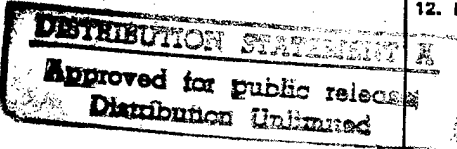


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6. AUTHOR(S) Prof. Mark Cutkosky; Prof. Larry Leifer Dr. Charles Petrie; Dr. George Toye				
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a. DISTRIBUTION / AVAILABILITY STATEMENT No limitations.			12. DISTRIBUTION CODE 	
13. ABSTRACT (Maximum 200 words) <p>The objective of this work was to help teams of engineers achieve a shared understanding of their designs and design processes, using agent-based computational tools and services for communication, collaboration, analysis, and synthesis. The approach was based on developing:</p> <ol style="list-style-type: none"> <li>1. Design representations that encompass decisions and rationale linked to the design artifact</li> <li>2. A distributed architecture that enables agents (human and computational) to communicate and cooperate in solving engineering problems</li> <li>3. Incremental, interactive concurrent engineering tools for analysis and synthesis</li> </ol> <p>As the SHARE tools and environment were developed, they were tested on industry-sponsored design projects. Their impact on the design process was analyzed to assess their effectiveness and provide a basis for models of concurrent design and redesign processes.</p> <p style="text-align: center; font-size: 2em; font-weight: bold;">19980317 131</p> <p style="text-align: right; font-weight: bold;">DTIC QUALITY INSPECTED 2</p>				
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**SHARE: A Scalable Framework  
and Methodology for Concurrent Engineering**

**FINAL REPORT**

**February 1998**

**Prof. Mark Cutkosky  
Prof. Larry Leifer  
Dr. Charles Petrie  
Dr. George Toye**

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**Principal Investigator**

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  - \* Grant Title:SHARE: A Scalable Methodology and Framework for Concurrent Engineering
  - \* Grant/Contract Number: N00014-92-J-1833
  - \* Mipr Number: None
  - \* R&T Number: 3333046--03
  - \* Period of Performance: 5/1/92 - 5/31/96
  - \* Today's Date: 14-11-95
-

## Productivity Measures

- \* Number of refereed papers submitted not yet published: 0
  - \* Number of refereed papers published: 14
  - \* Number of unrefereed reports and articles: 6
  - \* Number of books or parts thereof submitted but not published: 0
  - \* Number of books or parts thereof published: 0
  - \* Number of project presentations: 10
  - \* Number of patents filed but not yet granted: 1
  - \* Number of patents granted and software copyrights: 0
  - \* Number of graduate students supported  $\geq 25\%$  of full time: 11
  - \* Number of post-docs supported  $\geq 25\%$  of full time: 4
  - \* Number of minorities supported: 6
- 

## Summary of Objectives and Approach

The objective of this work is to help teams of engineers achieve a shared understanding of their designs and design processes, using agent-based computational tools and services for communication, collaboration, analysis, and synthesis.

The approach is based on developing:

1. design representations that encompass decisions and rationale linked to the design artifact
2. A distributed architecture that enables agents (human and computational) to communicate and cooperate in solving engineering problems
3. Incremental, interactive concurrent engineering tools for analysis and synthesis

As the SHARE tools and environment are developed, they are tested on industry-sponsored design projects. Their impact on the design process is analyzed to assess their effectiveness and provide a basis for models of concurrent design and redesign processes.

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## Detailed Summary of Technical Progress

1. A mature edition of the SHARE environment, including the PENS electronic notebook has continued to be tested. engineering design teams in ME210. The SHARE environment was used by all ME210 teams. This year, all teams have remote participants, three of them are international: one in Spain, one in the Netherlands, and one in Sweden. Supporting files for each project were captured on laptop computers and published on CDROMs and the World Wide Web, and analyzed to study design processes and design re-use. Exercising SHARE in real design activity continues to guide development of the next generation environment.
2. The SHARE Next-Link work on agent-based software for design collaboration has been largely concluded. We continue to maintain the

demonstration of several CAD-based agents working over the Internet to design a missile cable harness. We also built a web-based simple demonstration of Redux - planning a trip. This work has led to a complete redesign of the agent protocols and the addition of several new generic agents in a new project called ProcessLink. A major result has been the prototype of a Constraint Manager agent.

3. SHARE continues to collaborate with Sandia National Laboratories to develop an agile, Internet-based service for design and manufacturing on the Sandia Intelligent Agents for Manufacturing project, of which the CDR SIAM project is part. Demonstration agents using JAVA(tm) have been constructed. We continue to develop the JAT, now at version 0.4. The JAT has been used and experimented with by researchers all over the world.

