# Welcome to the

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June 8, 2004

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Nashville, Tennessee

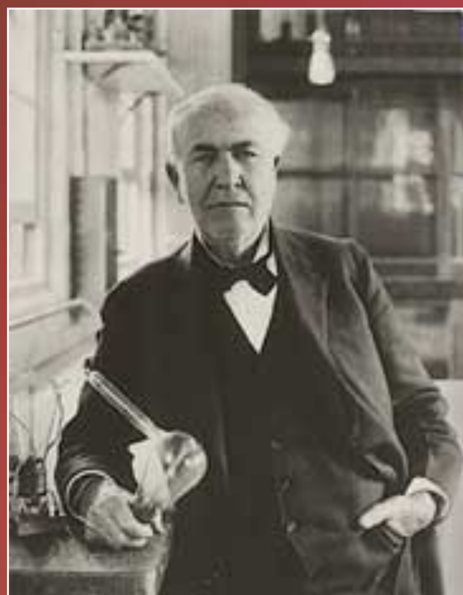
IEEE

# About the IEEE

- World's largest technical membership association with over 362,000 members in 154 countries
- Publishing in all aspects of technology
- Publishing, conferences, membership

# IEEE is. . .Entrepreneurs

*Founding officers of the American Institute of Electrical Engineers in 1884:*



Thomas A. Edison

Alexander Graham Bell

IEEE

# IEEE is. . .Innovators

*Founding member of the Institute of Radio Engineers in 1912:*

AIEE & IRE merged in 1963 to form the IEEE

**G. Marconi**

IEEE

# IEEE members are still leaders of today and tomorrow


**Herbert Kroemer**
IEEE Medal of Honor
2002
Nobel Prize 2000
Developed principles of semiconductor lasers


**Nick Holonyak**
IEEE Medal of Honor
2003
Developed the first light-emitting diode (LED)


**Tadahiro Sekimoto**
IEEE Medal of Honor
2004
Revolutionized satellite communications

IEEE

# Quality of Content

**ISI Journal Citation Report documents high quality**

- **19 of Top 22** in Electrical Eng *(203 journals analyzed)*
- **Top 7** in Telecommunications *(53 journals)*
- **11 of Top 15** in Computer Sci H'ware & Arch *(46 journals)*
    - **3 of Top 10** in Computer Theory & Methods
    - **4 of Top 10** in Software Engineering
    - **4 of Top 10** in Information Systems
    - **2 of Top 10** in Artificial Intelligence
- **3 of Top 12** in Applied Physics *(71 journals)*
- **4 of Top 10** in Manufacturing (35 journals)
- **5 of Top 15** in Automation (49 journals)
- **#1 CITED** journals in Information Systems, Imaging Science, Rehabilitation, Robotics, Electrical Eng, Telecommunications & Transportation

***Source: ISI 2002 Journal Citation Report***

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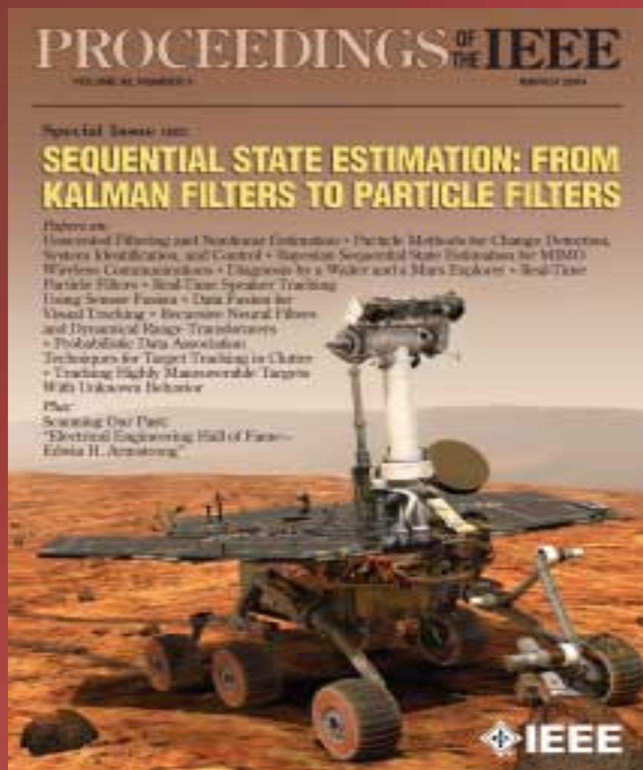
# Proceedings of the IEEE




- Perhaps the top scientific journal in technology
- IEEE will post all legacy data for this journal back to 1913 into IEEE Xplore by 2006

# Breadth of content

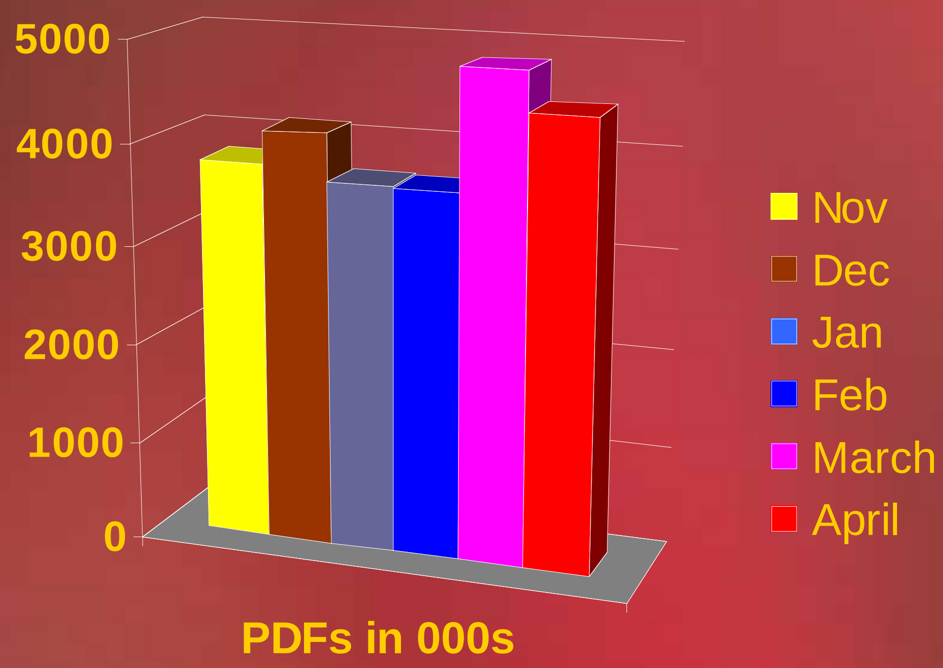
**IEEE is increasingly publishing in all areas of technology**

