/oif/leo/filman/text/oif/docs-pubsub.pdf>
4. Robert E. Filman, "Applying Aspect-Oriented Programming to Intelligent Synthesis," Workshop on Aspects and Dimensions of Concerns, 14th European Conference on Object-Oriented Programming, Cannes, France, June 2000.
<http://ic-www.arc.nasa.gov/ic/darwin/oif/leo/filman/text/oif/cannes.pdf>
5. Joan Walton, Robert E. Filman, and David J. Korsmeyer. "The Evolution of the DARWIN System." 2000 ACM Symposium on Applied Computing March 2000, Como, Italy, pp. 971-977.
<http://ic-www.arc.nasa.gov/ic/darwin/oif/leo/filman/text/darwin/evolution-of-darwin.pdf>
6. Robert Filman, "The Arachnoid Tourist: 2020 Hindsight," IEEE Internet Computing, Vol. 43, No. 1, January 2000, pp. 79-82.
<http://ic-www.arc.nasa.gov/ic/darwin/oif/leo/filman/text/aracht/v4n1at.pdf>

II.B.iii.g Future Plans

- Develop an overall theory of aspect-oriented computing.
- Apply these mechanisms to a NASA application. ISE would be ideal, but at the moment is in a fair amount of administrative and directional transition.
- Demonstrate some additional injector-based systematic approaches to particularities.

II.B.iii.h Problems Encountered:

None

II.B.iii.i Problem Resolution

N/A

II.B.iv Ames Center for Advanced Space Concepts (ACASC)**II.B.iv.a Task Summary**

The Ames Center for Advanced Space Concepts (ACASC) will establish a think tank environment to support development of cutting edge, cross-disciplinary, concept-based research in science and technology. ACASC aims to strengthen collaboration, not only across research disciplines at NASA Ames, but also with external partners in order to incubate new, innovative approaches to space mission design and mission control.

II.B.iv.b RIACS Staff

Zann Gill

II.B.iv.c Overview

The think tank will provide a petri dish for experiments in group collaboration and in collaborative computing. A meta-level research program will be designed in FY 01 that will make use of the think tank as its experimental testbed. Zann Gill has had initial conversations with a range of researchers about the design of such a research program. We will wait to begin its design until we have approval for the proposed Implementation Plan for the think tank.

II.B.iv.d Project Description

- Identify options for ACASC infrastructure and processes.
- Identify related cross-disciplinary research thrusts with potential to support innovation in NASA space mission design.

- Select several prototype cross-disciplinary fusion areas with potential to generate advanced concepts.
- Work with representatives to formulate a tactical approach in each fusion area.
- Survey similar centers to identify relevant programs, functions, and facilities.
- Initiate seminars series with associated work sessions to define cross-disciplinary advanced concept research opportunities.
- Define a methodology that ACASC can use to promote development of advanced concepts involving cross-disciplinary teams.
- Consider what benchmarks and metrics should be used to assess the effectiveness of ACASC at speeding the innovation of advanced concepts relevant to NASA's mission.
- Design an ACASC website, which will not only disseminate information, but also act as an interactive collaborative environment for the development of advanced concepts.
- The following collaborative activities have been initiated:
 - JPL/Ames/DARPA workshop on Bio-evolutionary Engineering Systems (BEES), December 2000
 - Ames/SETI/Stanford collaboration on the development of a collaborative web environment (Webtank) to support the Voyages Through Time curriculum and to try ideas that may be later adopted and expanded in a Webtank to support the NASA Think Tank.
- Prior to implementing a webtank for NASA's Think Tank it seemed useful to identify a testbed opportunity. So began a collaboration with the SETI Institute, which has several million dollars to develop a cross-disciplinary high school science curriculum (physics, chemistry, biology, evolution of technology) in which students explore how the concept of evolution underpins and integrates these disciplines. The requirements of the fourth Evolution of Technology curriculum module provided an opportunity to develop and pilot test a Collaborative Web Environment, a webtank to be adapted, augmented, and extended to support the NASA Think Tank. The webtank serves two complementary functions: providing process support for invention and collaborative problem-solving (active mode), and offering a knowledge management framework for information resources and project archives (passive mode). Users can click back and forth between active and passive modes. SETI has established a systematic method using external contractors for pilot testing, and later field testing, all elements of the Voyages Through Time (VTT) curriculum. Pilot testing of the SETI curriculum and Version 1.0 of the webtank will be completed by January 2001. This input will be used to redesign for the field test September 2001 to June 2002 and also to begin development of a prototype of the webtank for the NASA Think Tank.

The following two steps have been completed for the fall 2000 pilot test of the *Evolution of Technology* module:

- Work with Voyages Through Time (VTT) to design a series of activities to “turn kids into inventors.”
- Develop a multimedia presentation to make these activities available on the VTT CD and/or the web.

II.B.iv.e Accomplishments

During FY 2000 effort was directed toward accomplishing three objectives:

- Prepare a strategic plan for ACASC for presentation to senior management at NASA Ames and to potential outside collaborators.
- Develop the concept for a think tank spin-off research program and initiate meetings with possible key leaders for such a program within the half dozen potential research thrust areas designated for the program.
- Initiate meetings with potential external collaborators.

A preliminary package was presented in June to Harry McDonald, Jack Hansen, and Steve Zornetzer and thereafter externally. The presentation package is currently being revised for presentation to senior management, to HQ, potential external university and industry collaborators. In addition, work has been initiated on a possible cross-code spin-off program for FY'02 called BEACON (Bio-Evolutionary Advanced Concepts for NASA).

II.B.iv.f Publications and Presentations

Presentations on ACASC at the following locations:

- Institute for Advanced Study, Princeton
- Radcliffe Institute for Advanced Study
- Johnson Space Center

Publications:

1. Zann Gill, "A Design Method using Darwinian Principles for Collaborative Problem-Solving Environments (CPSEs), CSCL '99 (Computer-Supported Cooperative Learning) at Stanford University, December 1999, in press.
2. Zann Gill, "Guided Design of Smart CPSEs", Session on Collaborative Computing, SmartSystems2000 conference organized by Johnson Space Center, Houston Texas, September 2000.

II.B.iv.g Future Plans

- Support and develop a handful of cross-disciplinary research thrusts as pilot integration experiments involving cross-disciplinary skunk works teams.
- Establish ACASC Program Assessment metrics.
- Design the ACASC website.
- Determine program requirements for the ACASC facility.
- Design an ACASC program to include external speakers, workshops in collaboration with other NASA Centers or institutions.

- Establish external collaborations, both with other centers (e.g. JPL), with other institutions (e.g. SETI) and with research teams at other universities (e.g. Stanford, Brandeis, M.I.T.) and with industry (e.g. Sun Microsystems).
- Design a meta-level research program on collaborative design and problem-solving for the think tank and specify the design of a smart website and CPSE tools to support this research program

II.B.iv.h Problems Encountered

Funding cross-code activities requires support at a high level and takes time because multiple management structures must be enlisted and be assured that their priorities are being met.

II.B.iv.i Problem Resolution

Ongoing discussions that appear likely to have a positive resolution.

II.B.v Human-Centered Computing: NASA Astrobiology Institute

II.B.v.a Task Summary

This task is to provide leadership and expertise in the area of human-centered computing to the NASA Astrobiology Institute (NAI), focusing on its efforts to create a “virtual institute” through Internet technologies, under the heading of “user studies”. The task is focused on projects in research, design and organizational and technological strategy. It also includes monitoring and advising projects for which it does not take priority responsibility. The work also includes working collaboratively with other people in the Institute to develop a research and operational strategy

II.B.v.b RIACS Staff

Jon Guice

II.B.v.c Overview

Human-centered computing efforts have been concerned with the working relationship among NAI researchers, staff and wider communities, with a focus on the enabling capabilities of information technology. The human-centered computing task performer did the following:

- Provided information and advice in discussions concerning institutional development and information technology strategy among NAI management and members.
- Assisted in the learning and use of information technology within the NAI.
- Identified needs and opportunities for new information technology for use in the NAI.

II.B.v.d Project Description

Postdoc:

- Provide recommendations on specific data to be collected through the NAI Postdoc system.
- Provide recommendations to improve usefulness/learnability/usability of NAI Postdoc.

Field Science Studies:

- Research and write overview of the extent, range and broad characteristics of fieldwork currently conducted in the Institute.
- Conduct review of relevant research literature.
- Conduct one or more pilot studies of field expeditions.
- Develop proposal for continued research and development.
- If proposal is accepted, follow plan for research and development.

ScienceDesk:

- Act as liaison to Institute management and members
- Provide advise on user studies issues based on experience in the Institute.

II.B.v.e Accomplishments**Overall:**

Jon Guice recommended the hiring of a new NAI Collaboration Manager who would share and be able to support a human-centered perspective on the NAI. This resulted in RIACS hiring Dr. Lisa Faithorn for the position.

Postdoc:

A joint committee is being formed, following Jon Guice's recommendation, to conduct a trade study evaluating Postdoc in the context of current commercial offerings, involving the NAI, the Ames Information Technology Directorate (My Ames) and the Computational Sciences Division.

Field Science Studies:

Jon Guice wrote and submitted a paper for publication based on his research. (See below.)

ScienceDesk:

ScienceDesk is currently expected to have its funding continued and possibly increased in FY01..

II.B.v.f Publications and Presentations

Publications:

1. Guice, J., T. W. Likens and R. Duffy, "The Future of the Internet in Science", Communications of the ACM (under review).
2. Guice, J., H. Hoffower, "Science in the Wild: Technology Needs and Opportunities in Scientific Fieldwork", Computer Supported Cooperative Work (under review)

Presentations:

1. Workshop proposal accepted, with Richard Keller: Lifecycle Support for Collaborative Science, Saturday, December 2, 2000 at the ACM-sponsored Conference on Computer-Supported Cooperative Work (CSCW2000) in Philadelphia, PA USA
Workshop URL: <http://sciencedesk.arc.nasa.gov/cscw2000>
Conference URL: <http://www.acm.org/cscw2000>

RIACS Technical Reports:

1. The Future of the Internet in Science TR00-04
2. Field Science TR00-003

II.B.v.g Future Plans

Future plans are currently under discussion with the new NAI Collaboration Manager.

II.C High Performance Computing and Networking

Advances in the performance of computing and networking continue to have major impact on a variety of NASA endeavors, ranging from modeling and simulation to data analysis of large datasets to collaborative engineering, planning and execution. RIACS and NASA collaborate in several areas as described in the following sections.

II.C.i Information Physics

II.C.i.a Task Summary

This task provides leadership and expertise within NASA in the areas of physics-based information storage and processing. The focus is on the use of analytical models and simulations to describe the structure of the materials and devices being used. Emphasis is placed on understanding the physical features relevant to information storage and processing, and developing efficient algorithms based on the underlying physics. Currently, two projects in the areas of holographic optical data storage and quantum computing are being pursued.

II.C.i.b RIACS Staff

Dogan Timucin
Meric Ozcan

II.C.i.c Overview

The overall research vision is one of developing a fundamental understanding of the underlying physics for novel information storage and processing systems, and harnessing the power and potential of these systems for NASA applications. The optical data storage work has been performed with a novel organic material called bacteriorhodopsin (BR). The quantum computing work is just being initiated; the broad objective at this point is to develop and carry out a synergistic research program at the intersection of quantum physics and computer science.

II.C.i.d Project Description

Holographic storage project (technical work on this project is nearing conclusion):

- materials issues pertaining to the development of polymer-based BR films with optimized recording sensitivity and storage lifetime;
- BR film characterization in the laboratory;
- quantum-chemical modeling and genetic engineering of the BR molecule;
- systems issues concerning optimal data multiplexing schemes and achievable storage capacities and bit-error rates;

- system-level theoretical analysis, simulations, and experiments.

Quantum computing project (this project is just getting off the ground):

- literature search and networking to determine potentially ripe areas for exploitation;
- contacts with colleagues in academia and industry for cultivation of potential partnerships;
- theoretical work on quantum algorithm development for solving difficult (NP-complete) problems.

II.C.i.e Accomplishments

- Theoretical calculations, computer simulations, and laboratory experiments on the BR-based holographic data storage system were continued, and several journal papers describing this work are in press, review, or preparation.
- A proposal on quantum optimization for solving NP-complete problems was submitted to the NASA Intelligent Systems Program, and received high marks in phase 1, with phase 2 proposal currently in preparation.
- Technical partnerships with several quantum computing groups in US universities have been forged.
- Funds from the NASA Nanotechnology program have been secured for the development of an experimental component to the quantum computing research effort.

II.C.i.f Publications and Presentations

1. D. Timucin and M. Ozcan, "Information physics task review," RIACS Science Council Annual Meeting, 15 June 2000, NASA Ames Research Center.
2. D. Timucin, "Holographic optical data storage with bacteriorhodopsin," RIACS Seminar, 31 August 2000, NASA Ames Research Center.
3. D. Timucin and J. Downie, "Holographic optical data storage," to appear in the Oct./Nov. 2000 issue of the IEEE Potentials magazine.

II.C.i.g Future Plans

This task has terminated as Drs. Timucin and Ozcan have both left RIACS as of September 2000.

II.C.i.h Problems Encountered:

None.

II.C.i.i Problem Resolution

N/A

II.C.ii NGI/NREN Testbeds

II.C.ii.a Task Summary

The NREN project conducts research to enable the fusing of emerging network technologies into NASA mission applications. NREN provides a next-generation network testbed to serve as a platform for prototyping and demonstrating new applications that stress network capabilities. Emerging technologies will enable new methodologies for achieving NASA science, engineering, and education objectives. RIACS supports many of the major activities within this project.

II.C.ii.b RIACS Staff

Marjory Johnson
Jerry Toung

II.C.ii.c Overview

The objective of the NREN Project is to research and integrate advanced networking technologies to enable emerging NASA applications that stress high-end networking capabilities. The NREN testbed is a next-generation network testbed that peers with NGI testbeds sponsored by other Federal agencies and with the university-led Internet2 testbed to provide a nationwide network testbed for conducting network research and demonstrating revolutionary applications. RIACS provides support for the NREN project at NASA Ames, including conducting basic networking research, participating in projects to develop new networking technology and revolutionary network applications, and assisting with software engineering and network performance engineering. For more information about the NREN Project see <http://www.nren.nasa.gov>.

II.C.ii.d Project Description

M. Johnson is NREN Associate Project Manager. J. Toung is a member of the NREN applications and research group, specializing in network software engineering. Components of the RIACS task include assisting in the formulation of NGI/NREN projects, participating in specified research projects for the development of new networking technology, interfacing with the university research community, participating in development of revolutionary network applications, and publishing and presenting results at conferences.

