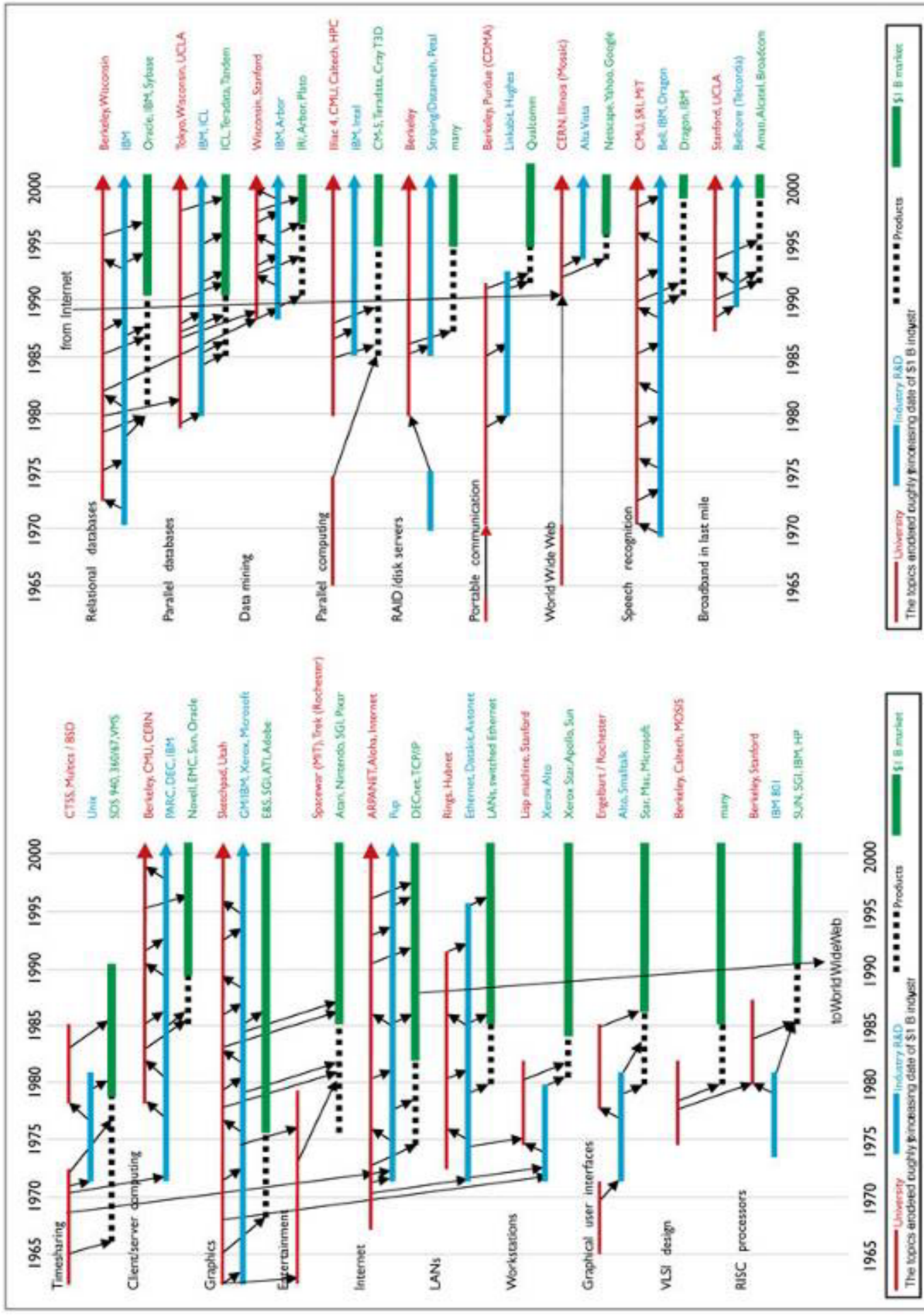


# The Role of DARPA



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History of Computing  
Autumn 2006





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# Overview of "Tire Tracks Diagram"