- Antennas
- Biomedical Eng
- Computing
- Electrical Eng
- Industrial Eng
- Nanotechnology
- Nuclear Science
- Power
- Remote Sensing
- Security

- Aerospace
- Circuits
- Communications
- Energy
- Info Technology
- Optics
- Radiology
- Software
- Transportation
- Wireless

# IEEE Xplore delivers over 3.5 million articles each month

*Nov'03 –April '04 IEEE Xplore Statistics*




- 1.5 million unique users each month
- 80,000 users/day
- Peak time 4am 83,000 visitors
- Usage doubled in 2003

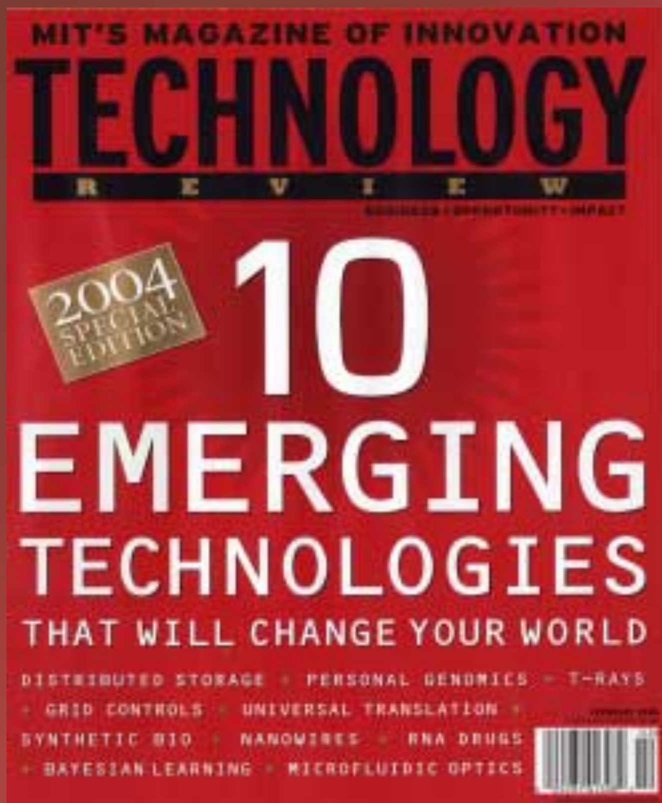
IEEE

# Science Direct v. Xplore Usage 2003

| Science Direct | IEEE Xplore |
|---|---|
| 5 million articles available | 1 million articles available |
| 175 million downloads | 45 million downloads |
| Average 35 downloads/article | Average 45 downloads/article |

Xplore is being used more!

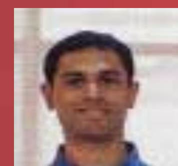
Source: Reed Elsevier Annual Review 2003




- Technology Review, Feb 2004 Special Edition
  - Ideas that MIT predicts will "affect our lives & work in revolutionary ways"

# “10 emerging technologies that will change your world”

Universal translation



Distributed storage

Synthetic biology

RNAi therapy

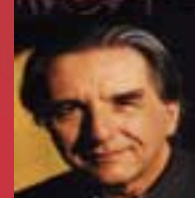
Nanowires

Power grid control

Bayesian learning machine

Microfluidic optical fibers

T-Rays



Personal genomics

IEEE

# "10 emerging technologies that will change your world"

Computer science

Work is in IEL

Biology

Physics

Work is in IEL

Computer science

Biomedical engineering

Work is in IEL

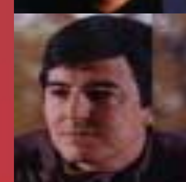
Computer science

Work is in IEL

Biochemistry

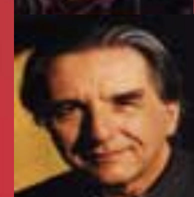
Electrical engineering

Work is in IEL



Physics

Work is in IEL



Biology

# Universal Translation

## Yuqing Gao

- Computer scientist at IBM
- PDA software that translates phrases in one language into any other language
- Ready for deployment late 2004 and widespread in 10 years
- Paper at IEEE ICASSP Conference in April 1987
- 137 other papers on machine translation in IEL

IEEE

# T-Rays
## Don Arnone


- CEO of TeraView, a Toshiba spinoff
- Terahertz radiation easily penetrates common materials
- Will transform medical imagining and security screening
- Paper at IEEE Biomedical Engineering conference in Sept 1988
- 112 other papers on T-Rays in IEL

IEEE

# Power Grid Control

## Christian Rehtanz

- VP of power system technology at ABB
- Hardware & intelligent software to track electric flows continent-wide several times per second
- Will make power outages 100 times less likely
- Paper in IEEE trans on Power Systems in Nov 1999
- 369 other papers on power grids in IEL

# "10 emerging technologies that will change the world"

- 6 out of these 10 innovators publish with IEEE
- All published <u>many years</u> before MIT's cover article
- Many papers were presented at IEEE conferences
- Papers span physics, biomedical engineering, computer science, not just EE
- Over 200 papers on personal genomics in IEL

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# BusinessWeek

March 8, 2004 issue

- In March 2002 asked CHI Research, Inc. for its Top 10 stock picks
  - Half the names "new" to BW
- Since then CHI's picks returned 59.2%/year
  - NASDAQ 4.2%
  - S&P 6.1%
- CHI's 2003 picks returned 162%
  - Average tech stock mutual fund 55.9%
- BW calls CHI "search engine for tech prospectors"

