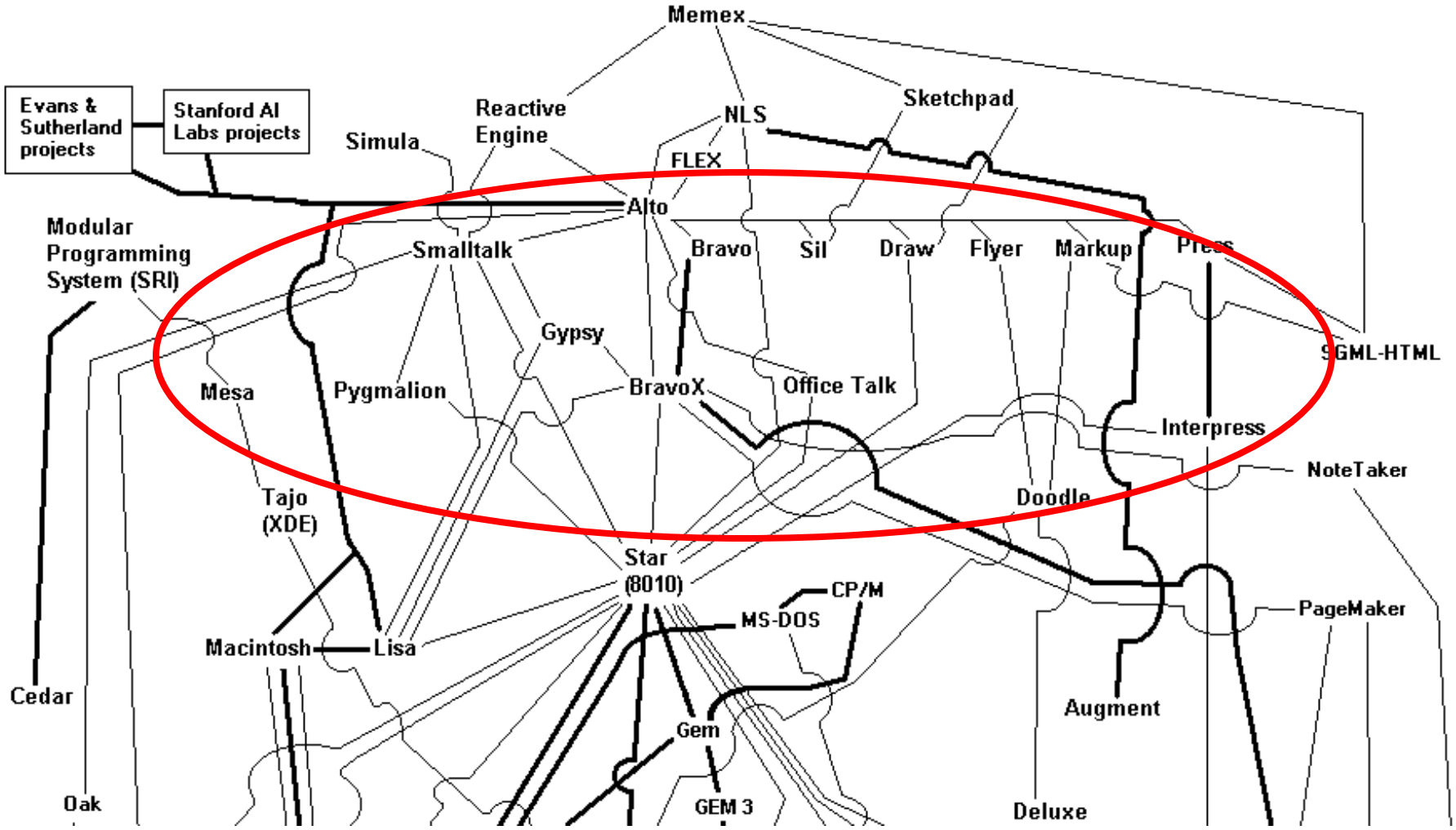
The Alto and Ethernet System Xerox PARC in the 1970's

Butler Lampson
Microsoft Research
October 17, 2006

Influences—"On the shoulders of giants"

- ARPA community
  - Man-computer symbiosis—Licklider
  - Time-sharing: CTSS, SDS 940, Tenex
  - Engelbart's On-Line System
  - Flex machine—Kay
  - Arpanet
  - Aloha packet radio network
- Xerox—"Office of the future"
  - The electronic office

Alto in Context



Organization

- CSL
  - Hardware: Alto, Ethernet
  - OS, Languages (BCPL, Mesa, Lisp)
  - Printing, file servers
  - Networking
  - Bravo (→Word), Draw (→Illustrator), fonts
  - Grapevine (email transport, server)
  - Laurel (email client)
- SSL
  - Printing, file servers
  - Smalltalk
  - Gypsy (→Word)
  - Markup (→Paint)

Timeline

- 1960s Time-sharing, Sketchpad, NLS
- 1970s Xerox PARC
  - Alto, Ethernet, laser printers
  - Bravo, Draw, Pup, Smalltalk
  - Altair, Apple II
  - Internet
- 1980s
  - 81 Xerox Star, IBM PC
  - 84 Macintosh, Laserwriter, MS Word/Excel
- 1990s Windows, Web

Themes

But a man's reach should exceed his grasp, or what's a heaven for? —Browning

- Computers can be used as tools to help people think and communicate
  - Licklider
  - ARPA time-sharing and networking
  - Engelbart and NLS
  - Alan Kay and Flex
- Xerox: Office of the Future
  - How do we grow after copiers?

Personal Distributed Computing

- Personal
  - Under the control of a person and serves his needs.
  - Performance is predictable, and *fast enough*
  - Reliable and available.
  - Not too hard to use
- Distributed
  - Everything in the real world is distributed
  - The computer is a communication device
  - Personal + communication = distributed
  - Need to share expensive devices too, esp. printers
- Computing
  - We programmed, but users didn't

Information Convenient For A Person

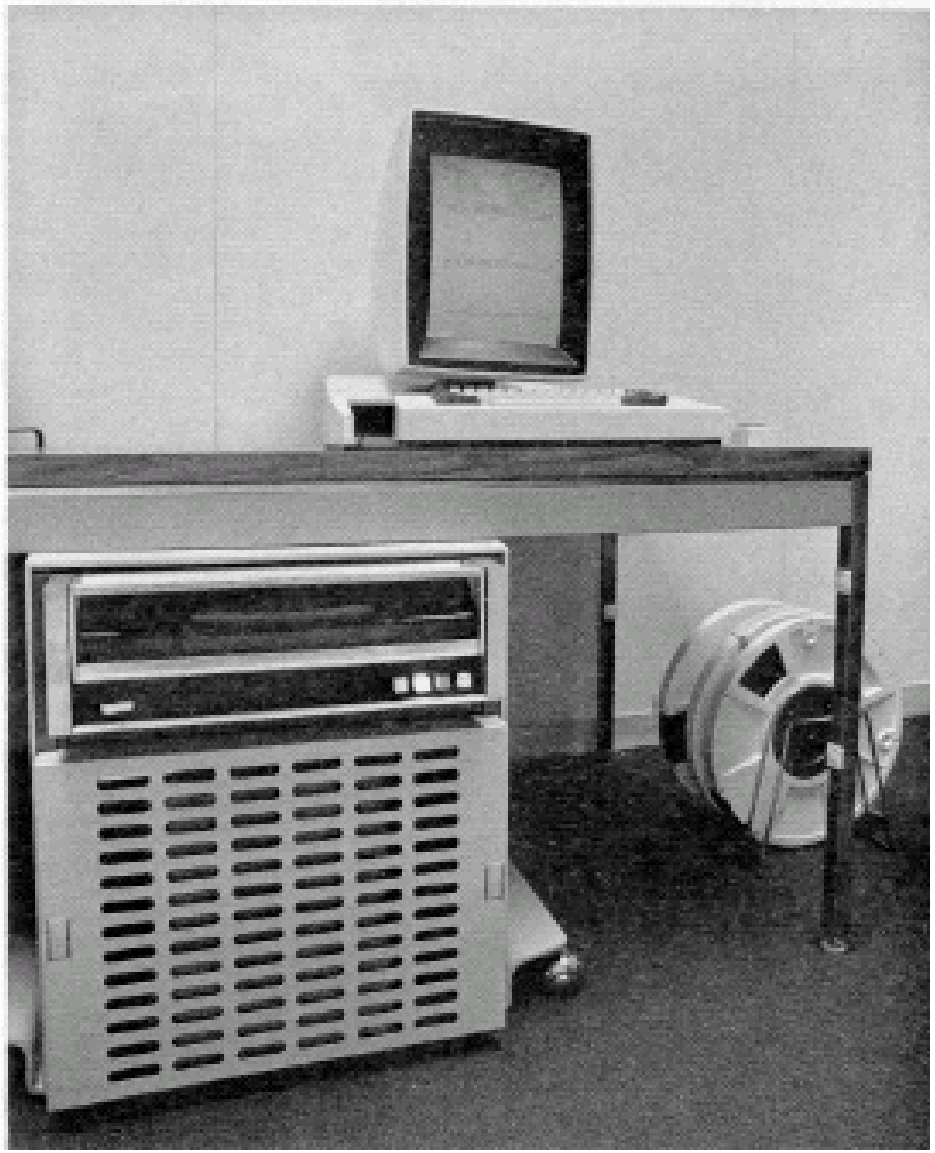
- Universal
  - Any (black-and-white) image, data, any software
    - Words, pictures, music, ...
  - Specialize with software
- Ink on paper
  - Present images
  - Point at places in the image
- The Alto can do this quite well
  - For a single 8.5" x 11" sheet of paper
  - With black ink
  - No restrictions on the form of the images
  - Cannot read images
- Voice and other sounds.
  - Later, less important