II.C.ii.e Accomplishments

Gigabit Networking Workshop

NREN hosted a workshop entitled "Gigabit Networking: The End-to-End View" in August 2000. The objective of the workshop was to determine the status of gigabit networking to the desktop, achieve consensus among the Federal agencies on remaining challenges, and establish roadmaps for demonstrating at least 10 gigabit applications by the end of the NGI program in September 2002. A highlight of the workshop was demonstrations of seven high-bandwidth applications representing the

efforts of several Federal agencies and the Internet2 organization. Three of these demonstrations achieved between 200 and 250 Mbps. Application areas addressed during workshop breakout sessions included teleseminars/telemeetings, models in real time, huge databases, and remote instrumentation; technology areas included gigabit testbeds, platforms, measurement, and middleware/integration.

M. Johnson helped to organize and conduct the workshop, to facilitate one of the breakout sessions, and to prepare the final report. This report is located at http://www.nren.nasa.gov/gn_report.html.

Network Quality of Service Monitoring

J. Toung developed software for a network monitoring tool called PCMon. PCMon measures throughput of individual traffic flows, in contrast to traditional tools which measure aggregate bandwidth. Hence, PCMon enables measurement of the effectiveness of various approaches for achieving network Quality of Service, e.g., assigning preferential treatment to specified traffic flows across a network. PCMon was successfully demonstrated in September 2000, measuring best-effort traffic and preferential traffic between three nodes on NREN: NASA Ames Research Center, NASA Glenn Research Center, and the Chicago STARTAP (a network exchange point).

Project Support

- M. Johnson helped develop NREN application demonstration for SC99.
- M. Johnson assisted in preparation of revised NREN Project Plan and preparation of HPCC Independent Annual Review material.
- M. Johnson is member of HPCC Application Integration Management team, to coordinate application activities within all the HPCC projects.
- M. Johnson is member of LSN Network Research Team, to coordinate research activities among the Federal agencies participating in the Next Generation Internet initiative.

University Collaborations

M. Johnson manages NREN research grants to universities, working with the PIs to integrate their research with on-site NREN activities. Some highlights of these grant activities include:

- **UIUC.** Professor Klara Nahrstedt at the University of Illinois - Urbana, Champaign, is PI of a grant entitled "QoS Programming and Development Environment." The objective of this project is to develop adaptive QoS middleware to enable multimedia applications to maintain acceptable performance while adapting to the availability of system resources. Under the NREN grant, the UIUC team validated their middleware approach with the Omni-directional Distributed Visual Tracking Application in their lab LAN environment. One of Professor Nahrstedt's students visited NASA Ames last spring to experiment with their adaptive middleware in a WAN environment, using the NREN testbed. The future focus of this project is development of general middleware framework to support the development of multimedia

applications with QoS as an integral part of the application. Application of adaptive QoS middleware to selected NASA mission applications is a key element of the NREN research program. M. Johnson coauthored an article highlighting Professor Nahrstedt's research, "Multimedia applications fly with new software," for the Insights magazine (published by the NASA High Performance Computing and Communications Program), summer 2000.

- **UC Davis.** Professor Matt Bishop, UC Davis, presented a seminar at NASA Ames on "Denial of Service: Old Problem, New Approaches," April 2000, discussing results obtained under an NREN grant.
- **Georgia Tech.** Hybrid networking protocols (modifications of TCP/IP) developed under an NREN grant at Georgia Tech were tested over the ACTS satellite in conjunction with CSOC personnel.

Other Activities

- M. Johnson chaired technical paper session at SC99 conference, November 1999.
- M. Johnson served on NSF Travel Grant Committee to select students to receive financial assistance to attend Infocom 2000, March 2000.
- M. Johnson participated in the USRA Educational Technology Workshop, "IT in the Service of Education," April 2000. M. Johnson facilitated breakout group on Distance Learning.
- M. Johnson chaired panel to review networking proposals for the High Rate Data Delivery thrust of the NASA program on "Advanced Cross Enterprise Technology Development for NASA Missions," May 2000.
- M. Johnson was member of program committee for IFIP Networking 2000 Conference, May 2000.

II.C.ii.f Publications and Presentations

1. Marjory Johnson, Matthew Chew Spence, and Lawrence Chao, "Using the NREN Testbed to Prototype a High Performance Multicast Application," Proceedings of SC99. Paper also published in the NASA Science Information Systems Newsletter, March 2000 (<http://www-sisn.jpl.nasa.gov/ISSUE55/issue55home.html>) and as RIACS TR 00.01.
2. Marjory Johnson and Richard desJardins, "Bridging the Gap from Networking Technologies to Applications," High Performance Computing and Communications Program/Computational Aerosciences (HPCC/CAS) 2000 Workshop, February 2000 Also published as RIACS TR 00.02.
3. Marjory Johnson presented talk "NREN Hybrid Network Applications" at 14th Annual IEEE Computer Communications Workshop, October 1999.

II.C.ii.g Future Plans

- Networking technologies that will be the focus of NREN activities next year include gigabit to the desktop, QoS and QoS middleware, hybrid networking, transfer of multicast technology to NASA operational networks, and measurement and monitoring of different classes of traffic flows.

- NREN grant activities will focus on QoS adaptive middleware.
- Future PCMon activities include determining how many individual traffic flows can be measured simultaneously and scaling PCMon to OC-12 (622 Mbps) rates.
- J. Toung will modify 3D visualization software developed for the Mars Rover Project, to enable interactive use of the software by clients located at remote sites, e.g., multiple NASA centers.

II.C.ii.h Problems Encountered:

None

II.C.ii.i Problem Resolution

N/A

II.C.iii ARCLAN 2000**II.C.iii.a Task Summary**

Perform studies and provide recommendations pertaining to the security, design, implementation, and operation of advanced networks in a distributed user environment.

II.C.iii.b RIACS Staff

David L. Gehrt

II.C.iii.c Overview

The Ames Research Center Local Area Network (ARCLAN) has been a collection of individual networks routed over a single FDDI backbone, with a security policy that allows access to all of its system from any system on the Internet. The primary activity of the Ames Networking group this year has been the conversion of the Ames Research Center's Local Area Network. This conversion will result in three separate backbone segments. These backbone segments are private, public and open. Each backbone has a different security policy allowing different access methods via firewalls and for the most secure network, the private, the access policy requires VPN for access from systems external to that network.

II.C.iii.d Project Description

This task was to assist the Ames Computer Security group in the development of the new security policies as they relate to the provision of Domain Name Service to the uses of the ARCLAN while hiding information about the private network from users external to AMES.

II.C.iii.e Accomplishments during FY1999:

- Experimented with Firewall systems and their associated rule sets in a private network in aid of the Ames firewall security systems:

- Maintained the security of the Authoritative DNS servers so as to provide continuous authoritative name service for users of Ames systems free of successful network attack.
- Established a centralized RDBMS archive of attempts to obtain unauthorized access to all the systems for which I am responsible and unauthorized zone transfers from the Ames authoritative name servers.
- Designed an approach for providing appropriate and secure DNS service for Ames as it transitions from a single routed network to three networks with different access and security policies which affect provision of DNS service.
- Participated meetings conducted to perfect the design and implementation of the new Ames Research Center Local Area Network.

II.C.iii.f Publications and Presentations during FY1999:

None.

II.C.iii.g Future Plans:

- Continue to log attempts to breach the security of the Ames Authoritative master and slave name servers and other system which I am able to monitor.
- Complete the implementation of a RDBMS based data management system for the storage of data for the generation and the generation of DNS tables. This will include evaluation of new features coming into the RFCs specifying DNS services and implementing those required at Ames.

II.C.iii.h Problems Encountered:

None.

II.C.iii.i Problem Resolution

N/A

II.D Applications of Information Technology

In addition to the areas of research outlined above, RIACS scientists and visitors have collaborated with NASA researchers in an interdisciplinary context to apply (and advance) information technology in a number of application domains, as described in the following sections.

II.D.i Collaborative Virtual Environments for Medical and Scientific Imaging

II.D.i.a Task Summary

Development of advanced 3D reconstruction and visualization techniques for cell biology and medical research, and collaborative virtual environments for interactive data analysis. This is a multi-project task oriented towards creating virtual reality technologies associated with biological models. Projects in 1999 included: High bandwidth distributed imaging, multiresolution data display, Wide Area Telemedicine, Distributed Virtual Environments, and 3D Image segmentation (CT, MRI, and Ultrasound) and reconstruction.

II.D.i.b RIACS Staff

Xander Twombly
Andreas Frank
Rei Cheng

II.D.i.c Project Description

- Multiresolution representation and display of complex 3D surface models. Multiresolution display allows the software to automatically adjust the modeling fidelity to maintain interactive display rates in a virtual environment.
- Real-Time linkage of 3D scenegraphs in multiple virtual environments. Provides the basic connectivity between virtual environments in a collaborative setting.
- High bandwidth image replication protocol. Used to leverage the rendering capabilities of a graphics supercomputer such as an SGI Onyx2 Infinite Reality2 system.
- 2D Ultrasound segmentation for the analysis and measurement of heart valve defects.

II.D.i.d Accomplishments

Virtual Collaborative Clinic v1.0 was completed and field-tested in FY2000. The following components were functional in the demonstration:

- Multiresolution display – two resolutions per object. The display system toggled between the low-resolution representation during manipulation of the object, and the high-resolution image for static display.
- Collaborative environment – using the World2World toolkit from Sense8 Inc. created a method for automatically analyzing and linking the objects in a scenegraph between all virtual environments participating in the collaboration.
- Remote display server – created an encoding protocol for capturing the display of the virtual environment on a graphics supercomputer and transmitting the images to all systems in the collaboration via the IP multicast protocol. This system stressed the high bandwidth capabilities of the next generation Internet and contained tuning control to account for network bottlenecks.
- Developed a segmentation method for use with Ultrasound data based on a modification of the Metropolis algorithm to aid in the identification of heart valve defects. Subsequent images were used in the Virtual Collaborative Clinic demonstration.

II.D.i.e Publications and Presentations

- Public demonstration of the VCC system on May 4th, 1999. The program was used to link physicians at ARC, Stanford University Hospital, Salinas Valley Memorial Hospital, Cleveland Heart Clinic, and the Navajo Nation health clinic at Shiprock, New Mexico via satellite.
- Awarded NASA Software of the Year runner-up, 1999.
- Submission of 3 patent applications for software components used in the VCC system.

II.D.i.f Future Plans

The focus of the Center for Bioinformatics is shifting from straight visualization to a more interactive technology. Leveraging the previously developed virtual reality environments, we are beginning to develop a simulation engine for real-time interactions with dynamic 3D models. In particular, we are developing a finite element-based simulator of soft tissue dynamics for use in simulated surgery. The surgical tools will be used in the development of a virtual glovebox (the glovebox workstations to be used on the International Space Station for biological experiments), designed to aid in the training of astronauts in animal surgery. The virtual glovebox will comprise an immersive environment of the same physical dimensions as the real glovebox, a series of force-feedback devices to provide realistic “feel” of the objects in the box, and a variable gravity to simulate all conditions under which the box may be used (terrestrial, zero gee, and centrifuge simulated gravity).

II.D.i.g Problems Encountered

None.

II.D.i.h Problem Resolution

N/A

II.D.ii Integrated Human/Robotics Exploration & Astrobiology

II.D.ii.a Task Summary

Increase USRA participation in the planning and execution of the Integrated Human/Robotics Exploration Program, assist in the establishment of a HEDS Human Exploration Science Community to facilitate greater academia involvement in HEDS exploration efforts, and support the formulation, planning and advocacy of the Astrobiology Program.

II.D.ii.b RIACS Staff

Lewis L. Peach, Jr.

II.D.ii.c Overview

There is a growing awareness that the integration of human exploration and robotics space sciences goals and objectives will result in a stronger, more comprehensive and productive exploration program that will lead to a time-phased, balanced set of objectives to drive future robotics missions and enable human exploration beyond low Earth orbit. This requires the collaboration of two formally somewhat diverse communities, in the development of an integrated set of objectives and requirements, and in the participation of a process to implement these requirements in the Integrated Mars Exploration Robotics Program. The Astrobiology Program further provides an overarching and integrating theme of this research as it relates to the questions of the possibility of life, past or present, elsewhere in the Universe, and in the possibility of sustaining human life in Space.

II.D.ii.d Project Description

- Co-Lead of HEDS '03 A/O Process for Mars Surveyor Program
- Co-Lead of extended definition period to further refine above instruments
- Member of various Mars Architecture Development Committees
- Member of International Mars Exploration Working Group (IMEWG)
- Member of Mars Exploration Program Analysis (Advisory) Group (MEPAG)
- Member of NASA Mars Integrated Program Team (IPT)
- Member (ex-officio) of initial Mars '03 Program Science Group (PSG)
- Member of the Mars '01 Program Science Working Group
- Provided Oversight of the implementation of the HEDS OSF '01 Instruments
- Member (ex-officio) of ASI (Italian) '03 A/O Peer Review Process
- Co-lead in the development of a program to effect collaboration between Russia and USA on Human Exploration

II.D.ii.e Accomplishments

- Successfully completed '03 A/O Process, selecting highest quality scientific flight investigations for this mission, in the areas of Radiation, Environmental and Biological Measurements and in in-situ R&T verifications experiments with significantly greater University (all PI's were from academia) involvement than in the previous mission.
- Oversaw successful completion and flight qualification of the '01 Mars Robotics Mission HEDS Instruments.
- Initiated a series of workshops and technical exchanges between the Russian Space Agency and NASA leading to an understanding of the two countries different approaches to human exploration and facilitating collaboration in these efforts.
- Co-chaired a technical session at a major Mars Architecture Development Workshop at LPI to provide a forum to introduce new and innovative ideas that could significantly impact the Mars Exploration Program, resulting in a number of concepts that have been adopted by the Program, including the development of a 'Digital Mars' database that would provide the community with a configuration controlled, state of the art and science understanding of all that is known about Mars at any given inquiry.
- Participated in, and helped facilitate, an advisory process to establish an integrated set of robotic science and human exploration goals, objectives and investigations which are framing the robotic exploration of Mars for the next two decades.
- Served as a member of the NASA Astrobiology Council, and assisted in the formulation and development of the Astrobiology Program, including providing personal leadership in the advocacy to establish a Computational Astrobiology Initiative, and Flight Program elements.
- Co-Led the successful effort to integrate HEDS, Space Science, Astrobiology and ASI objectives in the development of the Mars Organic Detector Flight Experiment for the Mars Robotics Program.
- Recipient of NASA Group Achievement Award for the Astrobiology Program.