IEEE

# R&D and Patents

## CHI's Basic Idea

- CHI examines patents as predictor of a company's market value
  - Patent portfolio is a product of R&D spending
  - Most valuable patents cite research papers ("science linkage") vs. other patents
  - Science linkage means idea is closer to basic science – fresher than ideas based on existing products

# Citation Analysis

## CHI's Basic Idea

- If you invent a new widget, you must cite all prior art
- New patents cite to older developments
- A patent that receives many forward citations is said to be highly cited

# Sci/Tech Literature and Patent Citations

### CHI's Basic Idea

- Highly cited patents correlate with inventor awards, increases in sales, profits, stock rises, patent licensability, and successful products
- Citation impact is a proxy for quality, and ultimately value

Based on articles in Business Week, MIT Technology Review, Bloomberg Personal Finance, and a study commissioned by IEEE and conducted by CHI Research, May 2003

IEEE

# Top patenting firms in 2002

| Top 15 Patenting Firms 2002 | | |
|---|---|---|
| Rank | Organization | #US Patents |
| 1 | IBM | 3334 |
| 2 | Canon Inc | 1937 |
| 3 | NEC Corporation | 1920 |
| 4 | Hitachi Ltd | 1882 |
| 5 | Micron Technology, Inc. | 1851 |
| 6 | Matsushita Electric | 1712 |
| 7 | General Electric Co | 1681 |
| 8 | Sony Corporation | 1601 |
| 9 | Samsung Group | 1563 |
| 10 | Mitsubishi Electric Corp | 1474 |
| 11 | Hewlett-Packard Company | 1391 |
| 12 | Fujitsu Limited | 1368 |
| 13 | Siemens AG | 1357 |
| 14 | Toshiba Corporation | 1352 |
| 15 | Koninklijke Philips Electronics | 1276 |

| Other Notable Firms and Universities | | |
|---|---|---|
| Rank | Organization | #US Patents |
| 16 | Advanced Micro Devices | 1152 |
| 17 | Intel Corp | 1088 |
| 19 | Lucent Technologies | 818 |
| 21 | Motorola Inc | 778 |
| 22 | Ericsson (LM) Telephone | 767 |
| 23 | Texas Instruments | 744 |
| 26 | Xerox Corporation | 702 |
| 39 | Microsoft Corp | 515 |
| 40 | Sun Microsystems Inc | 505 |
| 42 | University of California | 466 |
| 136 | MIT | 152 |
| 178 | Cal-Tech. | 117 |
| 194 | Stanford University | 110 |
| 197 | Dell Computer Corp | 108 |
| 201 | University of Texas | 106 |

IEEE

# A Patent from Texas Instruments

**United States Patent** [19]

**Glover**

[11] **Patent Number: 6,101,229**

[45] **Date of Patent: Aug. 8, 2000**

[54] **DATA SYNCHRONIZATION METHOD AND CIRCUIT USING A TIMEOUT COUNTER**

[75] Inventor: **Kerry C. Glover**, Wylie, Tex.

[73] Assignee: **Texas Instruments Incorporated**, Dallas, Tex.

[21] Appl. No.: **08/819,314**

[22] Filed: **Mar. 18, 1997**

**Related U.S. Application Data**

[60] Provisional application No. 60/014,858, Apr. 4, 1996.

[51] **Int. Cl.**[7] .................................... **H04L 7/00**

[52] **U.S. Cl.** ...................... **375/354**; 375/365; 375/368; 375/369

[56] **References Cited**

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|---|---|---|---|
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| 5,692,021 | 11/1997 | Walker | 375/354 |
| 5,809,091 | 9/1998 | Barrow | 375/354 |

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(List continued on next page.)

*Primary Examiner*—Stephen Chin
*Assistant Examiner*—Mohammad Ghayour
*Attorney, Agent, or Firm*—W. Daniel Swayze, Jr.;

[57] **ABSTRACT**

A data synchronization method and circuit are provided. A data synchronization circuit (**28**) includes a header timer (**40**), a timeout counter (**44**), a compare circuit (**46**), and a synchronization field register (**48**) for use in a read channel (**10**). During a read operation in the read channel (**10**), the data synchronization circuit (**28**) searches for the presence of a synchronization field in a read signal indicating that user data will be provided next. The search occurs over a predefined period of time. The header timer (**40**) enables a header timer signal for a first predefined period of time. The timeout counter (**44**) receives the header timer signal and enables a timeout counter signal for a second predefined period of time after the first predefined period of time expires. The compare circuit (**46**) compares the read signal to the known value or synchronization field stored in the synchronization field register (**48**). This comparison occurs during the second predefined period of time, the time in which the timeout counter signal is enabled to determine if a synchronization field is present in the read signal. Finally, the compare circuit (**46**) provides a synchronization detect signal that indicates whether a synchronization field was found during the second period of time.

Science Linkage

References to IEEE Publications

# IEEE Drives Blockbuster Patents

- Over 1,000 US patents are highly cited and reference 3+ IEEE articles.
- IEEE provides much of the science base for key technologies

# Flash EEPROM Array 1991

## A Blockbuster Patent

- Advanced Micro Devices patent
  - Enables Flash memory devices to operate from single power supply
- Builds on 12 IEEE articles
- 198 citations from later patents
- Significant royalties for AMD