Principles

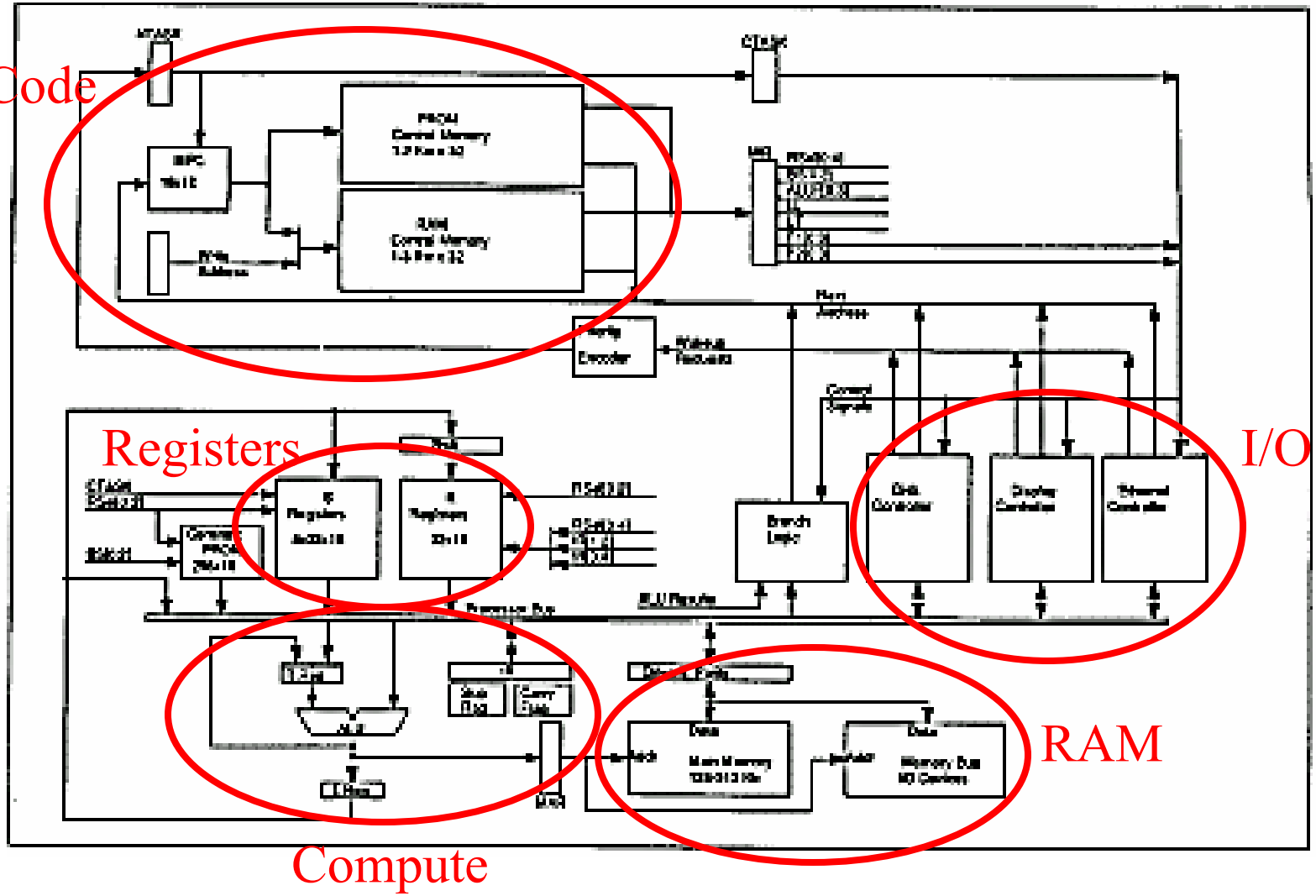
- "Time machine"—simulate the future
- Use what you build
  - Good for text, pictures, printing, sound, email
  - Bad for spreadsheets, databases
- Personal machine
  - "People are fast, machines are slow"
  - Performance is predictable
- No grand plan for the system: integration
  - Not enough experience, cycles or memory
  - Open OS, world-swap
  - Exception: Smalltalk

Alto Hardware

- 0.3 MIPS
- 128 KB RAM
- 2.5 MB disk
- 3 Mbit Ethernet
  - for 50 Altos
- 600x800 x 1 display
- $12,000 to make



Alto Block Diagram



Hardware

- Moore's law: live in the future if you can

	Price	X Alto	CPU MIPS	RAM MB	Disk MB	Net MB/s
1974: Alto	$40k	**1**	0.3	0.1	2.5	.05
1984: Mac	$3k	**1**	1	0.5	1.5	.03
1995: PC	$3k	**100**	50	16	300	.1
2006: PC	$1k	**10000**	2000	1000	300G	100

Hardware Comparison

Item	Alto, 1973	Desktop PC 2006	Factor
CPU clock	6 MHz	3 GHz	500
RAM size	128 KB	1 GB	8000
RAM access	850 ns	100 ns	8.5
Display pixels	606 x 808 x 1	1600 x 1200 x 32	4 (pixels) 128 (bits)
Network	3 Mb Ethernet	1 Gb Ethernet	300
Disk capacity	2.5/5 MB	250 GB	100K
Cost	$12,000 to make	$1,000 to buy	12

Key Ideas For Hardware

- KISS
  - Had to be cheap enough to build lots of them
- Bitmap display
  - Display anything – like paper
- Programmable at all levels
  - Could change the instruction set and add new operations easily
- Flexible and powerful input-output
  - Ethernet and Laser Printer controllers were add-ins
- Distributed system
  - Connect many systems together with Ethernet