II.D.ii.f Publications and Presentations

Co-authored various Proceedings, Workshop Reports, and Requirements Documents resulting from the above activities.

II.D.ii.g Future Plans

Continue these tasks as initiated this past year, with greater emphasis on: 1) the development of a HEDS Science Community (initial Workshop planned for January '01); 2) stronger peer review processes (ongoing); and, 3) NRC review and prioritization of the integrated set of exploration requirements (established process to conduct this effort with the NRC for 2001).

II.D.ii.h Problems Encountered:

Mars Robotics Program re-planned following loss of Mars Climate Orbiter and Mars Polar Lander in 1999, resulting in loss of near-term flight opportunities for instruments selected for the '01 and '03 Mars Mission opportunities.

II.D.ii.i Problem Resolution

Participating in the reformulation of the Mars Exploration Program, overseeing completion of the various technical efforts to prepare for future flight opportunities, and continuing the development of a HEDS Science Community and incorporating these efforts with the integrated Human /Robotic Exploration and Astrobiology Programs.

II.D.iii ASRS – Aviation Safety Reporting System

II.D.iii.a Task Summary

The primary activity of this task is to support the NASA Aviation Safety Program (AvSP) and related international aviation safety liaison efforts. The objective of the research are to provide proactive risk assessment, safety economics analysis, international perspectives, and human factors expertise in support of the aviation safety program and system analysis team.

II.D.iii.b RIACS Staff

Matthias Schmidlin

II.D.iii.c Overview

The AvSP was established in 1999 by the National Aeronautics and Space Administration (NASA) with the goal of reducing the rate of fatal accidents by a factor of 5 by the year 2007 and by a factor of 10 by the year 2022. The program is integrated with complementary research activities within the Federal Aviation Administration (FAA), and industry partners in the aviation community.

In order the lessen the likelihood of aviation accidents, the AvSP is moving in the following directions:

- Shift the aviation safety paradigm away from reactive accident/ incident totals/ analysis towards proactive risk assessment and management.
- Help/ guide GAIN Government Support Team to inventory analytical tools, methods and sharing initiatives around the world and coordinate with these organizations efforts with the aim to inform airlines and sharing system operators about available options.
- Develop common terms, definitions, and taxonomies for aviation accident/ incident reporting systems to enable worldwide coordination and focus on common safety agendas.
- Development and implementation of an international AvSP coordination plan.
- Incorporate cost-benefit perspectives and developments into aviation safety.
- Provide added insight into airline operations, safety philosophies, and economical-constraints.

- Provide a fresh understanding of the insurance/ economic factors that can lead to erroneous interpretation of accident/ incident statistics and recommend better measures of system safety.

For more information:

<http://avsp.larc.nasa.gov>

II.D.iii.d Project Description

Tasks related to NASA AvSP level 1 office

- Member/ Independent assessment of the NASA Safety Assessment Paradigm Shift –SAPS team. Help shift the aviation safety paradigm away from reactive accident/ incident totals/ analysis towards proactive risk assessment and management.
- Co-chair of Global Analysis and Information Network (GAIN) WG – B & C¹. Help/ guide GAIN Government Support Team to inventory analytical tools, methods and sharing initiatives around the world and coordinate with these organizations/efforts with the aim to inform airlines and sharing system operators about available options.
- Member of the CAST/ICAO Common Taxonomy Team²
Help to develop common terms, definitions, and taxonomies for aviation accident/incident reporting systems to enable world-wide coordination and focus on common safety agendas
- Facilitate NASA's Aviation Safety Program's International leverage
Assist NASA's Aviation Safety Program in the development and implementation of an international AvSP coordination plan.

Tasks related to NASA AvSP level 2 & 3 office

- Development of better cost/benefit analyses for safety interventions and socio economic impact of public perception of aviation safety risk
Update AvSP on aviation safety cost-benefit perspectives and developments, e.g. DESIRE.
Provide support to the planned NASA/ NLR cooperation in related domain (ASTER).
- Facilitate coordination of international safety data collection efforts with similar domestic NASA/FAA activities.
Provide the AvSP with added insight into airline operations, safety philosophies, economic-constraints(e.g.BASIS).
- Conduct periodic "brown-bag" seminars for ARC staff on a selected range of topics.

¹ Initiated by the Federal Aviation Administration (FAA) in May 1996, GAIN is a concept for worldwide collection, analysis and dissemination of safety information to help reduce aviation accidents.

² Initiated by the Commercial Aviation Safety Team and the International Civil Aviation Organization on February 2nd 1999.

Provide the AvSP with a fresh understanding of the insurance/ economic factors that can lead to erroneous interpretation of accident/incident statistics and recommend better measures of system safety risk.

- Provide presentation to ARC AvSP community
Provide ARC AvSP community with an introduction to Matthias Schmidlin highlighting the background in aeronautical engineering, technology management, economic aspects of organizational aviation safety, and experience in confidential airline safety reporting systems and Airbus Crew Resource Management.
- Conduct PhD at the University of Manchester,
Continue PhD research and peruse empirical survey aimed at identifying the risk attitudes and perceptions of the travelling public as a function of national culture in order to identify the likely consequences of unsafe acts (aviation accidents or incidents) on consumer behaviour.

II.D.iii.e Accomplishments

- Member/ Independent assessment of the NASA Safety Assessment Paradigm Shift –SAPS- team.
 - Started support task in shifting the aviation safety paradigm away from reactive accident/incident totals/ analysis towards proactive risk assessment and management.
- Co-chair of Global Analysis and Information Network (GAIN) WG – B & C³.
 - Guided GAIN Government Support Team to identify, evaluate and inventory analytical tools, methods and sharing initiatives.
 - Fourth GAIN world conference.
 - Provide one of the two key address on economical benefits of airlines safety programs.
 - Present “Gain Working Group B: Activities and Products”.
 - Chair of the Implementation Workshop on Analytical Methods and Tools.
- Member of the CAST/ICAO Common Taxonomy Team
 - accident/incident reporting systems.
 - Participated to last working group meeting in ISPRA, Italy.
- Facilitate NASA’s Aviation Safety Program’s International leverage
 - Started the development and implementation of an international AvSP coordination plan.
- Conduct PhD at the University of Manchester.
 - Continuing the PhD research.
 - Finalized the development of survey questionnaire and survey methodology.

³ Following discussions with Steve Pinches, IAPA’s Managing Director and Dr. Hans Krakauer, Senior Vice President Aviation, IAPA expressed extremely high interest in the “never before done” survey and underlined its willingness to support the study. Supporting the development of common terms, definitions, and taxonomies for aviation

- Obtained industry support on public perception survey.

II.D.iii.f Publications and Presentations

1. Matthias J. Schmidlin. "Justifying Safety Dollars: Some thoughts on Accident Statistics and Accident Cost". Fourth GAIN World Conference, June 2000, Paris France.
2. Prof. Jim Luxhoj & Matthias J. Schmidlin. "GAIN Working Group B (WGB): Analytical Methods and Tools Review". Fourth GAIN World Conference, June 2000, Paris France.
3. Matthias J. Schmidlin. "Justifying the Cost of Safety: An Aviation Industry perspective". 2nd Nuclear Power Senior Executive Seminar, October 2000, Paris, France.

II.D.iii.g Future Plans

- Accomplish tasks as listed above.
- Publish at least two papers (preferably jointly with NASA staff) related to the ongoing PhD work in major scientific journals such as Cognition, Technology & Work (Springer).
- Give at least two presentations at major conference/ seminars on topics of interest to NASA
- Complete first draft of entire PhD theses.

II.D.iii.h Problems Encountered

None

II.D.iii.i Problem Resolution

N/A

II.D.iv AvSP Information Sharing

II.D.iv.a Task Summary

Serve as member of the Earth Science Technology Office inter-center team. Develop technology roadmaps and plans to support mid and far term earth science mission requirements.

II.D.iv.b RIACS Staff

Walter Brooks

II.D.iv.c Overview

The earth Science enterprise at HQ has consolidated all of its technology funding under a level II office located at GSFC. This office seeks to use agency wide expertise to staff the development and implementation of technology programs that support. The task involves both day to day support of the

Information Technology group within this office as well as representing the center as part of the ESE Technology Strategy Team.

II.D.iv.d Project Description

The goal of this project is to insure that NASA Ames IT technology expertise is brought to bear on high level planning as well as specific technology projects initiated by the Earth Science Technology Office. The task requires weekly support of ESTO staff meeting, AIST staff meetings and biweekly ESTO TST meetings.

II.D.iv.e Accomplishments

- Lead team of NASA and non NASA personnel that evaluated proposals to the AIST NRA for Space based IT technologies
- Developed and presented the results of the evaluation to senior NASA HQ staff to be used as part of their decision making process in developing a portfolio of research projects
- Led team of NASA and Non-NASA scientist and engineers in the development of technology roadmaps for long term storage and archiving.
- Participated in the Earth science Enterprise Workshop on technology requirements in support of the 20 year Vision including the development of the sensor and supporting systems for next generation Data Information Systems
- Supported the New DISS program through reviews of architecture and technology studies
- Arranged for visits and presentations of Vision and NEWDISS architecture to the Ames IT community
- Participated in and supported efforts to help define the long term Computational Sciences Division strategy

II.D.iv.f Publications and Presentations

None

II.D.iv.g Future Plans

Continue to support the HQ Earth Science Enterprise Technology Office. this includes participation and panel leadership at road mapping workshops, outreach to industry, universities and other agencies, development of mid and long term strategies based on Earth Science Mission Requirements and ongoing analysis of technology gaps. Day to day work includes representation of Ames at Weekly staff meetings for the ESTO office and the AIST group within ESTO as well as monthly TST telecons and quarterly meetings. Serve as coordinator and focal point for the Technology Strategy Team Workshop at Ames in Feb of 2001.

II.D.iv.h Problems Encountered:

None

II.D.iv.i Problem Resolution

N/A

II.D.v Integrated Thermal Protection**II.D.v.a Task Summary**

The goal of this task is for USRA to establish a cooperative research program with the Thermal Protection Systems development and Information Systems/Nanotechnology research groups at Ames that will lead to the developments of Adoptive Intelligent Thermal Protection Systems for future Space Transportation Vehicle systems. This effort will define and evaluate potential approaches to detecting diagnosing and repairing thermal protection systems damage on Reusable Vehicles and HEDS Space Transportation systems. It will also provide consulting on thermal protection materials and systems and other relevant technical issues.

II.D.v.b RIACS Staff

Howard Goldstein

II.D.v.c Overview

The development of future Space Transportation Vehicles is dependent on the development of reliable thermal protection systems that require minimum refurbishment and repair. Instrumentation that can detect, diagnose and report defects in a timely manner is required. Repairs must be performed easily and quickly on the ground and preferably automatically in Space. This research program will try to identify and develop technologies to fill these needs

II.D.v.d Project Description

- Evaluate capabilities and the potential pay-off of coupling information Systems technologies with Thermal Protection System technologies and Nanotechnology to develop Adaptive Intelligent TPS (aiTPS). Define possible approaches to detect, diagnose and repair TPS damage due to impact from micrometeorites and other on orbit debris..
- Define and investigate new concepts for aiTPS including self-healing heat shield materials, novel approaches to instrumentation and new material/instrument combinations that will diagnose and self-repair after damage from any source.
- Participate in technical reviews for Code AS and AX and other NASA organizations and programs as requested. Consult with these organizations on program related to atmospheric entry technology.

II.D.v.e Accomplishments

- Participated in the Stardust Space Craft thermal protection system review
- Initiated investigation of the state of the art of Adoptive Intelligent TPS
- Performed investigation of the status of Russian/European Inflatable reentry vehicle technology (IRDT) and developed contacts with organizations in the United States that are developing similar technologies.

II.D.v.f Publications and Presentations

None

II.D.v.g Future Plans

- Continue to investigate approaches to developing aiTPS and self healing TPS concepts
- Continue and complete participation in Stardust Project Review
- Continue studies of flexible/inflatable thermal protections systems

II.D.v.h Problems Encountered:

None

II.D.v.i Problem Resolution

N/A

II.E Visiting Students and Scientists

A major contribution made by RIACS is the sponsoring and hosting of visiting students and scientists from universities and industry.

II.E.i Summer Student Research Program (SSRP-2000)

Eleven undergraduate and graduate students, from universities across the country, were selected out of over 80 applicants in this, the inaugural year of the program. They spent 10 weeks at Ames, teaming with NASA scientists on research projects in a variety of areas in information technology, including automated planning and scheduling, natural language understanding, model-based autonomy for spacecraft and rovers, automated software synthesis and verification, visualization and collaborative virtual environments for medical and scientific imaging, quantum computing, and collective intelligence.

Toward the end of the summer, students were invited to submit a proposal to continue their research at their universities on their return. Three of these students, Brian Murphy, Ralph Benzinger, and Adrian Agogino, were chosen to receive these continuing research awards.

The following are descriptions of the research projects conducted by the SSRP participants.

II.E.i.a Controlling Multi-agent Systems in a New Way Adrian Agogino of University of Texas, Mentored by Kagan Tumer

This summer my mentor Kagan Tumer had me work on an exciting project where we designed machine learning algorithms that could be used to control multiple autonomous agents. We did this in the context of controlling multiple Mars rover so that they would work together to try to gather the most possible information. We felt that having multiple Mars rovers compared to one rover was useful as they share many of the benefits of other multi-agent systems, including robustness against catastrophic failures and greater ability to take risks in hazardous environments. We wanted to approach this task of controlling multi-agent systems in a new way that was less brittle than traditional rule based approaches yet could be applied to larger domains than many model-based approaches. Previous work done at NASA Ames with "Collective Intelligence" (COIN) attempts to deal with the problem of having multiple agents use reinforcement learning algorithms in such a way that they can learn in a dynamic environment, while at the same time work for a common goal. The major principle of COIN theory is that it gives the learners the appropriate reinforcement so that they learn a task that is both easily learnable and helps accomplish the common goal. My task was to find a way of using COIN theory to make a class of learning systems that could be applicable to situations relevant to Mars rovers.

II.E.i.b Rover Control as a Markov Decision Process Dan Bernstein from University of Massachusetts, Mentored by Rich Washington

This summer, I was assigned to work on the Advanced Autonomy for Rovers project. An autonomous planetary rover can use data from its sensors and information about the goals of the mission to make decisions on its own, rather than waiting for commands from Earth. Because communication with Earth consumes resources such as time and power, less communication can lead to increased productivity. One way to design a more autonomous rover is to explicitly program a decision-making strategy for the rover and put it on board. For simple decision making this may be a good approach, but as more factors are taken into account, it becomes difficult for us to guess what the optimal strategy should be. Sometimes it is easier to develop a model of the problem and allow the computer to automatically generate a strategy using the model. Ideally, this approach will allow us to take advantage of both human intuition and the number crunching ability of computers.