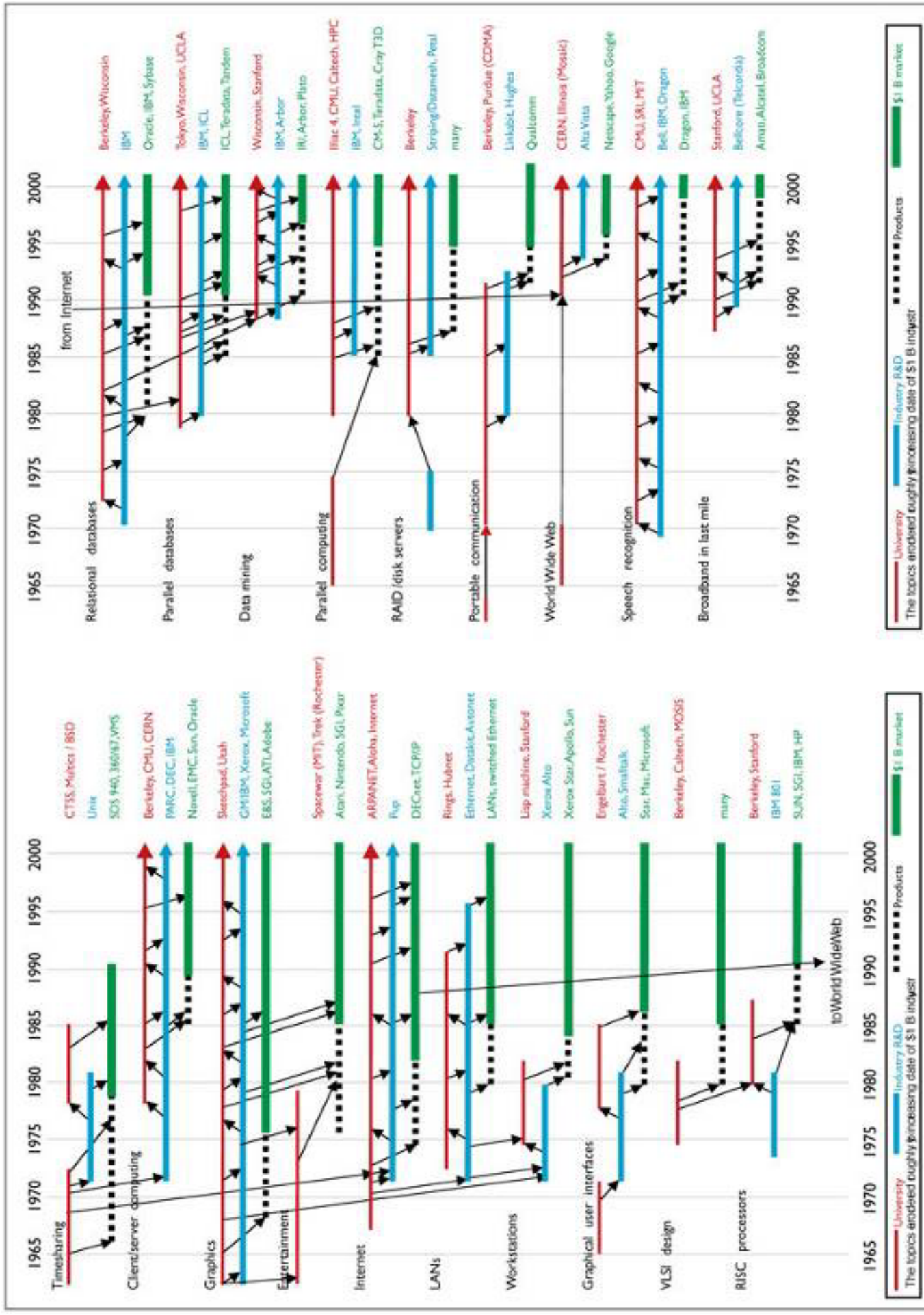
- Shows 19 \$1B (or larger) sub-sectors of IT
- Shows university research (federal funding), industry research (industry or federal funding), product introduction, \$1B market
- Shows flows within sub-sectors, and between sub-sectors
- Shows a subset of the contributors, for illustrative purposes