Alto In Use

Alto Awaiting Restoration

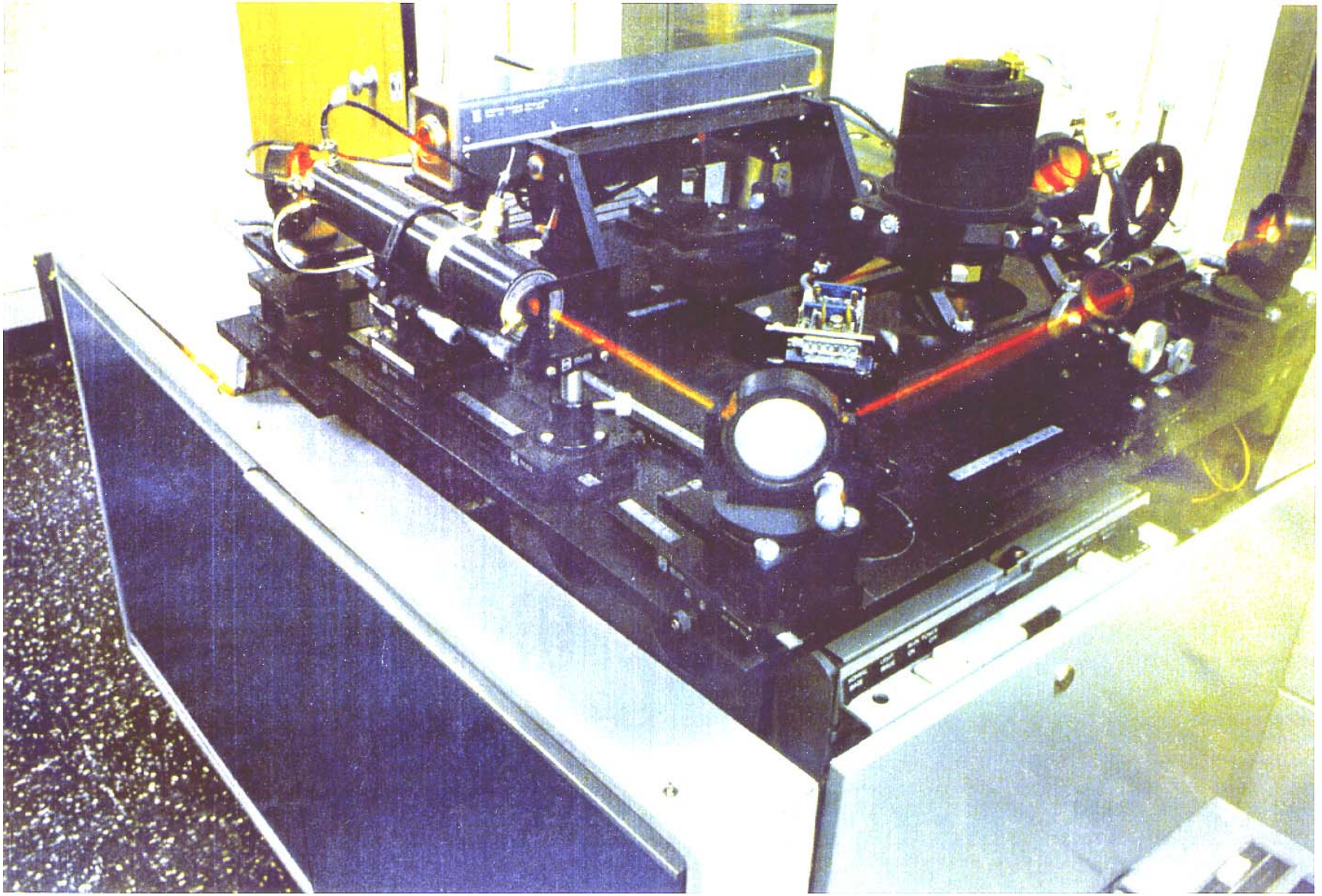
Ethernet

- CSMA/CD
  - Based on Aloha
  - Collision detect
  - Exp. Backoff
- 3 Mbits/sec
- Shared by 50 Altos
- Repeaters
- Much later, switches

Laser Printers

- Marriage of Xerography and Computing
- EARS was the first (1974) print *server*
  - **E**thernet
  - **A**lto
  - **R**esearch Character Generator
  - **S**canning Laser Output Terminal
- 1 copy/second, 500 dots/inch
- Lower-cost and color versions developed later
  - Dover: 300 dpi, small Alto interface. 100 copies
- Xerox understood it, built a successful business

SLOT Printer, 1972



The software

- Programming
- Servers
- User interface
- Applications

- Software is “thought-stuff”

Programming: OS, languages

- Main problem: live with
  - .1 MIPS, 128 KB RAM, 5 MB disk
- OS: files, programs, network, command line
  - *Open*: get rid of any parts you don't need
  - World-swap to change environments
- Languages
  - BCPL: father of C
  - Mesa
  - Smalltalk

Servers

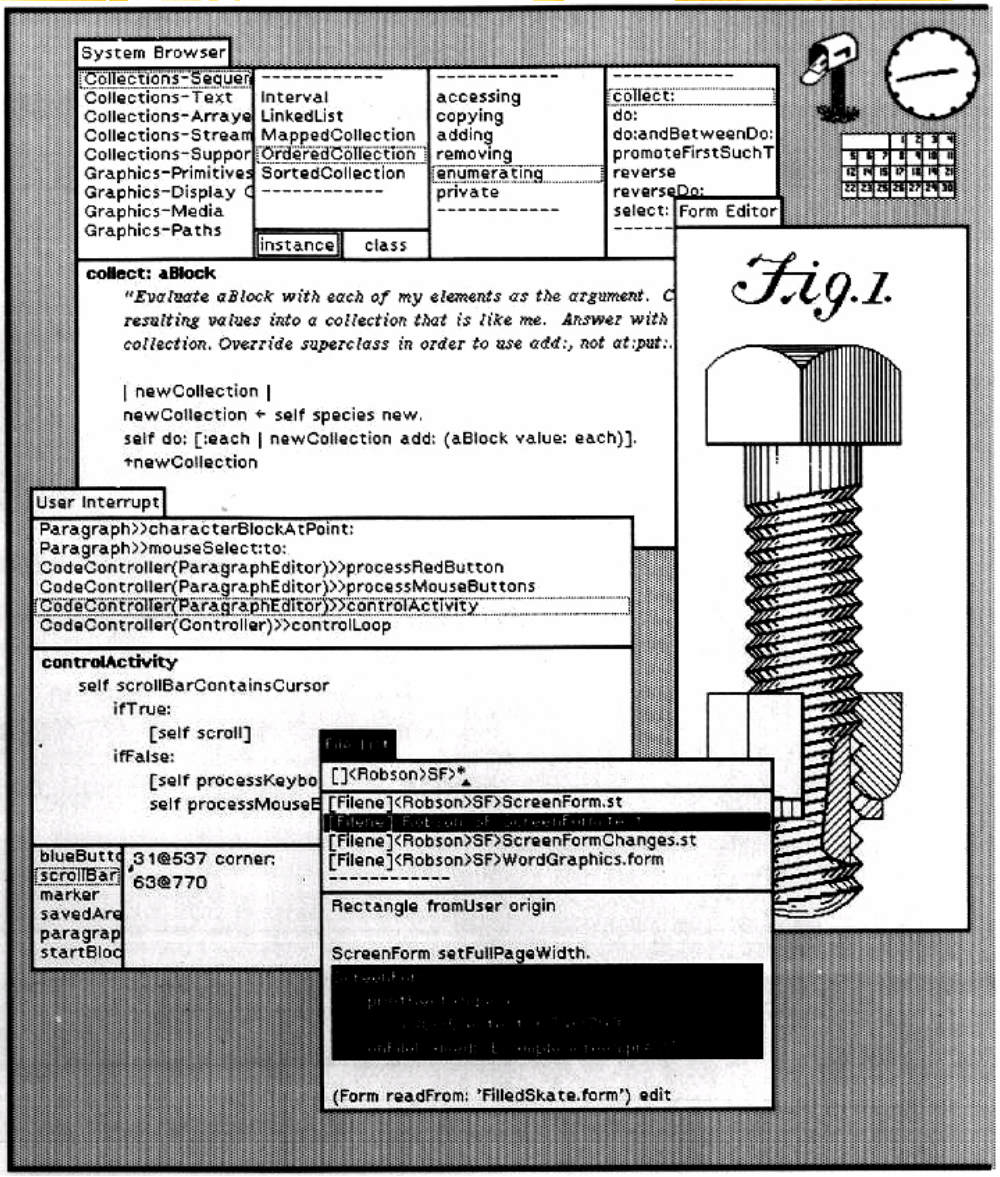
- Network: Ethernet and Pup
  - First internet: Ethernet, Arpanet, phone lines, ...
- Printing
  - 3 generations of laser printer hardware
  - 3 generations of imagers: Ears, Press, Interpress
- Files
  - “Interim” file system
  - Research file systems
- Email
  - Tenex Arpanet email
  - Grapevine distributed naming and email

User interfaces

- Windows
  - Smalltalk pioneered overlapping windows
  - Other software used tiled windows

Smalltalk

- Complete system
  - OO language
  - Integrated edit/debug
  - Windows
  - BitBlt



Bravo

- First WYSIWYG editor
- Prototype for MS Word
- Initial ideas
  - Piece table for document
  - Cache line bit maps
- Later
  - Fonts and layout
  - High-quality printing
  - Styles
- Modeless UI from Gypsy

READY: Select operand or type command
Last command was LOOK
{A␣substa...!␣way↲} {Computer... ↲XEROX↲}$

Personal Distributed Computing
The Alto and Ethernet Software

Butler W. Lampson
Digital Equipment Corp. Systems Research Center

Abstract

The personal distributed computing system based on the Alto and the Ethernet was a major effort to make computers help people to think and communicate. A complex and diverse collection of software was built to pursue this goal, ranging from operating systems, programming environments, and communications software to printing and file servers, user interfaces, and applications such as editors, illustrators, and mail systems.