II.E.i.c Remote Agent Planner & Domain Representation

Kristin Branson from Harvard University, Mentored by David Smith

Implemented a program that converts a STRIPS domain to a Remote Agent domain by creating an attribute for each instantiation of each STRIPS predicate and allowing these attributes to take on true, false, and action values.

II.E.i.d NP-Complete Problems with Quantum Computation

Brian Murphy from Stanford University, Mentored by Dogan Timucin

The summer's research involved investigation of the following:

- Why would QC be able to solve NP-Complete problems?
- Proven result: A QC can implement any classical algorithm with same complexity.
- Therefore, we can efficiently generate an exponential number of possible solutions in polynomial time (specific example later).
- HOWEVER, measurement does not reveal an exponential amount of information.
- Proven result: Relative to an unstructured oracle, QC can at best provide a square root speed-up, not enough to efficiently solve NP-complete problems
- Therefore we MUST use structure of the problem to solve efficiently.

II.E.i.e The AutoBayes Project

Ralph Benzinger of Cornell University, Mentored by Bernd Fischer

This task involved the AutoBayes system, which employs several iterative algorithm schemata for approximating optimization problems for which no closed solution is known. The accuracy of the solutions obtained depends not only on the particular algorithm selected, but also on the convergence criteria used by that algorithm. The choice of algorithm schemata is largely predetermined by the model, but the selection of convergence criteria is open to experimentation. The goal of this research task was to enable the domain expert as the user of the system to specify customized convergence criteria that are model-sensitive but schema-agnostic. In particular, the user should be able to identify critical parameters, to comfortably select appropriate progress measures, to relate accuracy required to other model variables, and to relax the optimization problem for potential speed up. As a result of this

research we found that manual convergence control in combination with careful selection of sensible progress measures and norms greatly enhances both the reliability and the ease of use of the system.

II.E.i.f Using Statistic Matching for Cross-validation Error to Improve Generalization
Sergey Kirshner from University of CA – Irvine, Mentored by David Wolpert

This task involved exploring advanced machine learning (data mining) techniques, techniques that, if they prove useful, will have extremely broad applicability. The first task is a set of computer experimental explorations comparing two general-purpose statistical algorithms, algorithms that judge whether two data sets were generated from the same underlying probability distribution. The second algorithm explored is called "statistic matching". It is a technique for supervised learning, i.e., for learning the mapping from an input space to an output space from a set of examples of that mapping. The technique is a "meta-algorithm", in that it is a way to combine supervised learning algorithms to produce a (hopefully) better one. It is based on a completely novel approach to the combining task.

II.E.i.g Integrating NLP and Eye Tracking in Interfaces for Semi-autonomous Agents
Jason Baldrige of University of Edinburgh, Mentored by Beth Ann Hockey

Construct a prototype system that combines the eye-tracking technology developed in Code IHH and the spoken language technology developed at RIACS. Integration of these two lines of research is currently of great interest within Code IC and is to be funded as a new research effort. The initial version of the prototype is scheduled to be completed during FY00, with a more elaborate system to be developed during FY01. The system will include at least two key functionalities: activation of speech recognition through eye-gaze detection permitting completely hands free operation, and dynamic modification of recognition vocabulary in response to the users' eye movements.

II.E.i.h Iterated Forward Checking in (non-binary) CSPs
Glen Nuckolls from University of CA – Davis, Mentored by Jeremy Frank

Constraint Satisfaction Problems (CSPs) involve forward inference to reduce branching. This research considered the utility problem and the use of iterative forward checking to solve constraint satisfaction problems. The research experiments considered 3SAT and measured a number of nodes (of successful variable instantiations) in the search tree. Conclusions from research results suggest that some inference is useful beyond FC and the size of search tree seems to level off before full AC.

II.E.i.i Implementation of Haptics in an Immersive Virtual Environment
Forrester Cole of Harvard University, Mentored by Xander Twombly

This project involved the implementation of an immersive environment that combines haptic and visual stimuli. The challenges included determining how to create and maintain an effective illusion and developing and implementing an immersive workbench concept. That lead to need for calibration of the haptic device with the visual rendering and dealing with variations of the observer observing with his head fixed or head free. The results of this research are as follows:

- Demonstration software showed the effectiveness of the interface.
- A least squares calibration method proved workable, but limited.
- Head tracking proved necessary, but the magnetic hardware noisy.
- Off the shelf solutions were tested but proved insufficient.

II.E.i.j Property Specification for Java Pathfinder

Jeff Thompson of University of Minnesota, Mentored by Willem Visser

The project involves initial definition of a property specification language for Java based on several existing specification languages. The results of the exploration suggest that the appropriate path consists of the following:

- Use a full-featured specification language, for example, JML as a base.
- Add the temporal features of, for example, BSL to the language above. For semantic purposes, the expressions of the base language can be treated as state expressions in the temporal logic.
- For system properties that do not map to any code module, utilize the sequence diagrams (and potentially state machines) normally produced in the development process to generate the properties.

II.E.i.k Non-parametric State Estimation for Rovers,

Vandi Verma of Carnegie Mellon University, Mentored by Maria Bualat

This task involves the Autonomy and robotics area problem of diagnosis of hybrid systems.. The focus is on the problem of rover diagnosis since this problem was particularly troublesome when applying Livingstone to the rover. This in turn involved framing of the problem to assist us in understanding how different techniques can be applied and explored. Statistical techniques for reasoning about uncertainty has complemented the existing expertise in logic-based approach to diagnosis existing within the group.

II.E.ii Visiting Scientists' Research Project Descriptions

RIACS regularly sponsors and hosts visiting scientists from universities and industry to provide highly specialized expertise to various NASA projects. The following are descriptions of the research conducted by these visitors.

II.E.ii.a Abdellah Hadjadj, Bjorn Sjogreen, Neil Sandham, Turan Coratekin

Task Supported

Computational Fluid Dynamics – Helen Yee of NASA Ames

Research Description

Three research topics were addressed by this team:

1. Construction of stable, efficient and low dissipative high order shock-capturing schemes

2. Entropy splitting of inviscid flux derivatives for high order numerical simulation of compressible turbulence
3. Multiresolution wavelet based adaptive numerical dissipation control for high order shock-capturing schemes

Our focus is on improving the speed, accuracy, and nonlinear stability, and minimizing the use of numerical dissipation in large scale computational aerosciences, computational astrophysics and astrobiology simulations without resorting to extremely fine grids and time steps.

Accomplishments

Our recently developed class of low dissipative high order schemes requires only a 10% increase in operations count over standard second-order TVD schemes for 2-D direct numerical simulations. Studies showed that higher accuracy was achieved with fewer grid points when compared with that of standard higher-order TVD, positive, ENO or WENO schemes. The results are published in [1-3].

Publications and Presentations

1. Colloquium, Dept. of Mathematics, Florida State University, Tallahassee, March 3, 2000 (Invited Presentation with full reimbursable travel)
2. Symposium on Computational Fluid Dynamics for the 21st Century, July 15-17, 2000, Kyoto, Japan (Invited Presentation)
3. National Taiwan University, Taipei, Taiwan, July 17-19, 2000 (Three Invited Lectures with reimbursable travel)
4. The First International Conference on CFD, July 10-14, 2000, Kyoto, Japan (Contributed Paper).
5. H.C. Yee, B. Sjogreen, N.D. Sandham and A. Hadjadj, "Progress in the Development of a Class of Efficient Low Dissipative High Order Shock-Capturing Methods," RIACS Technical Report 00.11, June, 2000, NASA Ames Research Center, 2000, also, Proceedings of the Computational Fluid Dynamics for the 21st Century, July 15-17, Kyoto, Japan, Notes on Numerical Fluid Mechanics, Vieweg.
6. N.D. Sandham and H.C. Yee "Entropy Splitting for High Order Numerical Simulation of Compressible Turbulence," RIACS Technical Report 00.10, June, 2000, NASA Ames Research Center, 2000, also, Proceedings of the 1st ICCFD Conference, July 10-14, 2000, Kyoto, Japan.
7. B. Sjogreen and H.C. Yee, "Multi-Resolution Wavelet Based Adaptive Numerical Dissipation Control for Shock-Turbulence Computations," RIACS Technical Report, October, 2000, NASA Ames Research Center.

II.E.ii.b Hector Geffner

Task Supported

Spacecraft Autonomy - Nicola Muscettola of NASA Ames

Research Description

Hector Geffner got his Ph.D in UCLA with a dissertation that was co-winner of the 1990 Association for Computing Machinery (ACM) Dissertation Award. Then he worked as Staff Research Member at the IBM T.J. Watson Research Center in NY, USA, for two years before returning to the Universidad Simon Bolivar, in Caracas, Venezuela, where he currently teaches. He is the author of the book "Default Reasoning: Causal and Conditional Theories" published by MIT Press in 1992. He is interested in models of reasoning, action, planning, and learning. During his visit at Ames he discussed the HSP approach to planning with researchers in the Planning and Scheduling group, and compared it with the approach to planning applied in the Remote Agent planner.

II.E.ii.c Daniel Hammerstrom**Task Supported**

High Performance Computing – RIACS/NASA Ames

Research Description

Massively parallel VLSI architectures for intelligent systems.

The goal of this on-site research is to focus my efforts on the Associative Data Processor (ADP), a chip architecture that I am developing in the Cognitive Architecture Project, which I lead at the Oregon Graduate Institute.

Recently there have been revolutionary advances in *computational neurobiology*. In fact, I believe that the greatest result of the recent resurgence in neural network research has been the fundamental change that has occurred in neuroscience. Neuroscientists are thinking more in functional terms, and they are using sophisticated mathematical and systems analysis to understand the computation being performed by biological nervous systems. In parallel to this, silicon technology has been advancing at a phenomenal pace. We will soon have the ability to place 100s of millions of transistors on a single piece of silicon. The merging of these two technologies is creating what Andy Grove (ex-CEO of Intel) refers to as a *strategic inflection point*.

Although previous attempts at combining these technologies were premature, it is my belief that silicon and computational neurobiology will merge over the next ten years to create an extremely powerful, and radically new form of computation, which will lead to a large, new market in neuromorphic silicon for

solving a number of important problems ranging from Internet routing and content recognition to robotic control and speech processing.

The goal of the Cognitive Architecture Project, or CAP, is to derive new kinds of silicon architectures based on neurobiological models. As semiconductor technology approaches fundamental physical limits, the massive parallelism and fault tolerance of biological computing models becomes ever more appealing. In addition, there are still fundamental problems in computing which have no good solutions and which computational neurobiology may provide these solutions.

We eventually intend to create a family of commercial ICs for use in a range of ISP solutions. Tentatively we plan for the first commercial chip that will be derived from this work to be the Associative Data Processor (ADP). The ADP will implement high speed, high capacity, *best-match*, associative memory.

II.E.ii.d Mohamed Hafez

Research Description

For studying viscous flows over a train of bumps representing a general topography, as for example in the Earth Simulator Project, one has to solve a large system of equations involving a small parameter ($1/Re$). Two zones can be identified and in the outer one inviscid flow model is adequate. To take advantage of this fact, a new formulation is introduced which reduces to irrotational flow in the outer zone. Generalized Cauchy/Riemann equations, with a non-homogenous term representing the vorticity, are solved for the velocity components. The vorticity is evaluated only in the viscous flow regions using the momentum equations. The present formulation can be viewed as a heterogeneous domain decomposition method to deal effectively with viscous/inviscid interaction since communication is achieved through the forcing function and not just through the interfaces among the zones as in the standard methods. Currently, some test cases are calculated to assess the validity of this approach.

II.E.ii.e Flavio Lerda

Research Description

The main focus of the research is the application of distributed and parallel architectures in scaling up the effectiveness of software model checking. To this end a distributed version of the Java model checker (JPF) has been developed that execute on multiple SUN workstations. This work included a number of innovative extensions to the core JPF system. Current work focuses on developing a parallel version of the JPF model checker to run on a massively parallel shared memory machine (SGI Origin 2000).

II.E.ii.f Dimitris Maroudas

Research Description

In collaboration with Dr. S. P. Walch of NASA's Ames Research Center, we conducted a systematic theoretical and computational study of the mechanisms and energetics of hydrogen abstraction from the hydrogen-terminated dimerized Si(001) surface by H atoms impinging from a gas phase. These abstraction reactions were analyzed following a hierarchical computational approach that combined molecular-dynamics simulations with ab initio density functional theory calculations. For H atoms impinging at thermal energies, a new two-step abstraction mechanism was identified involving surface dihydride formation and subsequent desorption of a hydrogen molecule from the surface; at higher kinetic energies of the impinging H atoms, an athermal Eley-Rideal abstraction mechanism was found to be operative.

During his two-week visit to NASA Ames and RIACS, June 19-30, 2000, the PI (Prof. Maroudas) focused his research efforts on two tasks. The first (in collaboration with his co-PI, Prof. E. S. Aydil and their students S. Sriraman and S. Ramalingam) was analysis of the evolution of structure, morphology, and reactivity of hydrogenated amorphous silicon (a-Si:H) film surfaces grown by molecular-dynamics (MD) simulation. The second (in collaboration with Dr. S. P. Walch at NASA Ames) was the detailed analysis of chemical reactions between chemically reactive radicals, such as SiH₃, and crystalline silicon surfaces, such as Si(001), based on quantum mechanical calculations within the framework of density-functional theory (DFT); these reactions are crucial elementary steps in the growth of silicon thin films from silane (SiH₄) containing plasmas.

Specifically, the relationship between the structure, hydrogen coverage, morphology, and chemical reactivity of plasma deposited hydrogenated amorphous silicon (a-Si:H) film surfaces was investigated using MD simulations. These a-Si:H films were generated computationally by nanosecond-scale MD simulations using the silyl radical (SiH₃) as the sole deposition precursor. The corresponding a-Si:H surfaces were found to be remarkably smooth due to a valley-filling mechanism where mobile precursors, such as SiH₃ and Si₂H₆, diffuse and react with dangling bonds in the valleys on the surface. Analysis of the MD trajectories revealed that surface valleys are reactive due to the increased concentration of silicon dangling bonds and the decreased hydrogen coverage in these regions. This was the first computer simulation work to provide definitive evidence for a mechanism that has been speculated for over a decade in the experimental literature. According to our MD simulations, the previously speculated physisorbed configuration, where SiH₃ is weakly bound to the surface through an H atom, is highly unlikely to be the mobile precursor state. This work has been submitted for publication in Applied Physics Letters.