## Key concepts illustrated

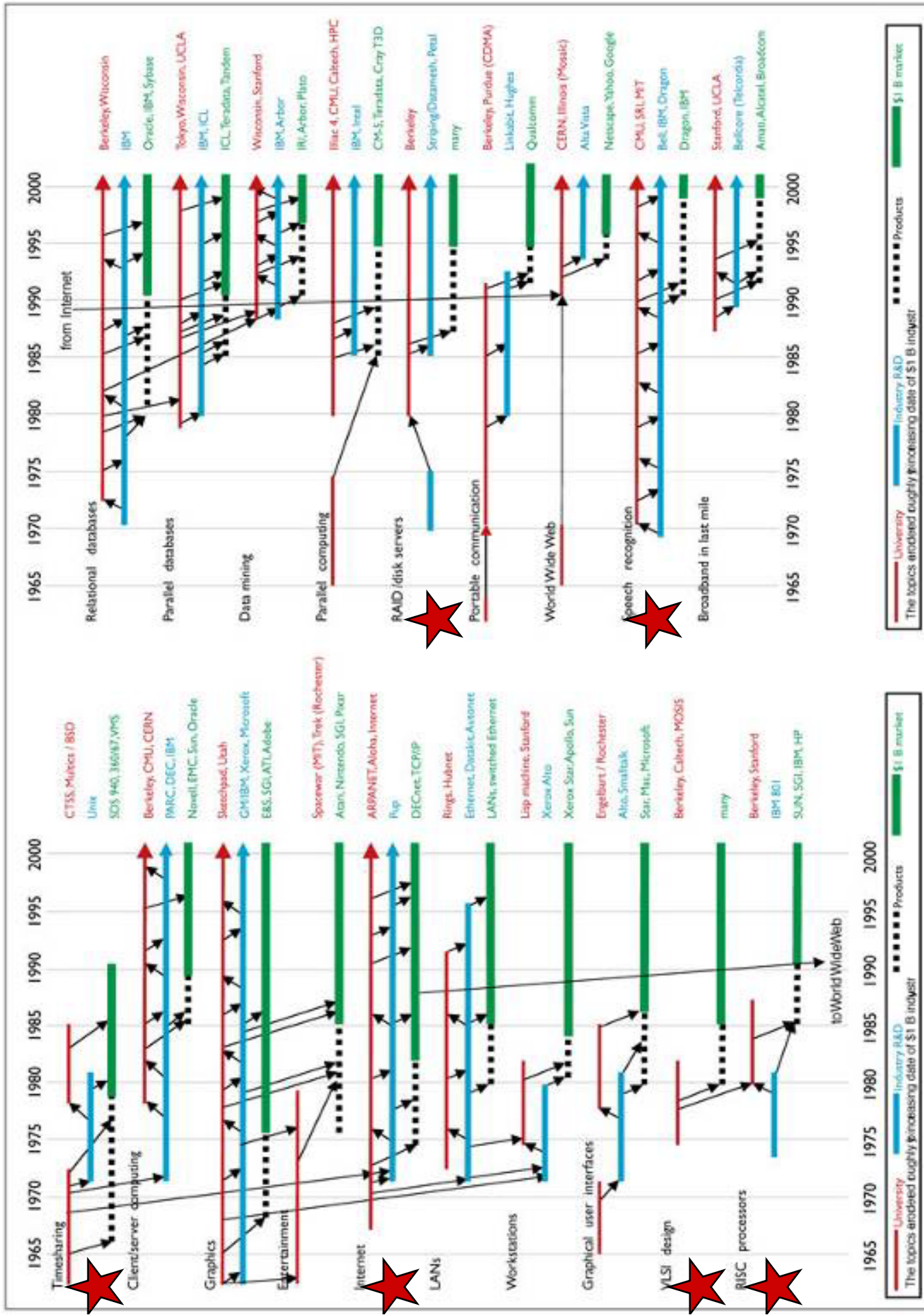
- Every major \$1B IT sub-sector bears the stamp of federal research funding
- Every sub-sector shows a rich interplay between university and industry
- It's not a "pipeline" - there's lots of "back-and-forth"
- It typically takes 10-15 years from idea to \$1B industry
- There are many research interactions across sub-fields