1. Introduction

A substantial computing system based on the Alto [Thacker et al.

Computer Science Laboratory
Xerox Palo Alto Research Center
3333 Coyote Hill Road
Palo Alto, California 94304

XEROX

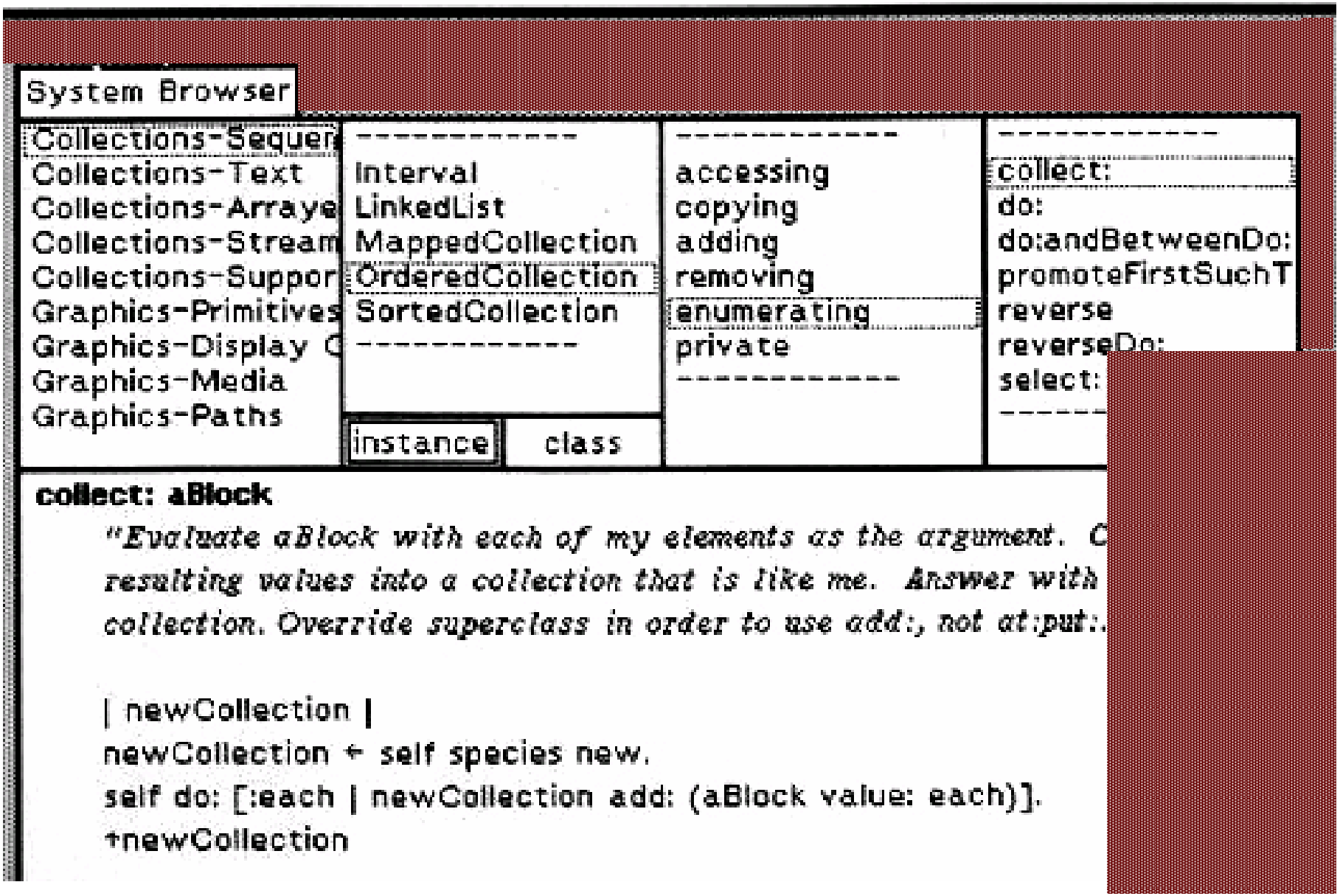
Glen J. Culler
608 Litchfield Lane
Santa Barbara, CA 93109

Dear Glen:

This is a follow-up to earlier correspondence you received from Alan Perlis regarding the ACM Conference on the History of Personal Workstations. As you know, the conference is scheduled for January

User interfaces

- Windows
  - Smalltalk pioneered overlapping windows
  - Other software used tiled windows
- Views—compute what you see
  - Smalltalk browser
  - Bravo multiple document views
  - Laurel email folders


System Browser
Collections-Sequer
Collections-Text
Collections-Arraye
Collections-Stream
Collections-Suppor
Graphics-Primitives
Graphics-Display C
Graphics-Media
Graphics-Paths
Interval
LinkedList
MappedCollection
OrderedCollection
SortedCollection
instance
class
accessing
copying
adding
removing
enumerating
private
collect:
do:
do:andBetweenDo:
promoteFirstSuchT
reverse
reverseDo:
select:
collect: aBlock
"Evaluate aBlock with each of my elements as the argument. C
resulting values into a collection that is like me. Answer with
collection. Override superclass in order to use add:, not at:put:.
| newCollection |
newCollection ← self species new.
self do: [:each | newCollection add: (aBlock value: each)].
↑newCollection