In addition, quantitative surface chemical reaction analysis based on DFT was completed for a number of reactions identified by MD simulations and further detailed study of the corresponding reaction paths was carried out by quenching the MD trajectories along the reaction paths. The analysis included insertion reactions of SiH₃ on hydrogen-terminated Si(001)-(2x1) surfaces, adsorption of SiH₃ on the pristine Si(001)-(2x1) surface, and both Eley-Rideal and Langmuir-Hinselwood pathways for abstraction of surface H atoms from hydrogen-terminated Si(001)-(2x1) surfaces. This work elucidated the corresponding reaction mechanisms and provided, for the first time, definitive answers to various proposals that were made over the past decade in the experimental literature. Part of this work

has been published in Chemical Physics Letters and other parts are in preparation for submission for publication (Publications No. 4, 9, 10, and 13 in the attached List of Publications).

II.E.ii.g Francesca Rossi

Task Supported

Soft temporal constraint reasoning

Research Description

Francesca Rossi's expertise is in the area of constraint reasoning with soft constraints. A representation of soft constraints is useful for applications, such as planning, in which certain plans can be said to be preferred over others. Soft constraints is a representation of such preferences. During her week at Ames, Professor Rossi discussed her framework for representing soft constraints with the Planning and Scheduling group, in particular, with Paul Morris, Lina Khatib, and Robert Morris. She also presented a seminar on her work to a wider IC audience.

II.E.ii.h Neil D. Sandham

Task Supported

CFD

Research Description

An entropy-splitting Navier-Stokes code, previously developed and run for turbulent channel flow, was further refined during this visit. The technique involves a canonical splitting of the Euler terms to satisfy conditions for a nonlinear stability bound. Compatible boundary schemes are also used, along with a reformulation of the viscous terms. The schemes can successfully simulate compressible turbulent channel flow, even on relatively coarse grids. The previous density equation treatment was found to be incompatible with the summation by parts (SBP) differentiation scheme for laminar flow, and is now normally turned off. For comparison, new routines with reduced order at boundaries were written. The sixth order scheme was significantly more stable with the order reduced successively to 4th and 2nd order at boundaries than the corresponding SBP scheme. To reduce truncation errors near boundaries an alternative geometrically-stretched grid was developed. Neither this, nor the other modification above were able to remove a small wiggle in the total averaged stress near the wall, which may be an unavoidable consequence of coarse grid simulations; the solution converges to the correct one as the grid is refined. High Mach number simulations (channel centerline Mach number up to 4.0) were run, although some additional dissipation was needed to integrate through the initial transients. It was not possible to simulate higher Mach numbers, perhaps due to a more extreme version of the same problem. Pushing the high Mach number limit of the code remains an issue for future investigation. A modified code was developed with no-slip adiabatic wall boundaries in two directions, remaining

periodic in the third. This was successfully applied to the Daru-Tenaud shock tube test case using an artificial-compression-method (ACM) shock and contact detector. This case will provide a challenging test for the Sjogree-Yee wavelet detector.

II.E.ii.i Sankaran Venkateswaran, Ph.D.

Research Description

Research focused on the implementation of a coupled CFD/neural network based formulation for chemical vapor deposition (CVD) reactor design and control. The model considered polysilicon deposition from a disilane/hydrogen mixture in a CVD reactor capable of accommodating a 300 mm wafer. CFD computations were used to generate deposition rate data (average and distributed), which were then used to train the neural net. In total, about 250 individual CFD computations were obtained to cover the parametric ranges of interest. The net was represented by a three-layer, feed-forward network. The trained net was then used to predict the functional behavior of the deposition rate with respect to the process variables. Additional CFD computations were used to validate the neural network predictions. Further, the research also included preliminary assessments of adapting the plasma-CVD code for space propulsion applications, such as Hall thrusters and pulsed plasma thrusters.

II.E.ii.j Simon Wildermuth, Ph.D.

Research Description

A digital, volumetric model of a rat was constructed from high resolution CT scans to create a 3D atlas of the rat's anatomy. Axial CT scans were taken along the entire length of the animal, with nominal sampling resolutions of 0.5 mm between slices. The data were combined into a single volumetric image of the animal, and used as a basis for segmentation and modeling of the anatomy. Isosurface segmentation was used to segment out bone, skin, and major organs such as heart, liver, kidney, and lungs. Extensive use of the AMIRA toolkit was used to isolate individual portions of the anatomy for segmentation, allowing distinct reconstruction bones as individual elements of the skeletal structure. Similar techniques were employed to segment and isolate different soft tissues, notably major organs and their connective systems.

The 3D models of the rat anatomy obtained from segmentation of the CT data were used in a virtual surgery system. In collaboration with the NASA-Stanford center for biocomputation, the anatomical models are used as a test data set in the development of a computer aided surgical simulator. Using force feedback devices to simulate physical interaction with the models, a system is under development to allow physicians to feel themselves cutting through the virtual objects, and practice basic surgical procedure in a virtual setting. This system will also be used to aid astronaut training in basic biological surgical procedures, a project in tandem development with the NASA Ames Center for Bioinformatics.

II.E.ii.k David Zingg**Research Description**

Prof. David Zingg visited the Algorithms and Application Group in code INA during his tenure for the summer 2000. His research included collaboration in the design, development and analysis of higher order finite difference methods for the Euler and Navier-Stokes equations. This was a continuation and culmination of research started by his group at the University of Toronto, see:

1. De Rango, S., and Zingg, D.W., "Further Investigation of a Higher-Order Algorithm for Aerodynamic Computations, AIAA 2000-0823, Jan. 2000.
2. Zingg, D.W., De Rango, S., Nemec, M., and Pulliam, T.H., "Comparison of Several Spatial Discretizations for the Navier-Stokes Equations," AIAA 99-3269, June 1999.

In addition, Prof. Zingg in collaboration with Tom Pulliam (Code INA) initiated research into "Numerical Uncertainty from Computational Algorithms", an attempt to develop a theory of error assessment and risk assessment for Computational Fluid Dynamics.

II.F Inventions

Based on the work described above as well as work performed in prior years of this cooperative agreement, the following inventions have been filed with NASA.

<u>Case No.</u>	<u>Title</u>	<u>Inventor</u>
ARC-14529-INP	IND 2.1 – Creation and Manipulation of Decision Trees from Data	Wray Buntine
ARC-141517-ICU	Remote Agent Planner/Scheduler: A System for Generating Complex	Paul Morris & Kanna Rajan
ARC-14287-1	Virtual Cutting Tool for Use With High Resolution Three-Dimensional Medical Imaging System	Steven Senger
ARC-14441-1	Method and Apparatus for Virtual Interactive Medical Imaging by Multiple Remotely-Located Users	Ian Twombly & Steven Senger
ARC-14490-1	Livingstone: A System for Automated Diagnosis and Discrete Control of Complex Systems	Barney Pell, Pandu Nayak & William Millar
ARC-14489-1	Ultrasound Segmentation and Echo-Cardiogram Using Stochastic Relaxation	Esfandiar Bandari
Table 1: Invention Disclosures		

III Seminars and Workshops

RIACS holds both regularly scheduled and special seminars which bring in speakers from the Ames scientific community, University researchers, and High-tech industry researchers. These seminars provide an excellent forum for education and collaboration with leaders in the field.

RIACS also holds workshops which address computer science issues in depth by bringing together NASA and RIACS scientists with leading researchers in the field from Universities and industry.

III.A Dates, Speakers, and Abstracts of RIACS Seminars

September 28, 2000: Hector H. Gonzalez-Banos, Stanford University, CS Robotics Lab, Motion Strategies for Autonomous Observers

This talk presents techniques to generate motion strategies for a new class of autonomous agent called the Autonomous Observer. An autonomous observer (AO) is a physical agent performing high-level vision-oriented operations, such as tracking a moving target or building maps of an environment. What distinguishes an AO from other autonomous agents is the use of its sensors as end-effectors. In traditional robotics, sensing is a means to an end --- e.g., sonars are used for collision avoidance in robot navigation, cameras are used to recognize individual parts in assembly tasks, and proximity sensors enhance grasping operations. For an AO, on the other hand, information gathering is the goal. Building models of objects and/or environments, detecting faults in large structures, tracking moving targets, or performing surveillance operations, are all examples of tasks for AO systems. One characteristic feature of all AO-based systems is the need to satisfy geometric visibility constraints while planning and executing motions. Although similar problems have been studied in other contexts, the material presented in this talk focuses on the fundamental motion planning problem rather than on the vision or sensing aspects: Which locations must be visited by a robot to efficiently map a building? How must a robot proceed in order to explore an environment? What motions will keep a target in view? How can we reduce the number of sensing operations? To answer these questions we propose randomized art-gallery and next-best-view algorithms. These algorithms have been integrated in robot systems and experimental results will be described. hhg@robotics.stanford.edu

Sept. 14, 2000: Robert Eklund, Telia Research & Linköping University, Disfluency Studies at Telia Research

Automatic speech recognition (ASR) has reached a level of reliability that allows use in commercial applications. However, not all problems with regard to ASR have been solved, and one particular field that remains to be solved is the handling of 'disfluencies', typical of spontaneous speech, i.e., filler words like "eh", "uh", unfilled pauses, repeated words, truncated words, mispronunciations, prolonged segments and other hesitation phenomena. This talk gives an introduction to ongoing disfluency studies at Telia Research, Sweden's biggest telecom operator. The talk will cover methodology and data collection as well as different speech corpora. Results from different corpora are presented, and comparisons are made between human-machine interaction using different modalities e.g. telephone

conversations vs. graphical interfaces. Some results from cross-linguistic studies (Swedish vs. American English; Swedish vs. Tok Pisin) are will also be presented.

Sept. 14, 2000: Lise Getoor, Stanford University, Learning Probabilistic Relational Models

A large portion of real-world data is stored in commercial relational database systems. In contrast, most statistical learning methods work only with "flat" data representations. Thus, to apply these methods, we are forced to convert our data into a flat form, thereby losing much of the relational structure present in our database. I'll describe recent work on probabilistic relational models (PRMs), and describe how to learn these models directly from structured data. PRMs allow the properties of an object to depend probabilistically both on other properties of that object and on properties of related objects. PRMs are more expressive than standard graphical models, such as Bayesian networks, and I'll show how to extend well-known statistical methods for learning Bayesian networks to learn these models. I'll describe a range of learning algorithms, beginning with methods for learning models with uncertainty over attribute values, next incorporating class hierarchies, and finally learning algorithms that handle structural uncertainty. As we go along, I'll present experimental results on both real and synthetic data. Joint work with Nir Friedman, Daphne Koller, Avi Pfeffer and Benjamin Taskar

August 31, 2000: Dogan A. Timucin, RIACS-NASA Ames, Holographic Optical Data Storage with Bacteriorhodopsin

The holographic storage paradigm has been pursued for nearly four decades as an alternative to traditional memory technologies. This quest has followed a cyclical path between vitality and dormancy over time - a typical symptom of the disease of fashion in science: interest was fueled by the promise of unprecedented storage capacities and access times on one hand, while real progress was hindered by the lack of many enabling technologies on the other. In this (tutorial) talk, I will start by reviewing the principles behind holography and optical information processing. I will then describe holographic optical data storage architectures and materials, and discuss the current status of research and development efforts in this field. Finally, I will highlight a promising bio-optical material, bacteriorhodopsin, with which we have worked recently toward building a holographic storage test-bed for NASA applications.

August 17, 2000: SSRP 2000 "Rover Control as a Markov Decision Process", Dan Bernstein, University of Massachusetts; "Property Specification for Java Pathfinder", Jeff Thompson, University of Minnesota; "Integrating Natural Language Processing and Eye Tracking in Interfaces for Semi-autonomous Agents", Jason Baldrige, University of Edinburgh; "Non-parametric State and Fault Identification for Rovers", Vandi Verma, Carnegie Mellon University; "Implementation Issues with Haptics in an Immersive Virtual Environment", Forrester Cole, Harvard University; "Incremental Reasoning in (non-binary) CSPs", Glen Nuckolls, UC Davis

Students discuss the problem or task(s) they are working on as participants in the SSRP, the goals to be accomplished with this work, the approach taken to solve the problem or perform the tasks, the current status of the work and possible interesting future extensions to this work (part II).

August 14, 2000: Jim Hieronymus, Gothenburg University, Spoken Dialogue Management using Dialogue Moves and Information States

Spoken dialogue systems which closely model human-human dialogues will be easy to use and more readily accepted by the general public. The EU Siridus project systems under development by Gothenburg University, SRI Cambridge, Telefonica and University of Seville attempt to model how humans behave in task oriented dialogues. Given a task domain, it is possible to define a set of dialogue moves which cover all of the utterances from a database of human-human dialogues on the same task. Information states provide a framework for implementing plans and flexible dialogue analysis to determine the present speaker move and the next move by the system. Example dialogues from the travel information domain will be shown, dialogue moves and information state structures used to manage a very natural, mixed imitative dialogue will be discussed. A new asynchronous implementation of the dialogue manager has just been implemented which allows processing of acknowledgement moves during system speech will be discussed and perhaps a demo will be shown of this system working.

August 11, 2000: Francesca Rossi, University of Padova, Italy, Soft constraints

Soft constraints add to the classical notion of constraint the possibility of dealing with important features like fuzziness, uncertainty, optimization, probability, and partial satisfaction. This talk will describe the current state-of-the-art in the area of soft constraints, by reviewing the existing frameworks and pointing out the relations among them. Then, it will focus on one of the most general frameworks for soft constraints, which is based on a semi ring structure, and, for such a framework, it will present its properties and constraint propagation algorithms. Notions of abstraction and learning for soft constraints will also be given. Finally, it will describe and show the usefulness of a logic-based programming language, called `clp(fd,S)`, where soft constraints can be naturally used and are efficiently implemented.

August 10, 2000: "Converting STRIPS Planning Domain Representations to Equivalent Remote Agent Representations", Kristin Branson, Harvard University; "Towards Solving NP-Complete Problems with Quantum Computation", Brian Murphy Stanford University"; Collective learning of action sequences in groups of semi-autonomous agents", Adrian Agogino, University of Texas; "Automated Analysis of Convergence Properties of Synthesized Programs", Ralph Benzinger, Cornell University; "Using Statistic Matching for Cross-validation Error to Improve Generalization", Sergey Kirshner, University of California, Irvine

Students discuss the problem or task(s) they are working on as participants in the SSRP, the goals to be accomplished with this work, the approach taken to solve the problem or perform the tasks, the current status of the work and possible interesting future extensions to this work (part I).