## Key concepts not directly illustrated

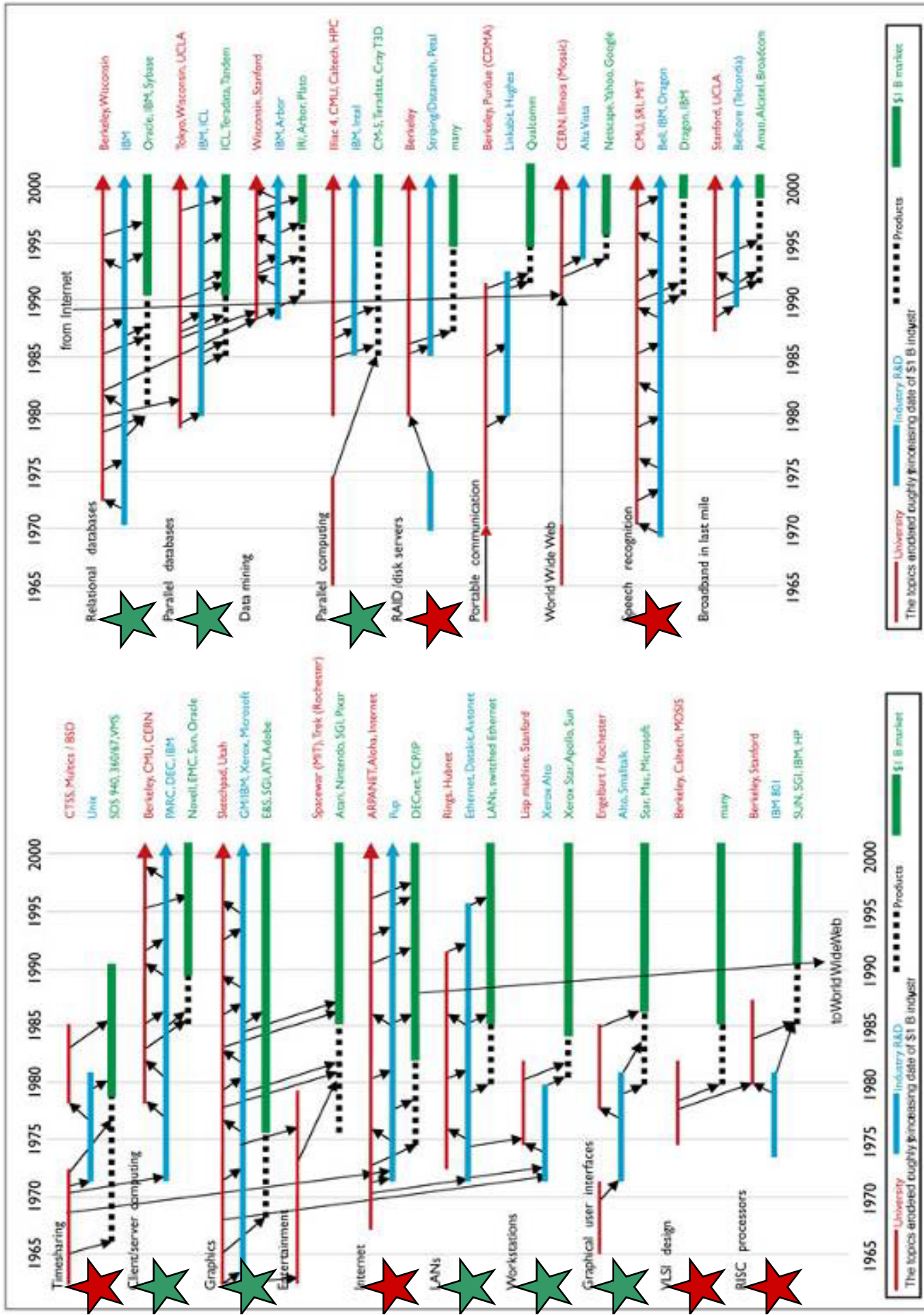
- Unanticipated results are often as important as anticipated results
- It's hard to predict the next "big hit"
- Research puts ideas in the storehouse for later use
- University research trains people
- University and industry research tend to be complementary
- Visionary and flexible program managers have played a critical role