# Spread Spectrum Multiple Access 1990

### A Blockbuster Patent

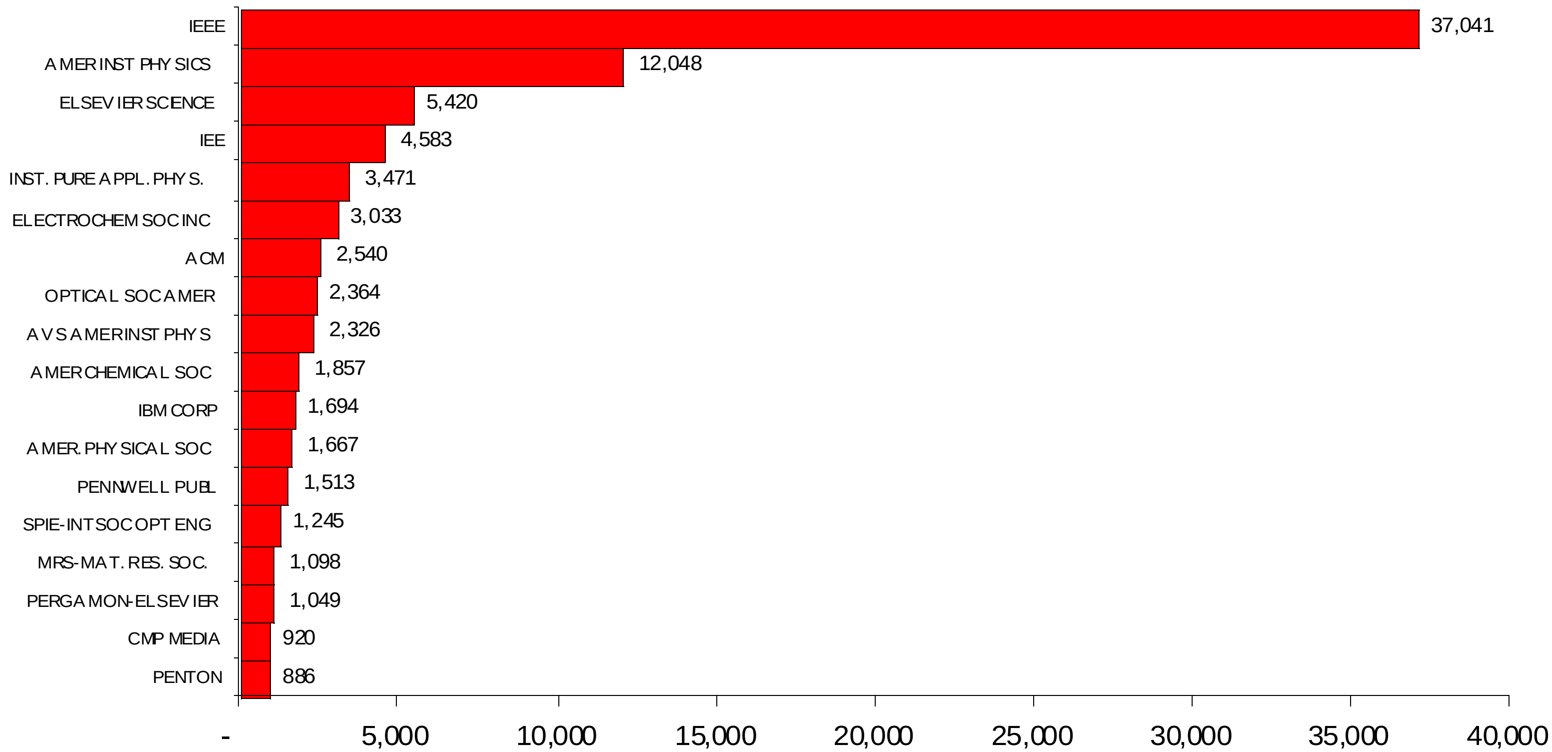
- Qualcomm, Inc.
  - CDMA technology – the North American standard for wireless phones
- Builds on 4 IEEE articles
- Cited 536 times by later patents, among the highest cited patents in the entire US patent system

# IEEE dominates invention

- Patenting increased 76% in the last decade
- Referencing to IEEE papers increased 267% in the last decade
- While patenting is increasingly important, IEEE's importance is growing at a faster rate

IEEE

# Number of patent citations from Top 25 organizations to top publishers




*Publishers compiled from all journals referenced 100+ times total from 18 organizations.

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# Patent Citations to IEEE Journals are Broad-Based

**62 IEEE Journals with 100+ patent citations**

| IEEE Journal | Citations from Patents 1985-2002 |
|---|---|
| Solid State Circuits | 10,639 |
| lectron Devices | 8,724 |
| roceedings of the IEEE | 6,577 |
| ommunications | 6,100 |
| agnetics | 5,965 |
| Computers | 4,602 |
| . Quantum Electronics | 4,040 |
| 8. Electron Device Letters | 3,803 |
| 9. Signal Processing | 3,356 |
| 10. Photonics Technology Letters | 2,927 |

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Technology Review's *most innovative companies worldwide*

# Patent Scorecard 2004


***Source: Technology Review May 2004; IEEE Sales & Mktg***

IEEE

# Four new IEEE journals in 2004

- Computational Biology & Bioinformatics
- Dependable & Secure Computing
- Automation Science & Engineering
- Geoscience & Remote Sensing Letters