July 26, 2000: David Traum, Ph.D. University of Maryland, Computational Models of Grounding in Collaborative Systems

Common ground (or mutual belief) between conversational participants is assumed to be crucial for many collaborative tasks. However, the process by which this common ground is augmented (called Grounding) has often been either oversimplified or studied in an off-line manner. I will present two computational approaches to grounding, using ideas from speech act theory, and discuss their advantages and short-comings for helping enable a computer system to analyze and engage in cooperative spoken and multi-modal communication. The first, from Traum 1994, views grounding

related action as performing one or more of seven types of "grounding acts", and uses finite state automata to track the state of grounding and serve as context for planning grounding related utterances. The second, presented in Traum and Dillenbourg 1996, 1998, generalizes the notion of grounding act function, and uses a utility theory model to help select an appropriate next action.

July 25, 2000: Theodore W. Berger, Ph.D. and Jim-Shih Liaw, Ph.D. Department of Biomedical Engineering, Center for Neural Engineering, University of Southern California
The Dynamic Synapse Speech Recognition System: Using Neural Nonlinear Dynamics for Temporal Pattern Recognition

Drs. Berger and Liaw will describe a novel neural network architecture based on the nonlinear dynamics of synaptic transmission in the hippocampus, a part of the brain involved in the formation of pattern recognition memories. A combined experimental-theoretical approach based on nonlinear systems theory is used to characterize functional properties of hippocampal neurons and synapses, and in particular, those properties that underlie the sensitivity of hippocampal neural elements to higher-order temporal patterns. These nonlinear transformational characteristics are then embedded in neural network models, and used as the instruments to extract features of temporally coded inputs, e.g., speech signals. A novel "dynamic learning rule," based on adaptive mechanisms of hippocampal synapses, is used to obtain an optimized feature set. Results demonstrate that this approach provides the basis for speaker-independent and speaker-specific word recognition with very small, highly simplified neural networks. Performance of trained networks is highly robust with respect to noise, with systems to date outperforming both human listeners and commercial speech recognition systems, when either Gaussian white noise or background speech from multiple, non-target speakers is used. Because the model assumes only neurobiological properties, the system also can be extended to other application domains involving temporal or spatio-temporal pattern recognition, e.g., speaker verification/identification, sonar classification, and sensor fusion. Also to be reviewed is related work involving analog VLSI implementations of the nonlinear neural network models, including those developed for speech recognition.

July 24, 2000: Paul Dan Cristea, Department of Engineering Sciences, "Politehnica" University of Bucharest, The evolutionary intelligent agent concept

The presentation will focus on preliminary results in exploring the Evolutionary Intelligent Agent (EIA) concept, that merges the Intelligent Agent and the Evolutionary - Genetic Algorithms approaches. EIAs are Intelligent Agents provided with a genotype that controls their capabilities to carry out various tasks, i.e., their phenotype. EIAs benefit of the two major forces of adaptation: learning - occurring at the level of each agent and at the time scale of an agent's life, and evolution - taking place at the level of the population and unfolding at the time scale of successive generations. Thus, EIAs can address the real-life problem of adaptation in complex and non-predictable environments as the nowadays worldwide computer networks. In this phase, a prototype of the EIA system has been implemented for study purposes, to experimentally investigate the EIA concept. The model is quite simple, but illustrates the basic features of an EIA system. According to the concept, the EIAs have not only a reactive behavior, but also cognitive features. To help visualize the EIA system dynamics, a sensorimotor type of agents has been considered, evolving in a two-dimensional world and performing several simple tasks. The system can comprise one or more agent populations (teams). The agents from different populations

interact only by acting in the same environment. The agents from the same population may also interact directly, e.g., through message exchanges, genetic interactions, etc. An agent holds subjective, partial information about the environment, at two levels of world representation: the sensorial level - depicted in a sensorial map constructed with the tactile and visual inputs, and the cognitive level - depicted in a cognitive map based on the information in the sensorial map, but modified and enriched through some heuristic processing and with the information received by communicating with other agents in the same population.

July 24, 2000: Adina Magda Florea, Professor, PhD - Department of Computer Science, "Politehnica" University of Bucharest, Self-interested agents: from competition to cooperation

In a multi-agent system, an agent exists and performs its activity in a society in which other agents exist and act. Therefore, coordination among agents is essential for achieving the goals and acting in a coherent manner. When agents in the system are self-interested, coordination and cooperation should be achieved through communication and negotiation. The presentation will focus on two aspects of self-interested cognitive agents behavior. A first part is dedicated to present a model and associated behavior of self-interested agents that are endowed, besides the widely accepted BDI attitudes, with preferences, obligations, norms, and gain. The behavior of the agents is mainly motivated by the gain they obtain while fulfilling their preferred goals and by the necessity to cooperate with other agents for achieving these goals. The main focus is on negotiation, an agent using a set of inference rules based on cost, gain, and the cooperation profile of the other agents developed during previous interactions. The model is fitted to develop multi-agent based applications for open environments but also for applications with cooperative agents in which agents are distributed and have a certain degree of independence. A second part of the presentation is dedicated to a multi-agent system that tries to solve the problem of rational exploitation of natural renewable resources, named also the "tragedy of commons" problem. The agents use a genetic representation to model the evolution of the unpredictable world in which they live, leading to ecological plans of actions to preserve the resources. The genetic approach is based on cooperative coadapted species and models the multi-agent world from the point of view of a particular agent. The proposed genetic representation may also be used to investigate, in a centralized manner, the behavior and features of the entire society of agents for the "tragedy of commons" problem. The aim of the work is to propose and investigate a hybrid type of intelligent agents that are basically cognitive but which are endowed with evolutionary components to overcome the limitations of their beliefs and lack of complete knowledge on the environment in which they act.

July 11, 2000: Yigal Arens – Intelligent Systems - USC/ISI

The Information Sciences Institute of the University of Southern California is a computer science research facility located off-campus in Marina del Rey. It is active in a number of areas of computer science, including networking, software engineering, and artificial intelligence. The Intelligent Systems Division at ISI is one of the largest AI groups in the country, with over 70 staff researchers, research faculty, students and visitors. AI research at ISI includes research in the areas of knowledge representation and ontologies, information management and integration, intelligent agents, natural language translation and summarization, modeling and simulation, distance education, digital government,

robotics, and more. My talk will describe the main AI projects at ISI, devoting special attention to those that overlap with ongoing research at RIACS.

July 7, 2000: Dr. Arun Jagota - University of California at Santa Cruz, Statistical Machine Learning for Large Scale Optimization

Difficult optimization problems arise in all fields of science, engineering, and industry; exact solution methods are often lacking, heuristic methods of all sorts abound. Recently, a group of researchers has begun to add yet another such meta-method to the mix. Optimization involves a search for good solutions. During the course of a search one visits several feasible/infeasible/partial/complete solutions. Perhaps something can be learnt from them, to be profitably applied to discovering a better solution, or perhaps towards solving a related problem. In this talk I will present an overview of the recent works of several groups on applying machine learning methods to optimization problems. I will also discuss my own work in this area.

July 6, 2000: Robert Filman, RIACS/NASA Ames, Applying Aspect-Oriented Programming to the Intelligent Synthesis Environment Problem

A critical issue in developing component-based and distributed systems is getting the assembled set of components to follow the policies of the overall system. To achieve qualities such as reliability, availability, responsiveness, performance, security, and manageability, all system components must consistently perform certain actions. One emerging example of a system in need of such regularity is NASA's effort to create an Intelligent Synthesis Environment (ISE). ISE aims to link scientists, design teams, manufacturers, suppliers and consultants in the virtual creation and operation of aerospace systems. In this talk, I describe the ISE problem and architectural issues for ISE. A solution to the architecture complexity of ISE lies in employing the technology of Aspect-Oriented Programming (AOP). AOP provides mechanisms for separating the specification of different qualities and weaving them together into running systems. I will present an AOP system we have implemented, the Object Infrastructure Framework (OIF), and discuss how OIF could be applied to the ISE problem.

June 28, 2000: Manny Salas, USRA – ICASE, Overview of Research at ICASE

The Institute for Computer Applications in Science and Engineering (ICASE) was established at NASA Langley Research Center on July 1972. The purpose of the institute when it was created was not only to do unclassified basic research in applied and numerical mathematics, fluid mechanics and applied computer science, but also to infuse the results of such research into Langley's programs, to expose the academic community to problems and programs of interest to NASA, and to foster interactions with that community. While research areas have changed over the years, the mission of the institute has remained true. For 28 years ICASE has played a critical role in advancing the state of the art in computational fluid dynamics, turbulence modeling, boundary layer stability and transition, parallel numerical algorithms, and parallel compilers. Today, in addition to these research areas, ICASE conducts research in structures and materials, formal methods, multidisciplinary optimization and other areas of interest to Langley. In this lecture I will give an overview of the institute and of its current research topics.

June 22, 2000: Logic-Based Subsumption Architecture, Pedrito Maynard-Reid II, Stanford University

We describe a logic-based AI architecture based on Brooks' subsumption architecture. In this architecture, we axiomatize different layers of control in First-Order Logic (FOL) and use independent theorem provers to derive each layer's outputs given its inputs. We implement the subsumption of lower layers by higher layers using circumscription to make assumptions in lower layers, and nonmonotonically retract them when higher layers draw new conclusions. We also give formal semantics to our approach. Finally, we describe four layers designed for the task of robot control and an experiment that empirically shows the feasibility of using fully expressive FOL theorem provers for robot control with our architecture.

June 8, 2000: Interactive Visualization of Large Graphs and Networks, Tamara Munzner, Stanford University

Many real-world domains can be represented as large node-link graphs: for instance, backbone Internet routers connect with 70,000 other hosts, mid-sized Web servers handle between 20,000 and 200,000 hyperlinked documents, and dictionaries contain millions of words defined in terms of each other. Computational manipulation of such large graphs is common, but previous tools for graph visualization have been limited to datasets of a few thousand nodes. Visual depictions of graphs and networks are external representations that exploit human visual processing to reduce the cognitive load of many tasks that require understanding of global or local structure. We assert that the two key advantages of computer-based systems for information visualization over traditional paper-based visual exposition are interactivity and scalability. We also argue that designing visualization software by taking the characteristics of a target user's task domain into account can lead to systems that are either more effective and scale to larger datasets than previous work. This talk includes an analysis of three specialized systems for the interactive exploration of large graphs, relating the intended tasks to the spatial layout and visual encoding choices. We present two novel algorithms for specialized layout and drawing which use quite different visual metaphors. The H3 system for visualizing the hyperlink structures of web sites scales to datasets of over 100,000 nodes by using a carefully chosen spanning tree as the layout backbone, 3D hyperbolic geometry for a Focus+Context view, and provides a fluid interactive experience through guaranteed frame rate drawing. The Constellation system features a highly specialized 2D layout intended to spatially encode domain-specific information for computational linguists checking the plausibility of a large semantic network created from dictionaries. The Planet Multicast system for displaying the tunnel topology of the Internet's multicast backbone provides a literal 3D geographic layout of arcs on a globe to help Mbone maintainers find potentially misconfigured long-distance tunnels. Each of these three systems provides a very different view of the graph structure, and we evaluate their efficacy for the intended task. We generalize these findings in our analysis of the importance of interactivity and specialization for graph visualization systems that are effective and scalable.

June 6, 2000: Distributed Shared-memory Programming with the Unified Parallel C Information Power Grid, Tarek El-Ghazawi, George Mason University

Parallel programming paradigms have been designed around three models. These are message passing, data parallel, and shared-memory. Shared-memory can simplify programming, as it provides a memory

view similar to that of uniprocessors. Practical experience, however, has shown that large-scale parallel machines should have physically distributed memories. Further, it has shown that as the programmer gets closer to the underlying hardware, higher performance execution could be achieved. Thus, designing parallel programming languages around a distributed shared-memory model has the promise of ease-of-programming as well as efficiency, since programmers can exploit features such as memory locality in distributed memory systems. Furthermore, the use of an abstract distributed shared-memory model can lead to program portability and allow efficient compiler implementation on other parallel architectures. UPC is supported by a forum of government, academia, and industry, and many implementations are available or will become available soon.

Dr. El-Ghazawi will also present an overview of his previous research in high-performance computing and future direction.

May 11, 2000: Optimal Reward Functions in Distributed Reinforcement Learning, Kagan Tumer, Code IC, NASA Ames

The mathematics of "Collective INtelligence" (COINs) is concerned with the design of multi-agent systems in order to optimize an overall global utility function when those systems lack centralized communication and control. Typically in COINs each agent runs a distinct Reinforcement Learning (RL) algorithm so that much of the design problem reduces to how best to initialize/update each agent's private utility function, so as to avoid their working at cross purposes as far as the global utility is concerned. Traditional "team game" solutions to this problem assign to each agent the global utility as its private utility function. In previous work we used the COIN framework to derive the alternative "Wonderful Life Utility" (WLU), and experimentally established that having the agents use it induces global utility performance up to orders of magnitude superior to that induced by use of the team game utility. In this work we discuss new utility functions that provide improvements over both the WLU and the traditional approaches.

April 27, 2000: Bayesian Super-Resolved Surface Reconstruction From Images, Vadim Smelyanskiy, RIACS/NASA Ames

Bayesian inference has been used successfully for many problems where the aim is to infer the parameters of a model of interest. In this talk we formulate the three dimensional reconstruction problem as the problem of inferring the parameters of a surface model from image data, and show how Bayesian methods can be used to estimate the parameters of this model given the image data. Thus we recover the three dimensional description of the scene. This approach also gives great flexibility. We can specify the geometrical properties of the model to suit our purpose, and can also use different models for how the surface reflects the light incident upon it. In common with other Bayesian inference problems, the estimation methodology requires that we can simulate the data that would have been recorded for any values of the model parameters. In this application this means that if we have image data we must be able to render the surface model. However it also means that we can infer the parameters of a model whose resolution can be chosen irrespective of the resolution of the input images, and may be super-resolved. Also, once the model is inferred we can produce high resolution images of a surface from the view points that are different from those of low-resolution input images. We present results of the large scale inference of surface models from simulated aerial photographs for the case of super-resolution, where many surface elements project into a single pixel in the low-resolution images.

March 2, 2000: Compiling Language Models from a Linguistically Motivated Unification Grammar, Manny Rayner, RIACS/NASA Ames

Systems now exist which are able to compile unification grammars into language models that can be included in a speech recognizer, but it is so far unclear whether non-trivial linguistically principled grammars can be used for this purpose. We describe a series of experiments which investigate the question empirically, by incrementally constructing a grammar and discovering what problems emerge when successively larger versions are compiled into finite state graph representations and used as language models for a medium-vocabulary recognition task.