---

### Transitions and DOD Interactions

1. 17 different industrial groups (FMC, Hughes, Peterbuilt, Schick, Baxter, Stanford Children's Hospital, Stanford Medical School, NASA, Nikon, GM, DEC, Western Digital, 3M, CapSnap, Western Sky, AT&T, DVI, Boeing) participated in the SHARE ME210 testbed environment. 3M, NASA and Hughes corresponded regularly with design teams via SHARE. Electronic documents were delivered to industrial sponsors for redesign and published as a design library on the World Wide Web.
2. SHARE is working with SIMA on finding applications of Next-Link technology. This work has continued under a new SIMA project: "Four-dimensional Production Models for Factory Conversion Projects".

---

### Software and Hardware Prototypes

1. Prototype Name: PENS (Personal Electronic Notebook with Sharing)
  - o Type: Web-based Personal Notebook
  - o URL:  
<http://www.ncsa.uiuc.edu/SDG/IT94/Proceedings/Educ/hong/hong.html>
  - o Availability: Can be obtained from Jack Hong at [cdr@cdr.stanford.edu](mailto:cdr@cdr.stanford.edu)
  - o Description: PENS is an off-line authoring client for the Web, which simplifies posting of Web information for both students and staff. It is currently being used by the teaching staff for curriculum development notes and for posting FAQs to the 210 Web. It is slated for student usage in team mini-projects. Technically, PENS is a HyperCard-based notebook database (see Figure 2) which sends a MIME-encoded message via SMTP to the 210 Web, where the message is received by ServiceMail(TM) and placed in a predetermined HTML directory. PENS eliminates the need for direct Web server write access to edit HTML documents, and eliminates the need for HTML markup by incorporating limited style parsing with pre-structured document organization schemes. The user only needs to pay attention to note content, as with any conventional word processor, and click the "SEND" button to post contents to the 210 Web.
  - Demonstration Examples: N/A

### List of Publications

1. C. Petrie, " Agent-Based Engineering, the Web, and Intelligence", IEEE Expert, 11:6, pp. 24-29, December, 1996.
2. C. Petrie, H. Jeon, and M. Cutkosky, " Combining Constraint Propagation and Backtracking for Distributed Engineering," Working Notes of the ECAI-96 Workshop on Non-Standard Constraint Processing, 1996.
3. S. Goldmann, " Procura: A Project Management Model of Concurrent Planning and Design", WET-ICE 96 Best Paper Award.
4. H.R. Frost and M.R. Cutkosky, "Design for Manufacturability via Agent Interaction," Paper No. 96-DETC/DFM-1302, Proceedings of the 1996 ASME Computers in Engineering Conference, Irvine, CA, August 18-22, 1996, pp. 1-8.
5. M.R. Cutkosky, J. Glicksman and J.M. Tenenbaum, "MadeFast: Collaborative Engineering Over the Internet", Communications of the ACM, 39:9, 1996, pp. 78-87.
6. G. R. Olsen, M.R. Cutkosky and J. M. Tenenbaum and T. R. Gruber, "Collaborative Engineering Based on Knowledge Sharing Agreements," Concurrent Engineering Research and Applications, 3: 2, 1995, pp. 145-159.
7. C. Petrie, T. Webster, and M. Cutkosky," Using Pareto Optimality to Coordinate Distributed Agents," Artificial Intelligence for Engineering Design, Analysis and Manufacturing (AIEDAM), 9, 269-281, 1995. Abstract available
8. J. Hong, G. Toye, and L. Leifer, "Personal Electronic Notebook with Sharing," Proc. 4th WET ICE, pp. 88-94, April, 1995, West Virginia, IEEE Press.
9. G.Toye, M.Cutkosky, L.J.Leifer, J.M.Tenenbaum and J. Glicksman, "SHARE: A Methodology and Environment for Collaborative Product Development," in Int. J. of Intelligent and Cooperative Information Systems, 1994. Abstract available
10. H.Park, M.Cutkosky, A.B.Conru and S-H. Lee, "An Agent-Based Approach to Concurrent Cable Harness Design," Artificial Intelligence for Engineering Design, Analysis and Manufacturing, Vol. 8, 1994, pp. 45-61. Abstract available
11. C.Petrie, M.Cutkosky and H.Park, "Design Space Navigation," Proceedings of Third Int. Conf. on AI in Design, August 1994, Lausanne, Switzerland. Abstract available
12. G.Olsen, M.Cutkosky and J.M.Tenenbaum and T.R.Gruber, "Collaborative Engineering based on Knowledge Sharing Agreements," to be presented at the 1994 ASME Engineering Database Symposium. Abstract available
13. S. Kambhampati, M. R. Cutkosky, J. M. Tenenbaum and S-H Lee, "Integrating General Purpose Planners and Specialized Reasoners: Case Study of a Hybrid Planning Architecture," IEEE Transactions on Systems, Man, and Cybernetics,, Vol. 23, No. 6, November/December, 1993, pp. 1503-1518. Abstract available
14. A.Conru and M.Cutkosky, "Computational Support for Interactive Cable Harness Routing and Design," Advances in Design Automation, DE- Vol 65-1, Proceedings of the 1993 ASME Design Automation Conf., Albuquerque, NM., Sept 19-22, 1993, pp. 551-558. Abstract available