# Two new IEEE journals in 2005

- Display Technology
- Industrial Informatics

# New! IEEE Enterprise

- New product for small technology companies
- Sells journal & conference proceedings articles in chunks
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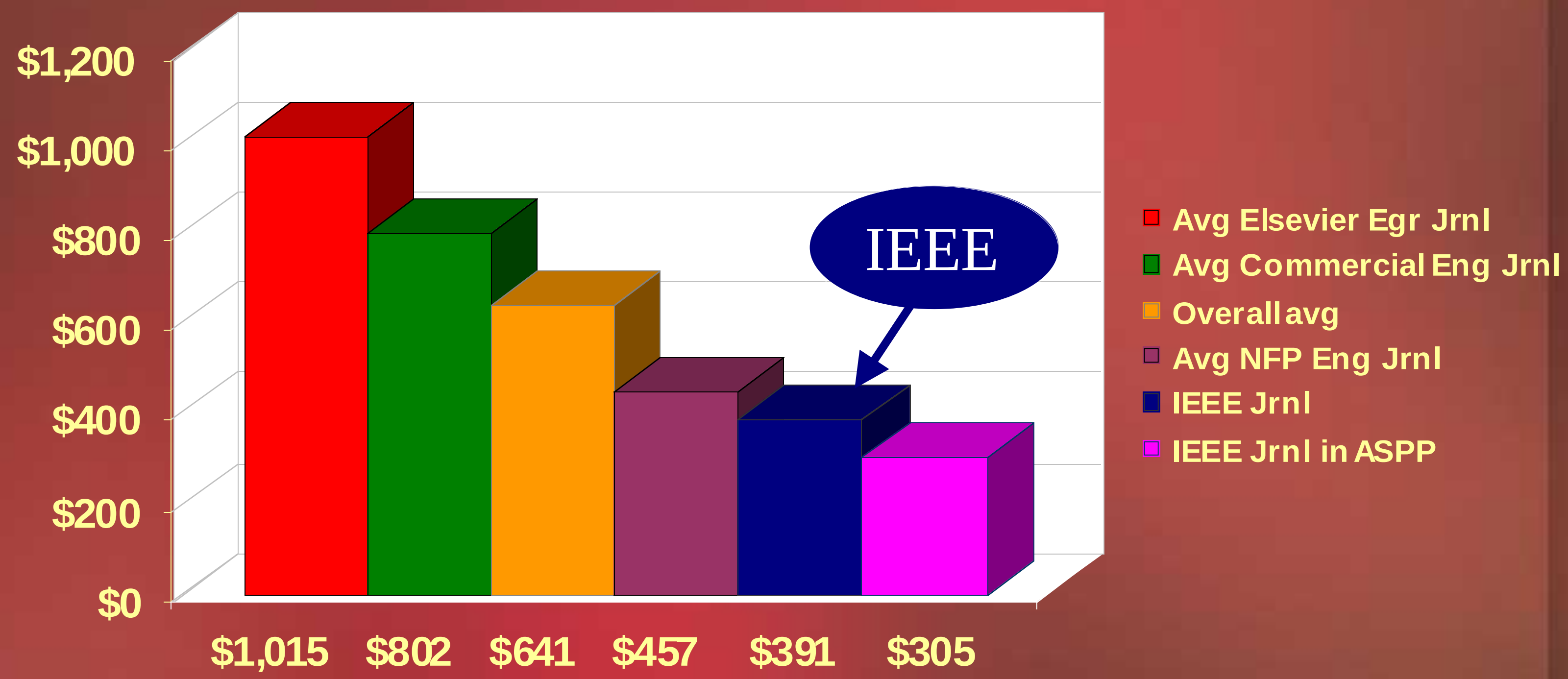
# 2004 Prices of Engineering Journals




IEEE is 61% of market average

# 2005 IEEE Prices

But print prices will be greater

| Product | % inc. |
|---|---|
| IEL | 4.0% |
| ASPP online | 4.3% |
| POP online | 4.3% |
| POP All Online | 2.4% |
| IEEE Enterprise | No change |
| Member Dig Library | No change |

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# IEEE Product Development Updates

Barbara H. Lange
Director, Publications Product Line Management and Business Development

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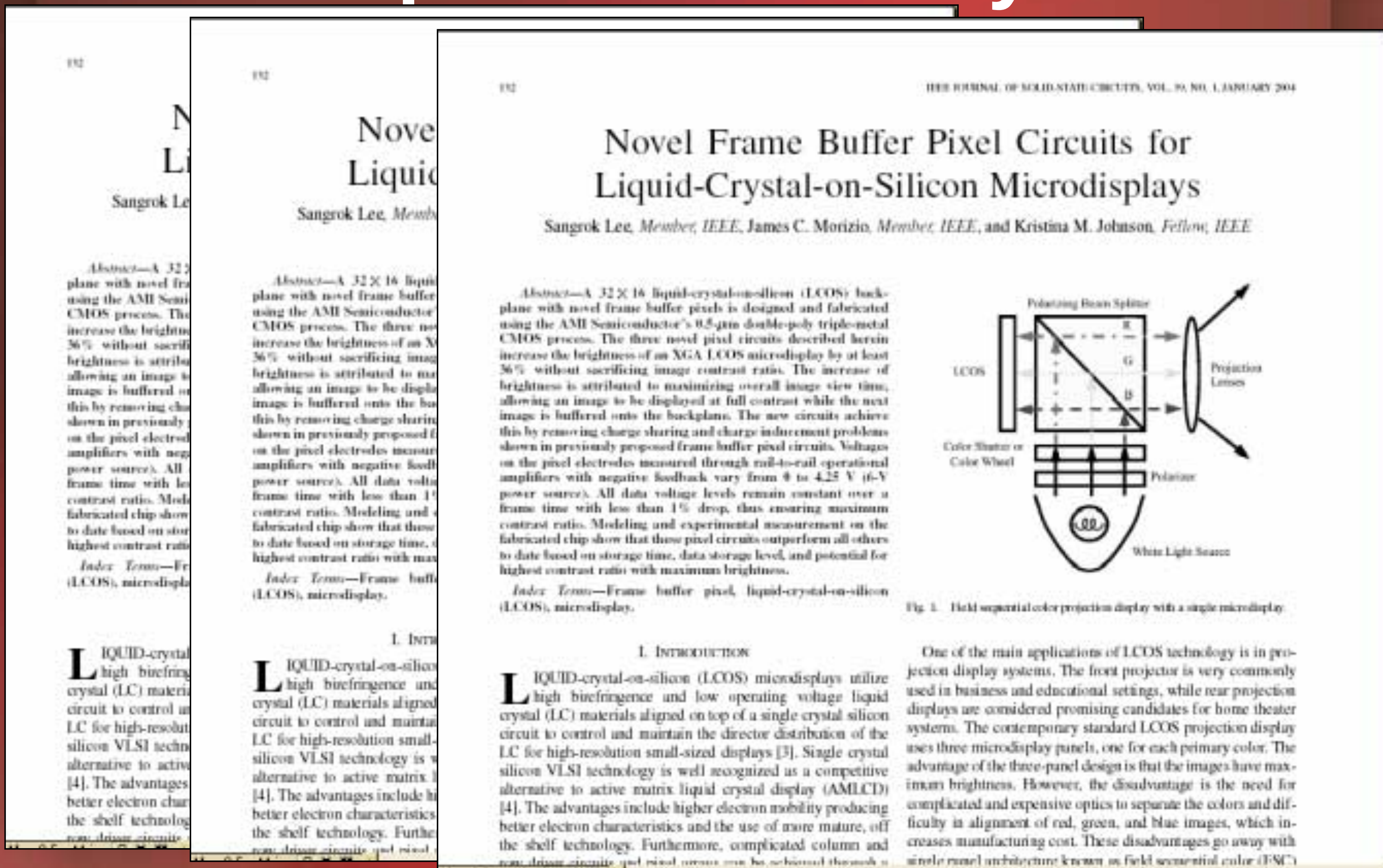
# One Millionth Article Posted to IEEE Xplore in January 2004