February 17, 2000: The Sun's Magnetic Attractions, Lyndsay Fletcher, Lockheed Martin, Missiles and Space

The last three decades, since the advent of space-borne solar observatories, has been a period of rapid flourishing in our understanding of the outer atmosphere of the sun. Observations in the ultraviolet to X-ray parts of the spectrum have shown clearly that the structure, the dynamics and the evolution for the solar atmosphere are dominated by its magnetic field, which is generated by a dynamo located at the interface between the radiative core and the convection zone. The manifestations of the sun's magnetic activity include sunspots, solar flares, coronal mass ejections, and aspects of the solar wind. I will attempt to summarize our current understanding of the magnetic solar atmosphere, with the aid of many beautiful images from satellites such as Yohkoh, TRACE and SoHO. I will also touch upon the implications of solar magnetic activity for life on our planet.

February 3, 2000: Knowledge-Based Abstraction, Visualization, and Exploration of Time-Oriented Data, Yuval Shahar, Stanford University Medical Center

I will describe a conceptual and computational architecture called Knowledge-based Navigation of Abstractions for Visualization and Explanation (KNAVE). KNAVE is a domain-independent framework specific to the task of interpretation, summarization, visualization, explanation, and interactive exploration in a context-sensitive manner through time-oriented raw data and the multiple levels of higher-level, interval-based concepts that can be abstracted from these data. The KNAVE domain-independent exploration operators are based on the relations defined in the knowledge-based temporal-abstraction problem-solving method, which is used to abstract the data, and thus can directly use the domain-specific knowledge base on which that method relies. Thus, the domain-specific semantics are driving the domain-independent visualization and exploration processes. By accessing the domain-specific temporal-abstraction knowledge base and the domain-specific time-oriented database, the KNAVE modules enable users to query for domain-specific temporal abstractions and to change the focus of the visualization, thus reusing for a different task the domain model that has been acquired from the domain experts. Although I will focus on the methodology, I also will present a preliminary evaluation of the KNAVE prototype in a medical domain. Our experiment incorporated seven users, a medical patient record, and three complex temporal queries, typical of guideline-based care, that the users were required to answer and/or explore. The results of that preliminary experiment have been quite encouraging. The KNAVE methodology has potentially broad implications for tasks such as planning, monitoring, explanation, and interactive data mining of time-oriented data.

January 20, 2000: Modeling and simulating work practices on the Moon - An agent-based approach, Maarten Sierhuis, RIACS

In recent years, interest in collaborative agents has increased due to the fact that most applications also require collaboration with other systems and their users. Although we have started from a different need, namely understanding the way people work, collaborate, and communicate in their environment, we have developed an agent-based simulation environment (Brahms) that deals with a lot of the same issues as the intelligent agent community is now addressing. In this talk I will present a multi-agent model of the collaborative work practices of the Apollo astronauts during the Apollo Lunar Surface Experiments Package (ALSEP) offload from the Lunar Module. The goal of this experiment was to investigate the use of the Brahms-language in describing an existing, though mostly forgotten, work practice. The challenge we faced in this experiment was to investigate if our theory of modeling work practice, as implemented in the language, would be sufficient to describe the work practice in the chosen domain. I will present an overview of the Brahms language and environment, based on this Apollo example.

December 13, 1999: An Overview of the Spoken Language Translator, Manny Rayner, RIACS

In this talk, I will give an overview of the Spoken Language Translator (SLT) project. SLT, which ran from 1992 to 1999 under sponsorship from Telia Research, Stockholm, was one of the first serious projects in the area of automatic translation of speech. The final prototype performed translation between English, French and Swedish in the domain of air travel inquiry systems, using a vocabulary of about 1500 words, and with an accuracy of about 75%. Average processing times are around 4 seconds per utterance.

The SLT system consists mainly of general purpose domain-independent components which are tuned to the domain using supervised training techniques, and uses a hybrid architecture which combines deep and shallow processing methods. Many of the techniques developed under the project are applicable to other types of spoken language understanding task.

A book about the SLT system will be published next year by Cambridge University Press.

December 02, 1999: Combining Prosodic and Language Models for Speech Segmentation and Recognition, Andreas Stolcke, SRI International

This talk will give an overview of recent work at SRI aimed at extending the output of speech recognizers beyond the usual stream of words, providing additional information such as sentence segmentation, disfluency detection, identification of proper names and topic segmentation. All of these tasks are addressed in a common approach: a combination of the (fairly standard) lexical modeling, using hidden Markov and statistical language modeling, and the (not-so-standard) exploitation of prosodic cues to the "hidden" events (tags) sought. I will discuss the modeling approaches used, and present results for sentence segmentation and disfluency annotation on the Switchboard corpus, as well as for sentence and topic segmentation in the Broadcast News domain. Prosodic modeling is shown to improve performance on these tasks, in some cases dramatically. It turns out that hidden event modeling can also improve word recognition itself, by constraining hypotheses to be consistent with prosodic characteristics of hidden events.

This is joint work with Liz Shriberg, Dilek Hakkani-Tur and Gokhan Tur.

Bio: Andreas Stolcke is a Sr. Research Engineer in SRI's Speech Technology and Research Laboratory, where he has been working on statistical language modeling, spontaneous speech modeling, and large-vocabulary recognition since 1994. Prior to that, he received his undergraduate education at the Technical University of Munich, and a Ph.D. from UC Berkeley, with a thesis on Bayesian unsupervised learning of grammatical structure.

November 18, 1999: The Intelligent Systems Program, Butler Hine – NASA Ames

Dr. Butler Hine has just returned to NASA Ames as a new Level 2 Program Manager for the Intelligent Systems (IS) Program. His area of responsibility will be the Autonomous Reasoning (AR) area, the goal of which is to create smart spacecraft, rovers, and ground systems capable of achieving mission goals independent of low-level human control. Prior to returning to NASA Ames, Butler was CEO of a Silicon Valley software start-up company and before that was the head of the Intelligent Mechanisms Group in Code IC. Butler's talk will begin with a brief summary of his background followed by a discussion of the goals and organization of the Autonomous Reasoning Program within IS.

November 04, 1999: Model Checking for Autonomy Software, Charles Pecheur - RIACS

To fulfill its mission of deep space exploration in a "faster, better, and cheaper" way, NASA is putting a lot of efforts in autonomous software such as Ames' Remote Agent (RA), demonstrated last May on Deep Space One (DS-1). The validation of such complex software systems poses a big challenge: because of internal decision taking and concurrency, the range of possible situations becomes so large that traditional black-box testing is very inefficient. Achieving and assessing the reliability of autonomous system will require the use of advanced V&V techniques such as model checking. After a succinct introduction to the ins and outs of model checking, this presentation will survey past, ongoing and planned work on applying model checking to autonomy software in NASA Ames Automated Software Engineering Group. As an initial case study, our team found important concurrency bugs in the executive subsystem of the RA, using the Spin model checker. Building on initial work at CMU, we are now extending a compiler that feeds models used by the Livingstone fault recovery system into the SMV symbolic model checker. Some similar work has been performed on a model for the HSTS planner (HSTS and Livingstone are also part of the RA). The next stage will be to address the validation of a model-based system as a whole, which poses a difficult problem: such a system is built around an inference engine that would be very hard to model in a form amenable to a model checker.

Oct. 21, 1999: Turning Speech into Scripts, Manny Rayner - RIACS

We describe an architecture for implementing spoken natural language dialogue interfaces to semi-autonomous systems, in which the central idea is to transform the input speech signal through successive levels of representation corresponding roughly to linguistic knowledge, dialogue knowledge, and domain knowledge. The final representation is an executable program in a simple scripting language equivalent to a subset of CSHELL.

At each stage of the translation process, an input is transformed into an output, producing as a byproduct a "meta-output" which describes the nature of the transformation performed. We show how consistent use of the output/meta-output distinction permits a simple and perspicuous treatment of apparently diverse topics including resolution of pronouns, correction of user misconceptions, and

optimization of scripts. The methods described have been concretely realized in a prototype speech interface to a simulation of the Personal Satellite Assistant.

Oct. 07, 1999: Barriers to Digital Libraries, Hector Garcia-Molina, Stanford University

In this talk, the speaker will discuss the challenges and barriers faced in implementing a modern digital library, including technical, legal, and societal ones. In particular, he will also give an overview of the Stanford Digital Library Project, and describe how we are addressing some of the technical barriers in the areas of interoperability, preservation, searching, mobile access, and protection of intellectual property.

III.B RIACS-supported Workshops

As part of its mission of fostering ties with the academic community in information technology, RIACS provides financial, administrative, and technical support for selected workshops involving RIACS scientists. There were three workshops supported during this reporting year:

**NASA International Workshop on Planning and Scheduling
San Francisco, CA. March 16-18, 2000**

This workshop brings together researchers in automated planning and scheduling to discuss the use of these technologies for space missions and applications involving both completely automated systems and those with human intervention in the exploration of space.

**NASA Workshop on Evolvable Hardware
Palo Alto, CA. July 13-15, 2000**

Evolvable hardware is an emerging field that applies simulated evolution to the design and adaptation of physical structures, particularly electronic systems. The Second NASA/DoD Workshop on Evolvable Hardware (EH-2000) brought together leading researchers and technologists from academia, government, and industry to discuss advances and the state-of-the-art in this field. A focus of this year's workshop is on real-world applications of evolvable hardware. Current application areas include adaptive and reconfigurable computing, circuit and antenna design, and evolutionary robotics. Evolvable hardware methods could also be effective in dealing with increased complexity and reliability requirements in areas such as sensors, MEMS, biomolecular design, quantum computing, and nanoelectronics.

**SPIN 2000
Stanford University August 30 – Sept. 1, 2000.**

The SPIN workshops constitute a forum for researchers interested in the subject of automata-based, explicit-state model checking technologies for the analysis and verification of asynchronous concurrent and distributed systems. Traditionally, the SPIN workshops present papers on extensions and uses of SPIN. As an experiment, this year's workshop was broadened to have a slightly wider focus than previous workshops in that papers on software verification were encouraged. Consequently, a small collection of papers described attempts to analyze and verify programs written in conventional programming languages. The workshop featured seventeen refereed papers selected from thirty-one

submissions, two invited talks, and four invited tutorials about formal method and testing tools, three of which were commercial.

IV RIACS Staff

The primary mechanism used at RIACS is the engagement of RIACS scientists in NASA projects. RIACS staff scientists are recruited from the broad university research community to provide a nucleus of activity to both collaborate with NASA scientists and to provide an “attraction point” for bringing in visitors from academia. These scientists typically work in clusters on NASA projects – collaborating closely with NASA scientists and onsite contractors, providing senior technical expertise and coordinating visitors from academia.

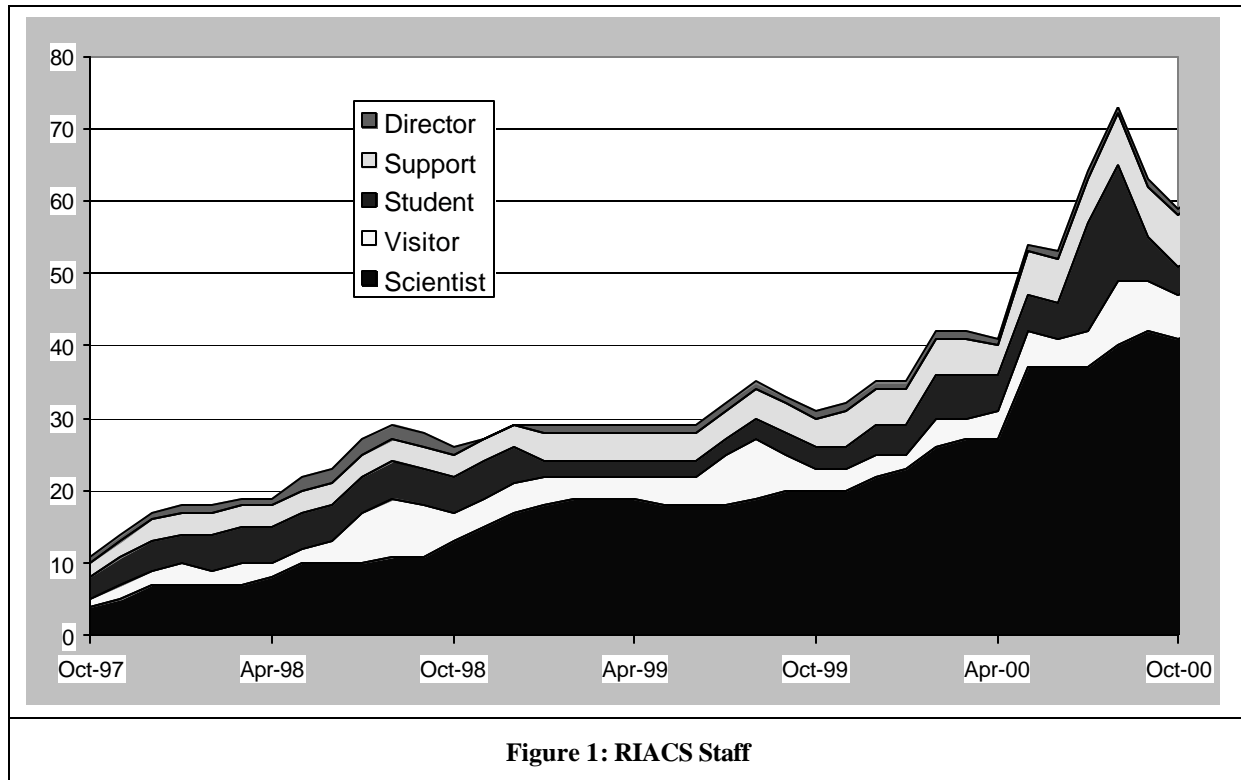


Figure 1 shows the growth in RIACS staff from 1997 through the reporting period. Over the period of the current Cooperative Agreement shown, the number of scientific staff onsite has grown from three to forty one.

The following sections lists both the permanent and visiting staff at RIACS over the reporting period, with the time they have been at RIACS shown in parentheses.