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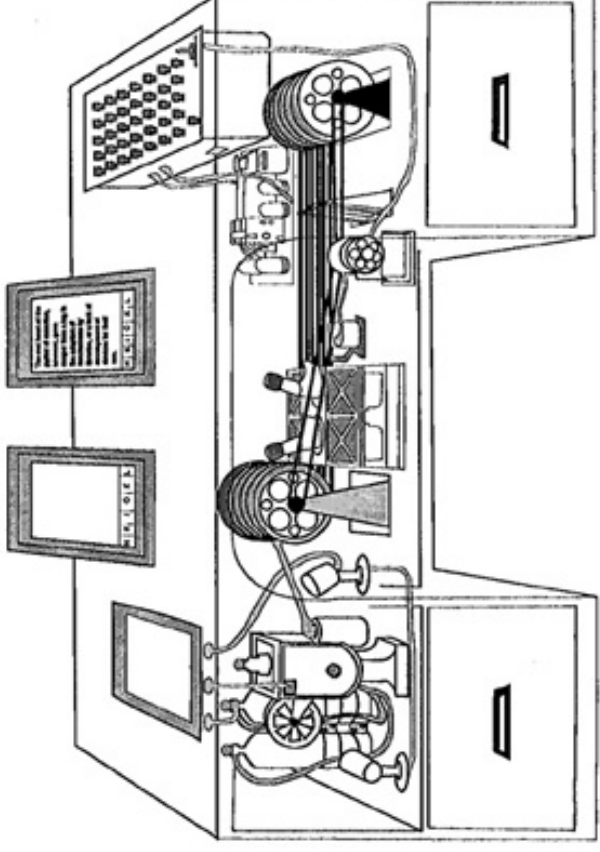




# Vannevar Bush



- Roosevelt's WW II science advisor; Director, OSRD
- "Pipeline model"; "one tent"
- *Science: The Endless Frontier*, 1945
- "One tent" fell by the wayside



# Eisenhower, Licklider

- ARPA established in 1957
- J.C.R. Licklider hired as first head of IPTO, 1962



## (D)ARPA's mission



- "DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use."

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■ *Stealth Fighter.*

■ ***Stealth Fighter***

Early efforts by DARPA led to the development of the Air Force F-117 tactical fighter that was so successful in the Desert Storm operation, flying 1,271 sorties without a single aircraft loss, penetrating air defenses, and delivering 2,000 tons of ordnance to account for some 40% of all targets with an 80%-85% hit rate.



■ *Stealth Bomber.*

■ ***Stealth Bomber***

DARPA's support to the design and fabrication of the TACIT BLUE low-observable stealth aircraft contributed directly to the development of the B-2 Stealth Bomber. Most notably, the TACIT BLUE was the first aircraft to demonstrate a low radar cross section using curved surfaces, along with a low probability of intercept radar and data link.

### ■ **Uncooled Infrared (IR) Sensors**

The U.S. military has “owned the night” because of generations of cryogenically cooled IR sensors. These sensors were a major reason for the ground victory in Desert Storm. Unfortunately, the high cost of cooled sensors has precluded wide distribution to combat troops for human-portable applications. The Low Cost, Uncooled Sensor Program (LOCUSP) at DARPA initially developed, fabricated, and demonstrated this new technology. The uncooled IR technology, furthered under DARPA’s dual-use initiatives, is a reality and has been accepted into the Army as a prototype and awaits production for fielding.



### ■ **Uncooled IR Sensors.**



### ■ **Head-Mounted Displays.**

### ■ **Head-Mounted Displays**

This program enabled soldiers to view information from a head-mounted sensor and also from a wearable computer. It developed a capability that never before existed and was not expected to exist until well into the twenty-first century.

DARPA awarded separate development contracts for miniature displays and an integrated head-mounted display system. They were mated under a technology development and integration effort. DARPA’s head-mounted subsystem is being integrated into the Army’s Land Warrior Program and the Generation II soldier. Both of these Army programs plan to upgrade their systems with DARPA-developed display technologies.



■ *Unmanned Undersea Vehicle.*

■ ***Unmanned Undersea Vehicle***

There are a number of Navy missions in the littoral that cannot be performed safely by a full-sized, manned platform. They include mine location and avoidance as well as remote surveillance. In 1988 a joint DARPA/Navy Unmanned Undersea Vehicle (UUV) Program was initiated with the goal of demonstrating that UUVs could meet specific Navy mission requirements.

The Navy initially pursued a submarine launched UUV that would either guide the submarine through an area that might be mined or search an area for mines. As a result of the end of the Cold War, the Navy revised the program with the objective of developing a tethered shallow water mine reconnaissance vehicle for littoral warfare. A system will be demonstrated in the Joint Mine Countermeasures Advanced Concept Technology Demonstration (ACTD) in 1998.