## Novel Frame Buffer Pixel Circuits for Liquid-Crystal-on-Silicon Microdisplays

Sangrok Lee, *Member, IEEE*, James C. Morizio, *Member, IEEE*, and Kristina M. Johnson, *Fellow, IEEE*

*Abstract*—A 32 × 16 liquid-crystal-on-silicon (LCOS) backplane with novel frame buffer pixels is designed and fabricated using the AMI Semiconductor's 0.5-μm double-poly triple-metal CMOS process. The three novel pixel circuits described herein increase the brightness of an XGA LCOS microdisplay by at least 36% without sacrificing image contrast ratio. The increase of brightness is attributed to maximizing overall image view time, allowing an image to be displayed at full contrast while the next image is buffered onto the backplane. The new circuits achieve this by removing charge sharing and charge inducement problems shown in previously proposed frame buffer pixel circuits. Voltages on the pixel electrodes measured through rail-to-rail operational amplifiers with negative feedback vary from 0 to 4.25 V (6-V power source). All data voltage levels remain constant over a frame time with less than 1% drop, thus ensuring maximum contrast ratio. Modeling and experimental measurement on the fabricated chip show that these pixel circuits outperform all others to date based on storage time, data storage level, and potential for highest contrast ratio with maximum brightness.

*Index Terms*—Frame buffer pixel, liquid-crystal-on-silicon (LCOS), microdisplay.

### I. Introduction

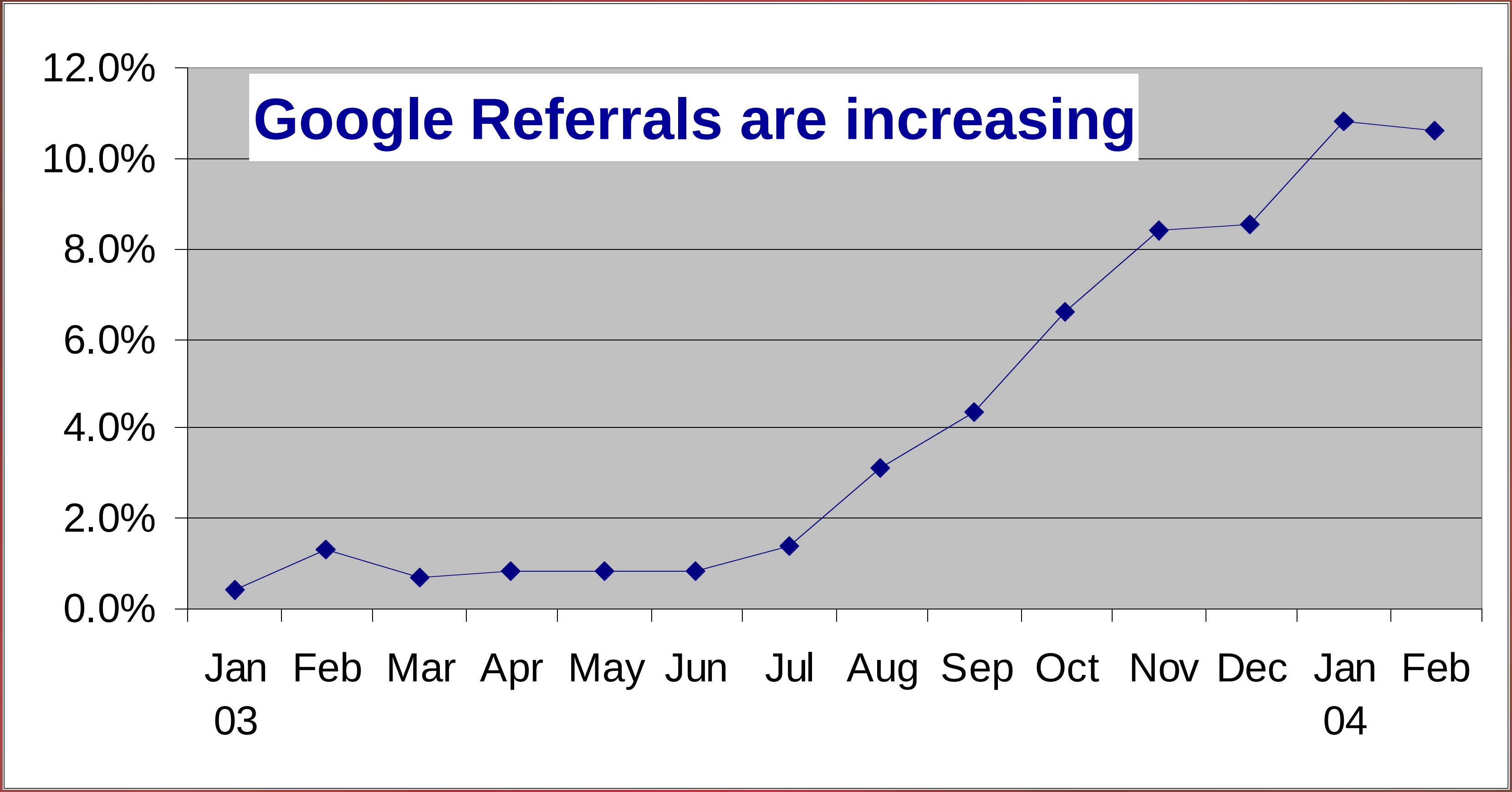
LIQUID-crystal-on-silicon (LCOS) microdisplays utilize high birefringence and low operating voltage liquid crystal (LC) materials aligned on top of a single crystal silicon circuit to control and maintain the director distribution of the LC for high-resolution small-sized displays [3]. Single crystal silicon VLSI technology is well recognized as a competitive alternative to active matrix liquid crystal display (AMLCD) [4]. The advantages include higher electron mobility producing better electron characteristics and the use of more mature, off the shelf technology. Furthermore, complicated column and row driver circuits and pixel arrays can be achieved through a

Polarizing Beam Splitter
LCOS
R
G
B
Projection Lenses
Color Shutter or Color Wheel
Polarizer
White Light Source

Fig. 1. Field sequential color projection display with a single microdisplay.