IV.A Management Staff

Barry Leiner, Director – Ph.D. Electrical Engineering, Stanford University, 1973. (06/28/99 – present)

Robert Morris, Deputy Director – Ph.D, Philosophy, Indiana University, 1984. (08/02/99 – present)

IV.B Administrative and Support Staff

Diana Martinez, Administrator (08/18/97 - present)

Beatrice Burnett, Administrative Assistant (11/3/97 - present)

Sue Christman, Administrative Assistant (4/06/00-present)

Rasheeda Shaheed, Administrative Assistant (04/16/99 – present)

Peggy Leising, Project Facilitator (04/01/00 – present)

Ryan Nelson, Systems Administrator (subcontractor) (6/17/00 – present)

Carson Little, Systems Administrator (subcontractor) (9/17/99 –6/17/00)

Ted Penabella Administrative Assistant (9/29/99 - 1/21/00)

Vincenzo Del Vecchio Administrative Assistant (1/19/00 - 3/31/00)

IV.C Scientific Staff

Anupa Bajwa, Ph.D., 1995, Aerospace Engineering, Pennsylvania State University, Model-based reasoning for autonomous systems diagnosis. (04/03/00 – present)

Esfandiar Bandari, Ph.D, 1995, Computer Science, University of British Columbia, Computational Vision, Signal Processing, 3-D Reconstruction and Medical Imaging (09/2/98 – present)

Walter F. Brooks, Ph.D., 1977, Physics, Stevens Institute of Technology, Advanced air traffic control, advanced information systems technology in support of Earth Science Enterprise. (04/04/00 – present)

Peter J. Cheeseman, Ph.D., 1979, Monash University, Artificial Intelligence, computational complexity, bayesian inference, computer vision, plasma physics (09/1/97-present)

Rei J. Cheng, BS, 1973, Pharmacy, Taipei Medical College, 3-D scientific visualization and medical visualization (09/1/98 – present)

Daniel J. Clancy, Ph.D., 1997, Computer Science, University of Texas, Austin. Model-based reasoning, artificial intelligence, diagnosis, health management (01/24/00 – present)

Richard Dearden, MS, 1994, Computer Science, University of British Columbia. Artificial intelligence, reasoning, and decision making under uncertainty (07/19/00 – present)

Gregory A. Dorais, Ph.D., 1997, Computer Science, University of Michigan, Autonomous systems, machine learning (04/01/00 – 9/10/00)

John Dowding, MSE, 1988, Computer Science, University of Pennsylvania, Spoken dialogue systems, speech recognition, language processing (9/18/00 – present)

Lisa Faithorn, Ph.D, 1990, Anthropology, University of Pennsylvania, Technology enhanced team research communication and calibration, human dimensions and technology options (9/18/00 – present)

Robert E. Filman, Ph.D., 1979, Computer Science, Stanford University. Frameworks for distributed computing. (12/01/99 – present)

Bernd Fischer, Ph.D., 1998, TU Braunschweig, Germany, Computer Science (11/01/98 – present)

Andreas Frank, Ph.D., 1999, Biomedical Engineering, University of Texas, Arlington. Numerical and mathematical modeling of biological tissue. (11/17/99 – present)

Dave Gehrt, JD Law, 1972, University of Washington, UNIX system administration, security, and network based tools (1/84 - 7/85, 2/1/88 - present).

Dimitra Giannakopoulou, Ph.D, 1999, Distributed Software Engineering, Imperial College, London, Distributed computing, design, analysis and implementation (8/28/00 – present)

Zann Gill, M.Arch, 1979, Harvard University, Collaborative problem-solving environments (CPSE), concept formation (the creative process). (03/07/00 – present)

Howard Goldstein, 1963, MS, Chemical Engineering, University of Arizona, Research on thermal protection systems that utilize intelligent systems technology and smart materials (7/1/00 – present)

Jon Guice, Ph.D., 1997, Sociology (Science Studies, University of California, San Diego. Research and development management, technology strategy. (04/01/00 – present)

Butler Hine, Ph.D., 1988, Astronomy, University of Texas, Austin. Autonomous Systems for Space and Planetary Exploration. (11/01/99 - present) (Currently IPA to NASA Ames)

Beth Ann Hockey, Ph.D., 1998, Linguistics, University of Pennsylvania, (01/01/99 – present)

Frances H. James, Ph.D., 1998, Computer Science, Stanford University, Speech understanding technologies and applications, developing interfaces using speech. (7/13/98 – present)

Marjory J. Johnson, Ph.D., 1970, Mathematics, University of Iowa, High-performance networking for both space and ground applications (1/9/84 -present).

Ari K. Jonsson, Ph.D., 1997, Computer Science, Stanford University, New Techniques in constraint satisfaction and Automated Planning. (10/1/97 - present)

Frank Kuehnel, Ph.D, 2000, Physics, Michigan State University, Computervision in 3D super-resolution and artificial intelligence. (08/01/00 - present)

John Loch, Ph.D., 1998, Computer Science, University of Colorado at Boulder (12/28/98 – present)

David Maluf, Ph.D., McGill University, Canada, 1995, Post Doctoral Fellow, Stanford University, knowledge-based systems, database management systems, image databases, computer vision, and man machine interfaces. (01/03/00 – present)

Paul Morris, Ph.D., 1984, Computer Science, University of California, Irvine. Automated reasoning, planning, constraint satisfaction, and knowledge representation. (04/01/00 – 9/11/00)

Robin D. Morris, Ph.D., 1995, Engineering, Trinity College, Cambridge, U.K., Bayesian Inference and Image Analysis, Mathematical Modeling of Natural Imagery and Associated Computational Methods. (3/1/98 – present)

John O'Neill, Ph.D., 1997, Computing, Royal Melbourne Institute of Technology (12/01/98 – present)

Meric Ozcan, Ph.D., 1991, Electrical Engineering, Stanford University. Quantum computing, quantum cryptography, optical data storage (4/03/00 – 9/19/00)

Seungjoon Park, Ph.D., 1996, Electrical Engineering, Computer Science, Stanford University (10/01/98 – present)

Lewis Peach – USRA Chief Engineer (09/04/99 – present)

Charles Pecheur, Ph.D., 1996, Electrical Engineering, Computer Science, University of Liege, (11/06/98 – present)

Kanna Rajan, MA, 1989, Computer Science, New York University, Automated reasoning, planning and scheduling. Model-based reasoning, knowledge representation and space craft autonomy. (04/03/00 – present)

Manny Rayner, Ph.D., 1993, Computer Science, Royal Institute of Technology, Stockholm, Natural language processing, speech recognition, Artificial Intelligence. (07/01/99 – 4/7/00)

Grigore Rosu, Ph.D, 2000, Computer Science, University of California, San Diego Formal methods in system specification and verification, applied logics in computer science. (9/1/00 – present)

Matthias Schmidlin, M.Sc., 1994, Technology Management, John Moores University, Liverpool. Organizational Aviation Safety and its Economical Implications (03/01/00 – present)

Johann Schumann, Ph.D, 1991, Computer Science, Technical University of Munich, Germany (Neural networks, automated theorem, parallel symbolic systems (03/03/00 – present)

Maarten Sierhuis, MS, 1986, Engineering, Mague Polytechnic University, Intelligent multi-agent simulation agent-oriented programming languages (4/1/98 – present)

Vadim N. Smelyanskiy, Ph.D., 1991, Physics, Institute of Semiconductors. Bayesian methods in computer vision, statistical physics, non-linear dynamics, control theory (02/16/00 – 07/21/00)

Mahadevan Subramaniam, Ph.D., 1996, Computer Science, State University of New York, Albany, Formal methods, verification of hw/sw, and software engineering processes (07/05/00 – present)

Dogan Timucin, Ph.D., 1996, Electrical Engineering, Texas Tech University, Physical, statistical, non-linear and quantum optics. Holography, signal and image processing. (04/03/00 – 9/22/00)

Jean Jerry Toung, MS, 2000, Electrical Engineering and Computer Science, Universite de Nantes, France, High performance WAN network monitoring and technology deployment for the NGI/NREN project. (07/15/00 – present)

Ian A. Twombly, Ph.D., 1997, Biophysics, John Hopkins University, (9/1/98 – present)

Willem Visser, Ph.D. (in progress), 1998, Computer Science, University of Manchester (10/19/98 – present)

Richard Washington, Ph.D., 1994, Computer Science, Stanford University. Artificial Intelligence, Robotics, Autonomous Systems, Plan Execution. (04/03/00 – present)

IV.D Visiting Scientists and Consultants

Note: Dates shown for visiting scientists are not necessarily continuous.

Marsha Berger, Ph.D., 1982, Department of Biomedical Engineering, Center for Neural Engineering, University of Southern California, The Dynamic Synapse Speech Recognition System: Using Neural Nonlinear Dynamics for Temporal Pattern Recognition, (06/13/00 – 08/19/00)

Turan Coratekin, Ph.D., 2000, Mechanical Engineering, RWTH Aachen. Hypersonic airplanes, shock/boundary-layer interaction. (06/13/99 – 12/11/99)

Paul Cristea, Ph.D., Department of Engineering Sciences, "Politehnica" University of Bucharest, Seminar: The evolutionary intelligent agent concept, (07/20/00 – 07/28/00)

Tarek El-Ghazawi, Ph.D., George Mason University, Distributed Shared-memory Programming with the Unified Parallel C Information Power Grid, (09/21/00 – 09/30/00)

Adina Magda Florea, Ph.D., Department of Computer Science, "Politehnica" University of Bucharest, Self-interested agents: from competition to cooperation, (07/10/00 – 07/30/00)

Hector Geffner, Ph.D, 1989, Computer Science, UCLA, Universidad Simon Bolivar, Planning and scheduling in artificial intelligence, (8/4/00 – 8/24/00)

Abdellah Hadjadj, Ph.D., Computational Fluid Dynamics (01/15/00 – 02/20/00)

Daniel Hammerstrom, Ph.D., 1977, EE University of Illinois. Oregon Graduate Institute. Massively parallel VLSI architectures for intelligent systems. (03/01/00 - present)

Mohamed Hafez, Ph.D, 1972, Aerospace Engineering. University of California, Davis. Computational Fluid Dynamics. (09/18/00 - 09/29/00)

Richard G. Johnson, Ph.D. - Physics, Indiana University, 1956, Global environmental problems and issues (11/1/92 - present).

Todd Leen, Ph.D., University of Oregon Graduate Institute, Theoretical Physics, Local adaptive algorithms for sensor data understanding (7/15/00 – 09/30/00)

Dimitrous Maroudas, Ph.D.- Chemistry, Analysis of the evolution of structure, morphology, and reactivity of hydrogenated amorphous silicon (a-Si:H) film surfaces (6/19/00 – 7/30/00)

Francesca Rossi, Ph. D. – Computer Science, University of Padova, Italy. Soft temporal constraint reasoning. (08/07/00 08/11/00)

Neil D. Sandham, Ph.D., 1989 – Mechanical Engineering, Stanford University, Numerical simulation of high speed flow involving interaction of shock waves and turbulence.(12/27/97 – 8/23/00)

Bjorn Sjogreen, Ph.D, 1988 - Numerical Analysis, Royal Institute of Technology. Advanced computational methods for fluid flows.(01/25/00 - 03/05/00)

Millind Tambe, Ph.D., USC/ISI, Multi-agent, distributed AI, agent modeling, plan recognition, and intelligent agents in synthetic environment. (08/16/00 – 08/19/00)

Sankaran Venkateswaran, Ph.D. -Sr. Research Associate, University of Tennessee Space Institute, preconditioning methods and use of neural networks for application to semi-conductor materials (5/18/98 – present)

Simon Wildermuth, MD, University of Zurich, Switzerland, Clinical radiological database and medical image post-processing. (03/10/00 – present)

David Zingg, Ph.D., University of Toronto, Aerospace Engineering, Navier-Stokes equations (07/01/00 – 09/30/00)

IV.E Visiting Students

Adrian Agogino, MS, 1999, Electrical Engineering, University of Texas, Agents Controlled by neural networks and collective algorithms (06/19/00 – 08/31/00)

Amrita Bhagat, Computer programming, DeAnza College. (7/26/99 – 6/30/00)

Jason Baldrige, MS, Computer Science, University of Edinburgh, Theoretical Syntax and Natural Language Processing (07/17/00 – 09/22/00)

Ralph Benzinger, MS, Computer Science, Cornell University , Computational Type Theory, Applied Logic, Constructive Mathematics (06/12/00 – 08/18/00)

Daniel S. Bernstein, BS, 1998, Computer Science, University of Massachusetts, Artificial Intelligence Reinforcement Learning (6/26/00 – 08/25/00)

Kristin Branson, BA, 2000, Computer Science, Harvard University (06/19/00 – 08/31/00)

Forrester Cole, BA, 2001, Computer Science, Harvard University (06/12/00 – 08/25/00)

Charlene Daley, (01/04/00 – present)

Sergey Kirshner, BA, 1998, Information and Computer Science, University of California, Berkeley, Machine Learning, Bayesian Learning (06/19/00 – 08/31/00)

K. Flavio Lerda, MS, 2000 – Computer Engineering, Politecnico di Torino, Distributed and parallel model checking (7/27/00 – present)

Satish Kumar Thittamaranahalli (T), BA, Computer Scientist, Stanford University, Diagnosis and tracking of hybrid models of physical systems (06/15/00 – 09/22/00)

Zara L. Mirmalek, BA, Public Administration, California State University, Hayward, Work Systems Design and Evaluation (06/12/00 – present)

Brian Murphy, BS, Physics, Stanford University, Potential implementation methods and algorithms for quantum computing (06/26/00 – 09/01/00)

Glen Nuckolls, MS, Mathematics/Computer Science, University of California - Davis, Algorithms Analysis (06/19/00 – 08/25/00)

Tae-young Oh, Device modeling and simulation, Stanford University. (1/1/98 – present)

Corina S. Pasareanu, MA, Computer Science, University of Kansas, Software Verification; model-checking and data abstraction. (4/17/00 – 6/30/00)

Shyam Ramalingam, Chemical Engineering, University of Santa Barbara, Computer Modeling of deposition of Si Films using PECVD. (9/2/97 - present)

Jeffrey M. Thompson, MS, 1999, Computer Science, University of Minnesota, Software for safety-critical systems (06/26/00 – 09/01/00)

Jean Jerry Toung, Universite de Nantes, France, Networking & Telecommunications. Provide programming support for the NGI/NREN project. (01/02/00 – 06/15/00)

Vandana Verma, MS, Robotics, Carnegie Mellon University, Probabilistic approach to fault diagnosis and detection (06/19/00 – 08/25/00)

IV.F Science Council

Dr. Jeffrey M. Bradshaw, Chair The Boeing Company

Dr. Nabil Adam, Rutgers University

Dr. David Bailey, Lawrence Berkeley Labs

Dr. Daniel G. Bobrow, Xerox Palo Alto Research Center

Dr. Burton I. Edelson, George Washington University

Dr. Ken Ford, University of West Florida

Dr. Abdollah Homaifar, North Carolina A&T State University

Dr. Mitchell P. Marcus, University of Pennsylvania

Dr. Alain Rappaport , Carnegie Mellon University