15. V.Kumar, J.Glicksman, G.A.Kramer, "A SHAREd Web To Support Design Teams," Proceedings of IEEE Third Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, April 17-19, 1994, Morgantown, WV. Abstract available
  16. Baudin, Catherine; Kedar, Smadar; Underwood, Jody G.; Baya, Vinod; "Question-based Acquisition of Conceptual Indices for Multimedia Design Documentation", In proceedings of the 11th National Conference on Artificial Intelligence AAAI-93, Washington D.C., pp 452-458, July 1993.
  17. Baudin, Catherine; Underwood, Jody G.; Baya, Vinod; "Using Device Models to Facilitate the Retrieval of Multimedia Design Information", In proceedings of the 13th International Joint Conference on Artificial Intelligence, Chambéry, France, pp 1237-1243, August 29-September 2, 1993.
-



## Invited and Contributed Presentations

1. ISAT Demonstration: An invited presentation of the MadeFast project was given by on August 26, 1994 by M. Cutkosky and G. Toye at the ARPA meeting in Woods Hole, Massachusetts.
2. At the ARPA MADE Program Workshop in Salt Lake City, Utah, on Thursday, November 10th, (PowerPoint slides available) the MADEFAST seeker was publicly demonstrated to work.
3. PowerPoint slides were furnished to Pradeep Khosla in June, 1994, for the annual ARPA MADE briefing.
4. MADEFAST and Agent-Based Engineering (ABE) were presented at the July, 1995 ARPA MADE PI meeting, hosted by the Stanford Center For Design Research. Slides are available.
5. Mark Cutkosky presented MADEFAST at the ARPA SISTO symposium (STISS) in August, 1995.
6. Using the WWW for a Team-Based Engineering Design Class: A presentation was given by Jack Hong, George Toye, and Larry Leifer as part of the CS547 Human-Computer Interaction Seminar on September 29, 1995.
7. The Next-Link project was the subject of the keynote address given by Charles Petrie at the German Conference on Knowledge-based Systems XPS-95 in March, 1995.
8. "An Experiment in Coordination of Distributed Agents" was a talk given by Charles Petrie in August and September of 1994 at the following sites:
  - o The AG Künstliche Intelligenz : the AI group within the CS department of the University of Kaiserslautern at the invitation of a research director of the German National AI Institute: Prof. Dr. rer. nat. Michael M. Richter <richter@informatik.uni-kl.de>.
  - o Austrian Research Institute for AI (OFAI) at the invitation of Prof. Dr. Robert Trappl <robert@ai.univie.ac.at >, Director of OFAI.
  - o The Humbolt University in Berlin at the invitation of the Information Science department (Institut fuer Wirtschaftsinformatik Humboldt-Universität zu Berlin) chair, Prof. Dr. Oliver Guenther < guenther@wiwi.hu-berlin.de >.
  - o DaimlerBenz Research (Forschung und Technik), Alt-Moabit in Berlin at the invitation of AI Director Dr. Kurt Sundermeyer <sun@DBresearch-berlin.de>.
9. "The Next-Link Project": talk given by Charles Petrie at the Informs Conference, Los Angeles, May, 1995.
10. "Agent-Based Engineering": talk given by Charles Petrie at the OOPSLA Workshop on Objects, Scripts and the Web in Austin, Texas, October, 1995.
11. Formalizing Distributed Concurrent Engineering by Charles Petrie was the invited keynote at AAAI SIGMAN'96.
12. "Agent-Based Concurrent Design" was an invited presentation given by Mark Cutkosky at the University of Wisconsin, Madison, April 24, 1995.