### ■ *Phased Array Radars*

DARPA pioneered the construction of large, ground-based, phased array radars, such as the FPS-85, with a program called Electronically Steered Array Radar (ESAR). The FPS-85 phased array radar had a range of several thousand miles and could detect, track, identify, and catalog earth-orbiting objects and ballistic missiles. The FPS-85 quickly became part of the Air Force SPACETRACK system and is operational today.



■ *Phased Array Radars.*



■ *Endurance Unmanned Air Vehicle.*

■ ***Endurance Unmanned Air Vehicles***

DARPA developed the first endurance unmanned aerial vehicle (UAV), Amber. DARPA-developed technologies from that and related programs led to the Gnat 750 UAV, the Air Force-operated Tier 2 Predator UAV that was used in Bosnia. Operating at altitudes of up to 25,000 feet for periods exceeding forty hours, the Predator operated successfully as an element of Exercise Roving Sands in early 1995 and has been deployed to the Bosnia crisis to support UN and NATO operations. Originally a Navy-Army joint effort, the Predator UAV was transitioned to the Air Force in 1995 for operation and maintenance



### ■ *Cermet Materials for Armor*

The Lanxide material discovered by M. Newkirk at Lanxide Corporation has resulted in hundreds of patents. Variations have been used successfully as appliqué armor for the Marine Corps' Light Armored Vehicles (LAV) in Operation Desert Storm (particularly for roof protection from artillery). This insertion was funded by the DARPA ceramic insertion program. Seventy-five LAVs were up-armored. Products were adopted in 1993 for the M-9 Armored Combat Earthmover (ACE) and for several transport aircraft, such as the C-17.

■ *Cermet Materials for Armor.*

# The Internet

- 1966: First experiments in digital packet switched technology
- 1968: ARPA issues RFQ for IMPs
  - AT&T says it'll never work, and even if it does, no one will care
- 1969: ARPANET inaugurated with 4 hosts
  - Len Kleinrock's student/programmer Charley Kline attempts remote login from UCLA SDS Sigma 7 to SRI SDS 940
  - System crashed partway through - thus, the first message on the Internet was "lo"

29 OCT 69

100

CSK

OP. PROGRAM

LOADED

EOIZ BEN BARKER

BBV

22:30

Talked to SRF

Host to Host

CSK


CSK


Left in program

running after sending

a host send message

to imp.

- 
- 1975: ARPANET has 100 hosts
  - 1977: Crufty internetworking demonstration
    - 4-network demonstration of ARPANET, SATNET, Ethernet, and PRnet - from a truck on 101 to England
  - 1980: Design of TCP/IP completed
  - 1983: Conversion to TCP/IP completed
    - Routers allowed full internetworking - "network of networks"
    - Roughly 500 hosts

- 
- 1988: ARPANET becomes NSFNET
    - Regional networks established
    - Backbone speed 56kbps
    - Roughly 100,000 hosts and 200 networks
  - 1989: CNRI interconnects MCI mail to the Internet
    - Wise policy choice
  - 1990: Backbone speed increased to 1.5Mbps by IBM and MCI
    - Roughly 250,000 hosts and 1,500 networks
    - Note: There still was “a backbone”!

- 
- 1992: NCSA Mosaic stimulates explosive growth of WWW
  - 1995: Full commercialization, at 45Mbps
    - 6,000,000 hosts, 50,000 networks
  - 2005: 400,000,000 hosts; GENI initiative conceived



# (D)ARPA I(P)TO

- J.C.R. Licklider, 1962-64
- Ivan Sutherland, 1964-65
- Bob Taylor, 1965-69
- Larry Roberts, 1969-73
- Al Blue (acting), 1973-74
- J.C.R. Licklider, 1974-75
- Dave Russell, 1975-79
- Bob Kahn, 1979-85
- Saul Amarel, 1985-87
- Jack Schwartz, 1987-89
- Barry Boehm, 1989-91
- Steve Squires, 1991-93
- John Toole (acting), 1993-94
- Howard Frank, 1994-97
- David Tennenhouse, 1997-99
- Shankar Sastry 1999-01
- Kathy McDonald (acting), 2001-02
- Ron Brachman, 2002-05
- Charlie Holland, 2005-present