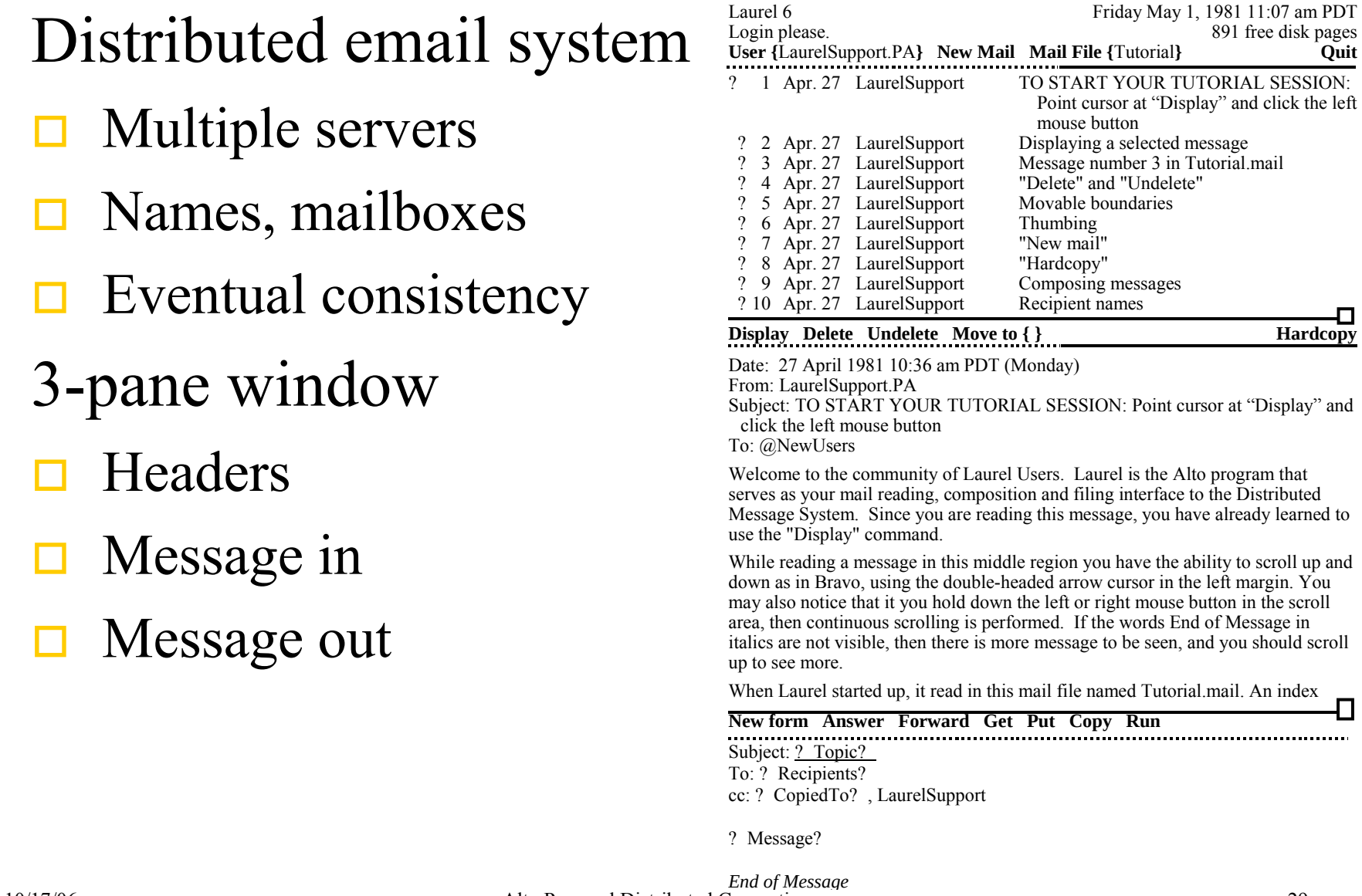
Laurel Email Header Pane

Laurel 6 Friday May 1, 1981 11:07 am PDT
Login please. 891 free disk pages
User {LaurelSupport.PA**}** **New Mail** **Mail File {**Tutorial**}** **Quit**

?	1	Apr. 27	LaurelSupport	TO START YOUR TUTORIAL SESSION: Point cursor at “Display” and click the left mouse button
?	2	Apr. 27	LaurelSupport	Displaying a selected message
?	3	Apr. 27	LaurelSupport	Message number 3 in Tutorial.mail
?	4	Apr. 27	LaurelSupport	"Delete" and "Undelete"
?	5	Apr. 27	LaurelSupport	Movable boundaries
?	6	Apr. 27	LaurelSupport	Thumbing
?	7	Apr. 27	LaurelSupport	"New mail"
?	8	Apr. 27	LaurelSupport	"Hardcopy"
?	9	Apr. 27	LaurelSupport	Composing messages
?	10	Apr. 27	LaurelSupport	Recipient names

Laurel/Grapevine

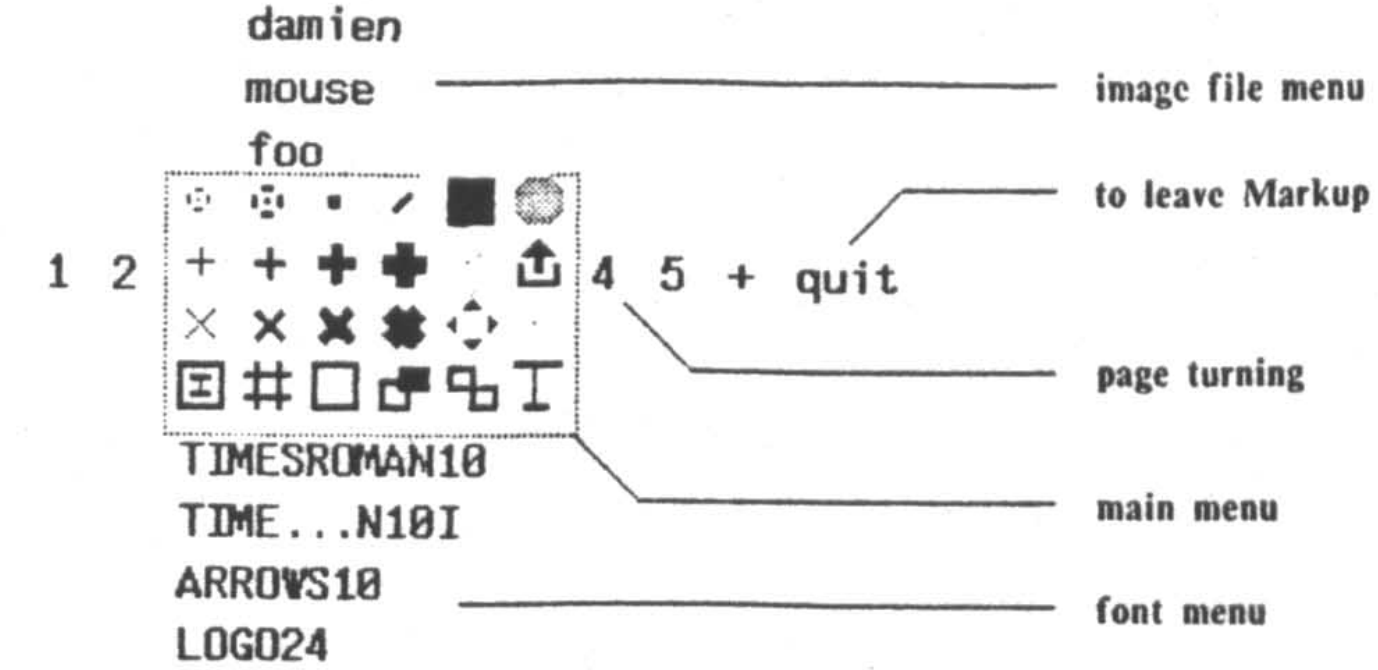
- Distributed email system
  - Multiple servers
  - Names, mailboxes
  - Eventual consistency
- 3-pane window
  - Headers
  - Message in
  - Message out

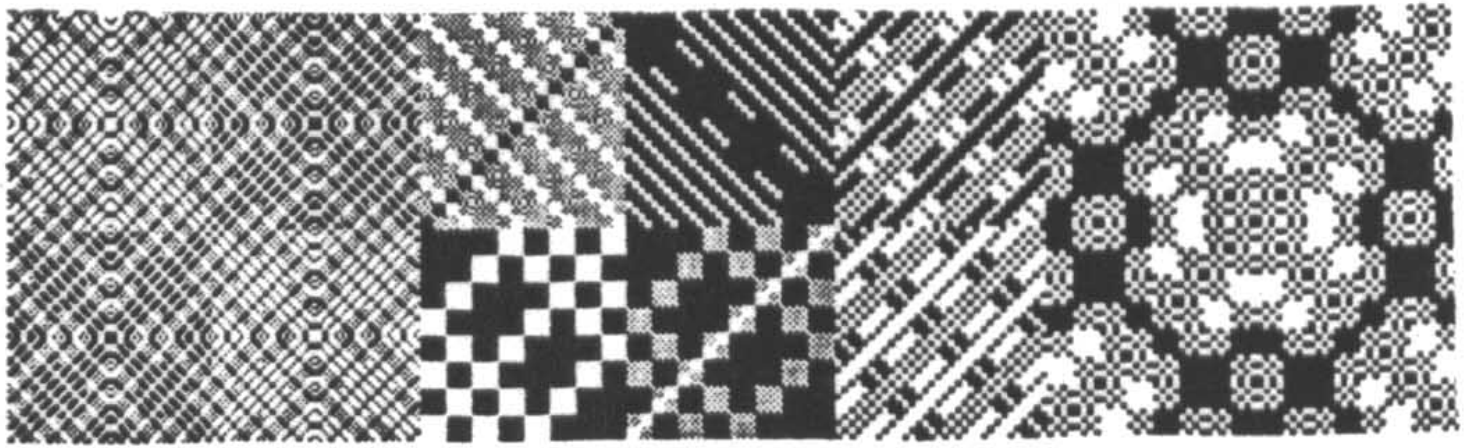


User interfaces

- Windows
  - Smalltalk pioneered overlapping windows
  - Other software used tiled windows
- Views—compute what you see
  - Smalltalk browser
  - Bravo multiple document views
  - Laurel email folders
- Menus
  - Markup had pop-up menus
  - Smalltalk had the first icons