13. "Agent-Based Engineering" by Mark Cutkosky was the keynote presentation and paper at Concurrent Engineering '96, University of Toronto, Toronto, CA., August 22, 1996.
-

### Honors, Prizes or Awards Received

- \* The Lincoln Foundation (related to, but separate from, the Lincoln Arc Welding Corporation) has sponsored a double-blind engineering design competition for about 50 years. They run an undergraduate and graduate division competition and see about 100 entries per year. There are a total of 12 awards in the graduate division. In part supported by Share collaboration technology, ME210 student design teams working on industry sponsored projects (e.g. Hughes, GM, Ford, 3M, ...) won 5 of the 12 awards in the 1993-1994 competition. The formal announcement of these awards has not yet been made but we know that 210-Share teams have won the top prize, "Best-in-Class" and the "Silver Medal". Successful competition in externally sponsored events such as this are important bench-marks for the assessment of Share developed collaboration technology.
  - \* Mark Cutkosky was appointed Charles M. Pigott Assoc. Professor of Mech. Engineering.
- 

### Project Personnel Promotions Obtained

\* none

### Project Staff

1. Name: Dr. Larry Leifer
    - o <http://cdr.stanford.edu/people/leifer-bio.html>
    - o Position: Professor, Co-PI, CDR Director
    - o Task: Responsible for ME210 Testbed.
  2. Name: Dr. Mark Cutkosky
    - o <http://cdr.stanford.edu/people/cutkosky/home.html>
    - o Position: Associate Professor, PI
    - o Task: MADEFAST project leader.
  3. Name: Dr. Charles Petrie
    - o <http://cdr.stanford.edu/people/petrie/home.html>
    - o Position: Research Associate
    - o Task: Next-Link project leader.
  4. Name: Dr. George Toye
    - o <http://cdr.stanford.edu/people/toye-bio.html>
    - o Position: Associate Director
    - o Task: ME210 support.
-

### **Multimedia URL**

1. EOYL FY95
  2. QUAD FY95
  3. EOYL FY94
  4. All CDR SHARE projects are on the WWW.
  5. A video of the MADEFAST project is available.
  6. Video tapes of all ME210 presentations have been made. In addition, CD-ROMs containing all ME210 design documentation are now available.
  7. The WWW Mechanical Engineering Virtual Library is maintained by the CDR and references the SHARE projects.
  8. The Sandia Intelligent Agents for Manufacturing (SIAM) project pages reference the CDR SHARE-based work.
  9. The SHARE Next-Link project is referenced by many other sites such as the UMass DIS Laboratory, Ralph Becket's Intelligent Software Agents page, the Webography of AI in Design resource, and the Multi-Agent Systems Webliography.
  10. Most of the CDR SHARE technical reports. are available on-line.
- 

### **Keywords**

1. ABSML
2. ACaPS
3. DEDAL
4. First-Link
5. GCDK
6. ICM
7. ISAT
8. MADE
9. MADEFAST
10. ME210
11. MediaKit
12. Mmphone
13. Next-Link
14. REDUX
15. SHADE
16. SHARE
17. StoryBoard

## **Business Office**

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- 

## **Expenditures**

1. Est. FY96: None
  2. FY95: 61%
  3. FY94: 100%
  4. FY93: 100%
- 

## **Students**

1. Name: Mr. Heecheol Jeon
    - o <http://cdr.stanford.edu/people/jeon-bio.html>
    - o Position: Research Assistant
    - o Nationality: Korean
    - o Available for Summer at DoD Lab: Yes
    - o Task: Next-Link Constraint Manager
    - o Thesis: N/A
  2. Name: Mr. Jack Hong
    - o <http://cdr.stanford.edu/people/hong/index.html>
    - o Position: Research Assistant
    - o Nationality: USA
    - o Available for Summer at DoD Lab: No
    - o Task: ME210/PENS Support
    - o Thesis: N/A
  3. Name: Mr. Brian Luehrs
    - o <http://cdr.stanford.edu/people/luehrb/index.html>
    - o Position: Research Assistant
    - o Nationality: USA
    - o Available for Summer at DoD Lab: No
    - o Task: ME210 Support
    - o Thesis: N/A
- 

## **Book Plans**

### **Sabbatical Plans**

### **Related Research**

1. Next-Link related research covers most of the agent-based SHARE-related work.
  2. The WWW Mechanical Engineering Virtual Library is managed with SHARE funding.
  3. The DesignNet resource is also managed with SHARE funding.
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## **History**

Note: the SHARE project has concluded and the the follow-on project is  
Design Space Colonization.

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