# IPTO under Bob Kahn, 1979-85

- **VLSI program**
  - Mead-Conway methodology
  - MOSIS (Metal Oxide Silicon Implementation Service)
- **Berkeley Unix**
  - Needed Unix with virtual memory for the VLSI program (big designs) and the Image Understanding program (big images)
  - Also a Trojan horse for TCP/IP
  - And a common platform for much systems and application research

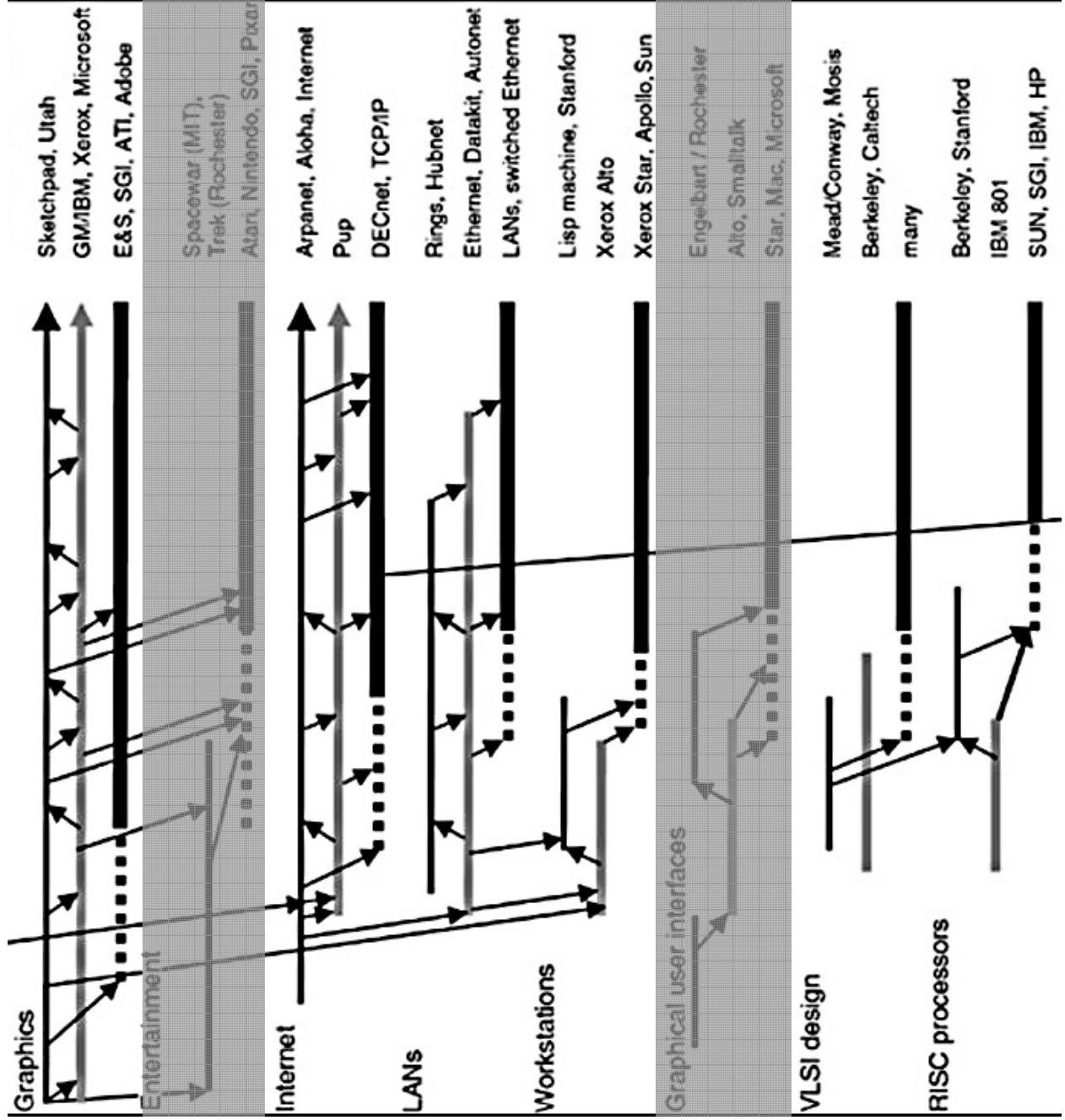


## ■ SUN workstation

- Baskett said no existing workstations could adequately handle VLSI designs (Bechtolsheim's frame buffer approach was unique)
- Kahn insisted that it run Berkeley Unix

## ■ Clear byproducts

- Sun
- SGI
- RISC (MIPS, SPARC)
- TCP/IP adoption
- Internet routers (Cisco, 3com)



# DARPA is a *mission agency*

- "DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security ..."
- Yes, DARPA has sponsored the vast majority of the groundbreaking research in speech and natural language ...