Markup's Popup Menu



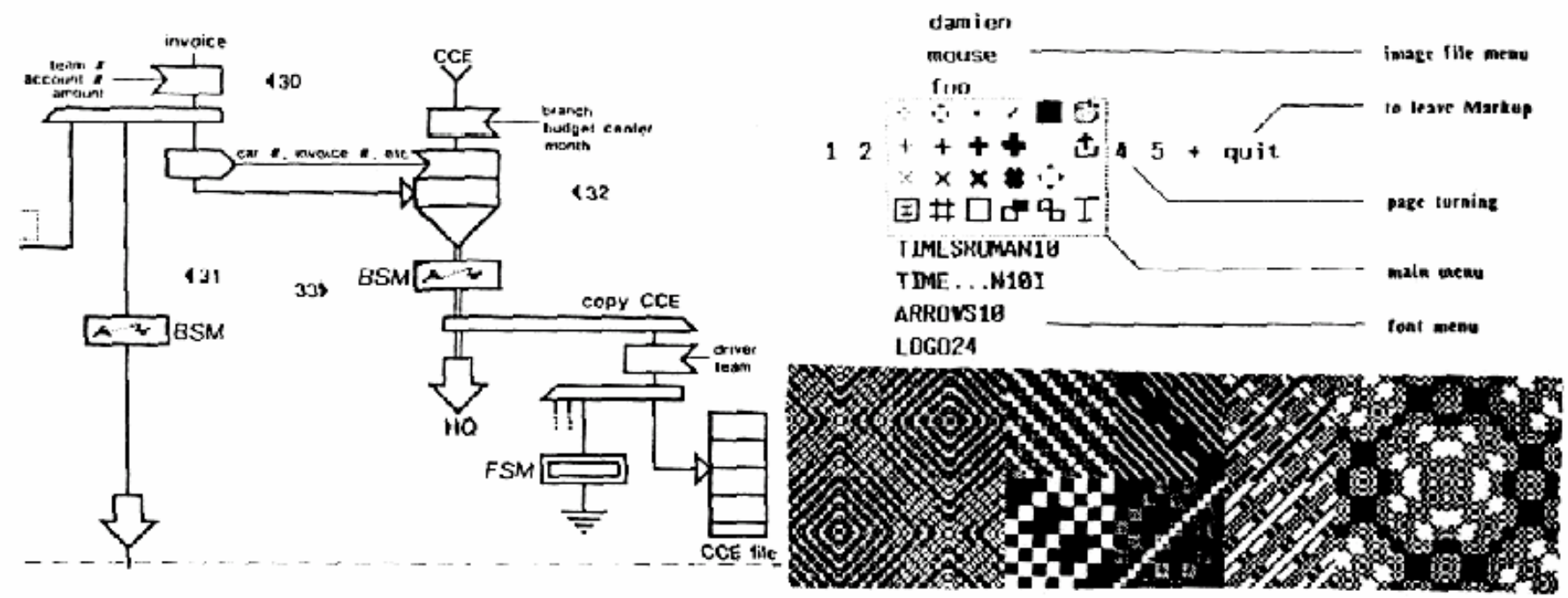


User interfaces: Displaying things

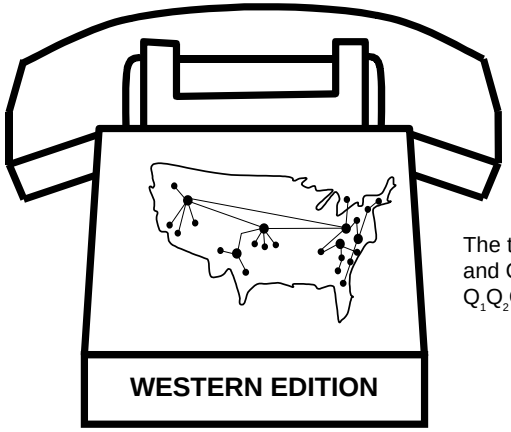
- Images
  - Bit-maps (as in Paint and Photoshop)
  - Object graphics (as in MacDraw and Illustrator)
- Fonts
  - Spline outlines for scalable fonts
  - Screen versions hand-drawn—hinting much later
- BitBlt
  - Computing with rectangular bitmaps