One of the main applications of LCOS technology is in projection display systems. The front projector is very commonly used in business and educational settings, while rear projection displays are considered promising candidates for home theater systems. The contemporary standard LCOS projection display uses three microdisplay panels, one for each primary color. The advantage of the three-panel design is that the images have maximum brightness. However, the disadvantage is the need for complicated and expensive optics to separate the colors and difficulty in alignment of red, green, and blue images, which increases manufacturing cost. These disadvantages go away with single panel architecture known as field sequential color (FSC)

# Google Continues to Drive Users to IEEE Xplore

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# IEEE Xplore Upgrades Add Convenience & Reliability

- Release 1.6 of IEEE Xplore – December 2003
  - Upgrade to search engine: Verity K2
  - Subscription identifier makes it easier for users to know what they may view
  - Introduce complete coverage of content
- "Warm" Failover Site - 15 April 2004
  - Mini IEEE Xplore Configuration: 1/2 capacity, but always on, always updated (content, permissions)
  - In disaster can be online within 1 hour
  - At SunGuard (IEEE's Business Continuity vendor)

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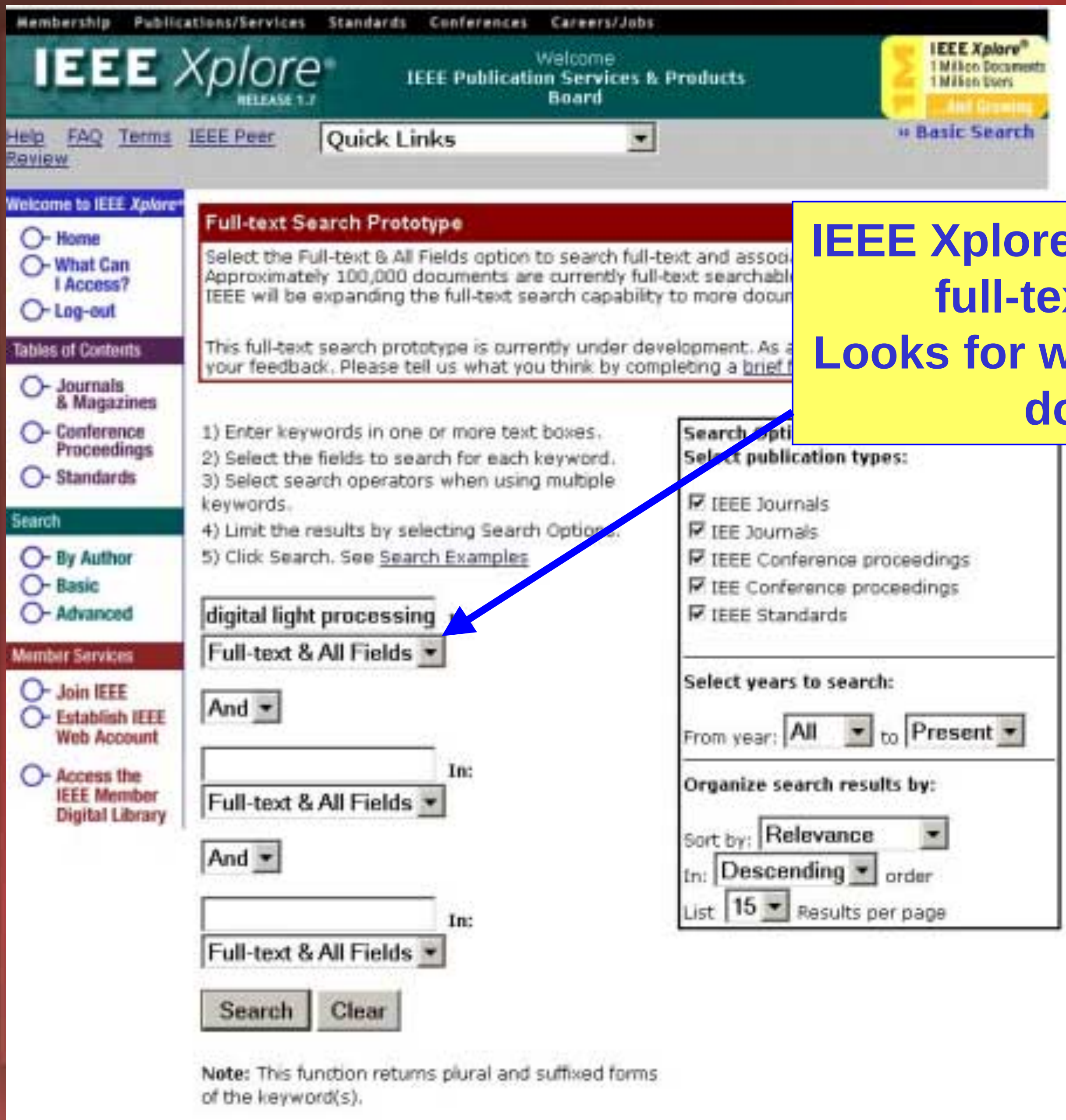
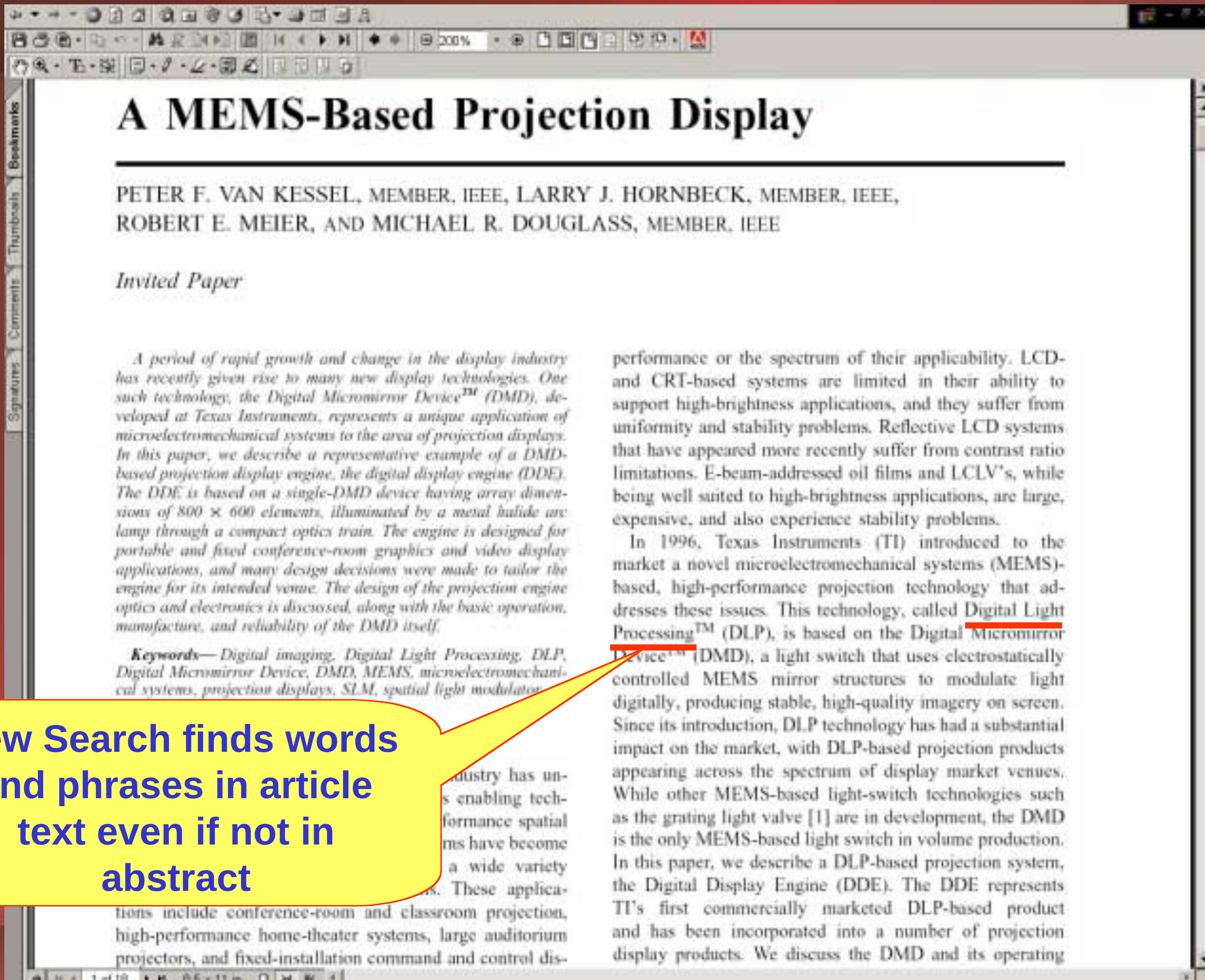
# IEEE Xplore Upgrades Add Convenience & Reliability