# Phraselator



## Phrase Translation Device for Military Use

- User speaks a phrase
- Automatic Speech Recognizer matches it to prerecorded translation
- Translation played through speaker
- Possible due to decades of ASR and systems research

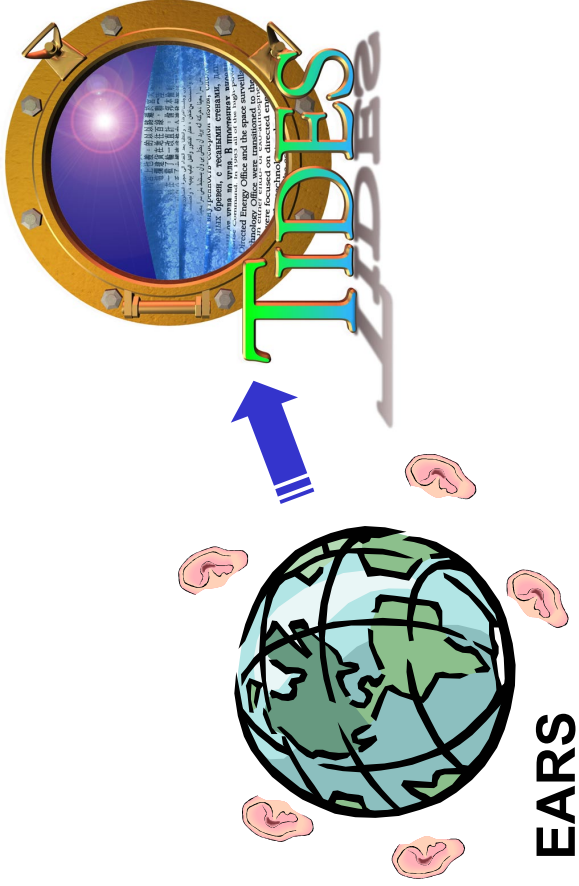
## Impact

- Deployed in Operation Enduring Freedom and Iraqi Freedom
- Facilitated time-critical information exchange when interpreters not available
  - Accepted by broad set of users
  - Interaction with civilians – information on UXOs and weapons caches

## Status

- Continued use in Iraq and Afghanistan
- Joint Forces Command fielding 800+ units
- SOCOM fielding 400 units
- Clear need for 2-way voice machine translation (VMT)

# TIDES+EARS: Automated processing of Arabic text & audio



## Automated translation and classification of foreign language text and audio

- **TIDES:** Translation – foreign language text to English text, including document classification
- **EARS:** Transcription – converts Arabic and Chinese speech to text
- **TIDES and EARS integration:** Statistical learning – robust foreign language processing to extract intelligence from open sources.

## Impact

- CENTCOM using automated processing to pull intelligence from Arabic text and audio
- English-only operators can now form a picture in their mind of what is being discussed in Arabic source material
- 100's of documents from dozens of sources translated daily; 5-10 sent to NVTC for human translation
- Technology first used by US Forces Korea


## Status

- Automatic speech recognition of English improved dramatically from 1984 to 1993. Now, equally dramatic improvement for Arabic ASR through EARS
- Text and audio processing of Arabic now possible end-to-end. Two deployment units to CENTCOM in 2004 for information exploitation from Arabic open source material

# DARPA's traditional "style"

- Small and flexible
- Flat organization
- Autonomy and freedom from bureaucratic impediments
- World-class technical staff
- Teams and networks
- Hiring continuity and change
- Project-based assignments organized around a challenge model



- 
- Outsourced support personnel
  - Outstanding program managers
  - Acceptance of failure
  - Orientation to revolutionary breakthroughs in a connected approach
  - Mix of connected collaborators