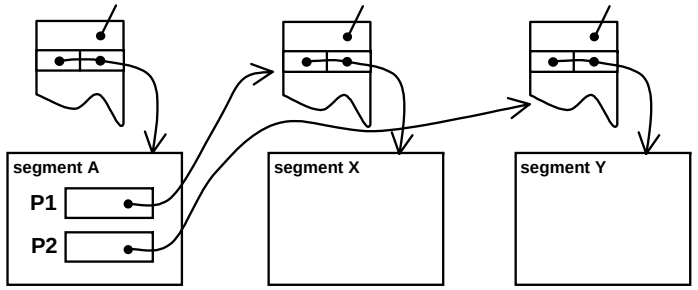
Markup

- Pure bit-map editing
  - Arbitrary images
  - Low resolution
- Popup menu

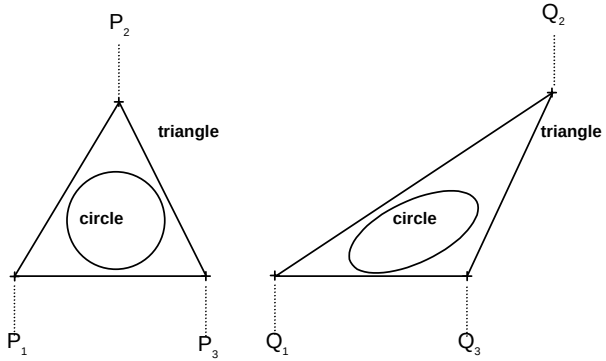


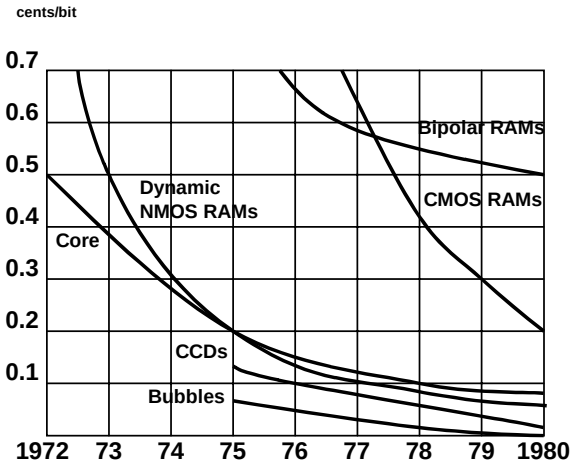
Draw

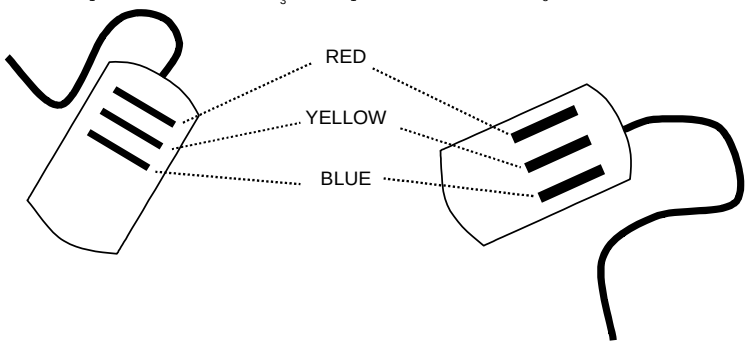




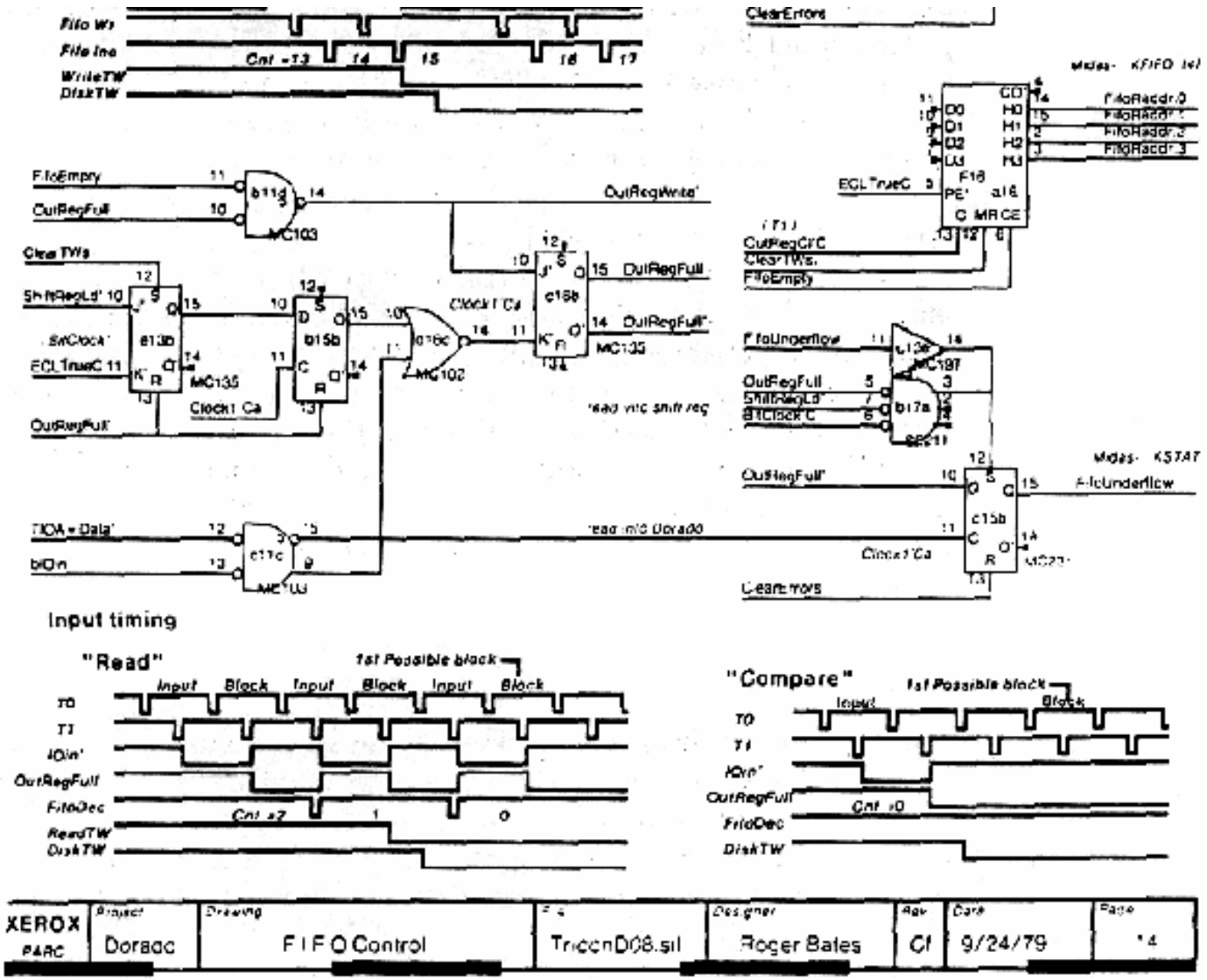
The transformation is specified by *six* points (say, in the order of input: P_1, P_2, P_3, Q_1, Q_2, and Q_3). It is defined by the mapping of the source triangle $P_1P_2P_3$ into the target triangle $Q_1Q_2Q_3$ as illustrated here:



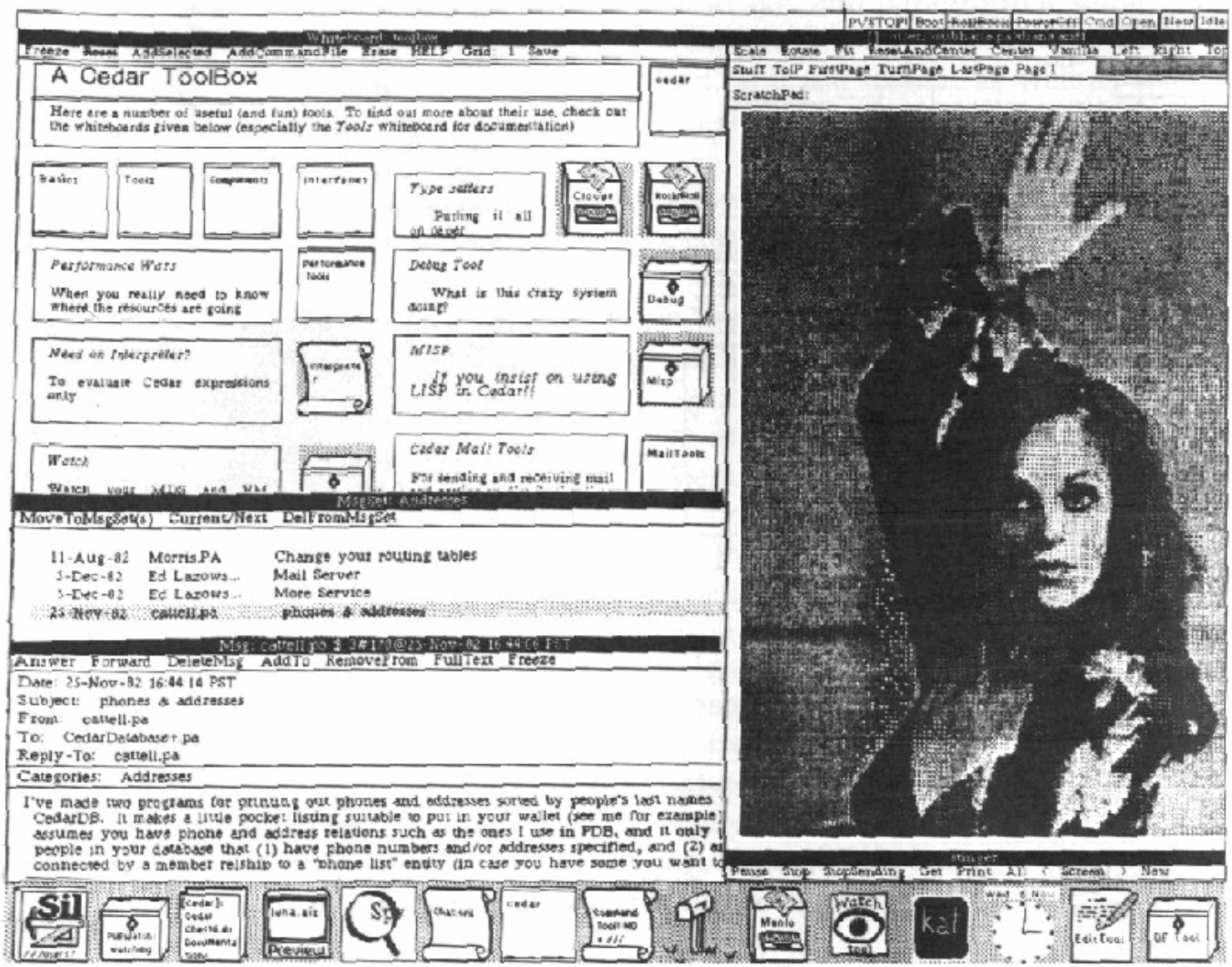




SIL for Logic Drawings



Cedar


A Cedar ToolBox
Here are a number of useful (and fun) tools. To find out more about their use, check out the whiteboards given below (especially the Tools whiteboard for documentation)
Type setters
Performance Wats
When you really need to know where the resources are going
Debug Tool
What is this crazy system doing?
Need an Interpreter?
To evaluate Cedar expressions only
MISP
If you insist on using LISP in Cedar!!
Cedar Mail Tools
Watch
MoveToMsgSet(s) Current/Next DelFromMsgSet
11-Aug-82 Morris.PA Change your routing tables
5-Dec-82 Ed Lazows... Mail Server
5-Dec-82 Ed Lazows... More Service
25-Nov-82 cattell.pa phones & addresses
Answer Forward DeleteMsg AddTo RemoveFrom FullText Freeze
Date: 25-Nov-82 16:44:14 PST
Subject: phones & addresses
From: cattell.pa
To: CedarDatabase.pa
Reply-To: cattell.pa
Categories: Addresses
I've made two programs for printing out phones and addresses sorted by people's last names
CedarDB. It makes a little pocket listing suitable to put in your wallet (see me for example)
assumes you have phone and address relations such as the ones I use in PDB, and it only
people in your database that (1) have phone numbers and/or addresses specified, and (2) a
connected by a member relship to a "phone list" entity (in case you have some you want t
ScratchPad:

Applications

- Writing: Bravo → Microsoft Word
- Drawing
  - Markup → Paint programs
  - Draw → MacDraw, Illustrator, Powerpoint, etc.
  - Sil → CAD programs
- Email: Laurel →mh, Eudora, Outlook, etc.

What the Alto system was like

- Just like today's personal computing world
  - Writing, drawing, music, networks, printing, email
- Except
  - The Web, search engines
  - Spreadsheets
  - Integration
  - Speed

Boca Raton—1976

- Big show-and-tell for Xerox execs
  - Lots of Altos
  - Ethernet
  - Laser printers
  - The apps you've seen
- Goal: Get Xerox to make products
- Result: Systems Development Division
  - Star office system
  - Limited sales of Alto office systems
    - E.g., to White House

What Xerox did with the Alto

- Electronic printing—many billions of dollars
- Xerox Star—Office system
- Fumbled the future?
  - Yes, but the real story is more interesting

- "It's easier to get a venture capitalist to give you money than to persuade the management of a large, successful company to try something new."
  —Gordon Moore

Xerox Products: Printing

- 9700—2 pages/sec computer printer
  - Based on Xerox 9200 copier
    - Hence sheet fed, good paper handling
    - Hence blue laser
  - "Character generator" based on PARC RCG
  - Competition: IBM laser printer
    - Fan-fold paper
- Low end printers
  - First for Star—8000 print server
  - Later OEMed, but too expensive
- Interpress—ancestor of Postscript

Xerox Products: Star Office System

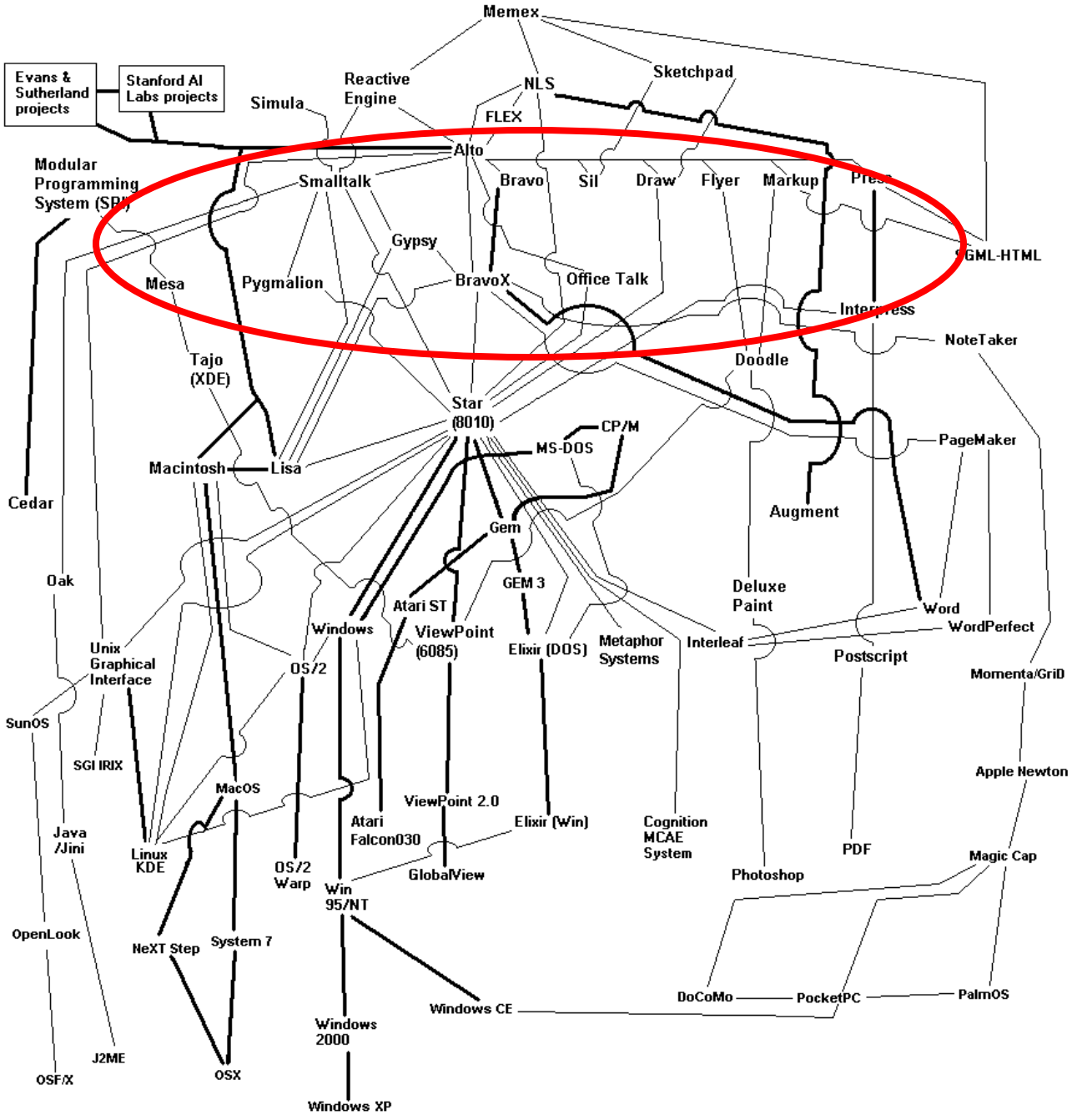
- Star, shipped 1981 (same as IBM PC)
  - Ran on Dandelion processor
- Built on Mesa and Pilot
  - Reliable, somewhat slow
- Highly integrated
  - Editing, spreadsheet, filing, printing
- Best office system for at least 10 years
  - Roughly = 1995 MS Windows /Office
  - Didn't sell—too expensive, closed
    - $20-25k/workstation in total; 25,000 sold
    - Apple Lisa in 1982 failed for the same reasons
- Irony: researchers wanted a much simpler product

What Went Wrong?

- Printing
  - Xerox focus on high end copiers and printers
    - "No money in low end"
  - Target existing markets: computer printing
    - Office printing ignored. Apple, HP won this in 1985
- Star Office System
  - Engineers had a vision, and achieved it
    - A wonderful system: 10 years ahead of its time
    - Too expensive, inflexible
  - Overwhelmed by IBM PC wave
  - Researchers pushed for something more like Alto

What Others Did with the Alto

Ethernet	Xerox-DEC-Intel
Laser printing, Postscript	Adobe, Canon, HP
Lisa, Macintosh	Apple
Windows, Word	Microsoft
Workstations	Apollo, Sun, Lisp machines
Networking	Internet, Novell
File and print servers	Novell


Memex
Evans & Sutherland projects
Stanford AI Labs projects
Reactive Engine
Simula
NLS
Sketchpad
FLEX
Alto
Modular Programming System (SPS)
Smalltalk
Bravo
Sil
Draw
Flyer
Markup
Press
GML-HTML
Gypsy
Mesa
Pygmalion
BravoX
Office Talk
Interpress
NoteTaker
Tajo (XDE)
Doodle
Star (8010)
CP/M
MS-DOS
PageMaker
Macintosh
Lisa
Cedar
Augment
Gem
Oak
GEM 3
Deluxe Paint
Word
Atari ST
Windows
ViewPoint (6085)
WordPerfect
Unix Graphical Interface
Elixir (DOS)
Metaphor Systems
Interleaf
Postscript
Momenta/GriD
OS/2
SunOS
SGI IRIX
Apple Newton
MacOS
ViewPoint 2.0
Java /Jini
Atari Falcon030
Elixir (Win)
Cognition MCAE System
Linux KDE
PDF
Magic Cap
OS/2 Warp
GlobalView
Photoshop
Win 95/NT
OpenLook
NeXT Step
System 7
DoCoMo
PocketPC
PalmOS
Windows CE
Windows 2000
J2ME
OSF/X
OSX
Windows XP

Today

- Today's PC is about 10,000 X an Alto
- Where did all the resources go?
  - Visual fidelity and elegance
  - Integration
  - Backward compatibility
  - Scale—books, not just memos
  - Time to market
  - Response time
- Did we foresee it?
  - Of course: Moore's law.

Tomorrow

- “The best way to predict the future is to invent it.”
- Are computers boring now? Hardly!
- Computers are good for three things:
  - 1955: Simulation
  - 1980: Communication
  - 2005: Embodiment—interact with the physical world
- The best is yet to come—see research.microsoft.com/gray
  - Robots
  - Computers that see, hear, talk, understand
  - Information at your fingertips