- Search R&D Project
  - Collaboration of IEEE with Rutgers University School of Information and Library Sciences
    - Will perfect parameters and techniques for relevancy ranking and recommender services
- Release 1.7 of IEEE Xplore - 29 April 2004
  - Full text searching - new option for users
    - Searches full text where available + AbstractPlus for all other documents
    - 130,000 of 1.1 million articles are full text searchable at outset

**IEEE Xplore Version 1.7 adds full-text searching**

**Looks for words anywhere in document**





# A MEMS-Based Projection Display

PETER F. VAN KESSEL, MEMBER, IEEE, LARRY J. HORNBECK, MEMBER, IEEE,
ROBERT E. MEIER, AND MICHAEL R. DOUGLASS, MEMBER, IEEE

*Invited Paper*

*A period of rapid growth and change in the display industry has recently given rise to many new display technologies. One such technology, the Digital Micromirror Device™ (DMD), developed at Texas Instruments, represents a unique application of microelectromechanical systems to the area of projection displays. In this paper, we describe a representative example of a DMD-based projection display engine, the digital display engine (DDE). The DDE is based on a single-DMD device having array dimensions of 800 × 600 elements, illuminated by a metal halide arc lamp through a compact optics train. The engine is designed for portable and fixed conference-room graphics and video display applications, and many design decisions were made to tailor the engine for its intended venue. The design of the projection engine optics and electronics is discussed, along with the basic operation, manufacture, and reliability of the DMD itself.*

***Keywords***—*Digital imaging, Digital Light Processing, DLP, Digital Micromirror Device, DMD, MEMS, microelectromechanical systems, projection displays, SLM, spatial light modulator.*

...ustry has un- ...s enabling tech- ...formance spatial ...ms have become ... a wide variety ...s. These applications include conference-room and classroom projection, high-performance home-theater systems, large auditorium projectors, and fixed-installation command and control dis-

performance or the spectrum of their applicability. LCD- and CRT-based systems are limited in their ability to support high-brightness applications, and they suffer from uniformity and stability problems. Reflective LCD systems that have appeared more recently suffer from contrast ratio limitations. E-beam-addressed oil films and LCLV's, while being well suited to high-brightness applications, are large, expensive, and also experience stability problems.

In 1996, Texas Instruments (TI) introduced to the market a novel microelectromechanical systems (MEMS)-based, high-performance projection technology that addresses these issues. This technology, called Digital Light Processing™ (DLP), is based on the Digital Micromirror Device™ (DMD), a light switch that uses electrostatically controlled MEMS mirror structures to modulate light digitally, producing stable, high-quality imagery on screen. Since its introduction, DLP technology has had a substantial impact on the market, with DLP-based projection products appearing across the spectrum of display market venues. While other MEMS-based light-switch technologies such as the grating light valve [1] are in development, the DMD is the only MEMS-based light switch in volume production. In this paper, we describe a DLP-based projection system, the Digital Display Engine (DDE). The DDE represents TI's first commercially marketed DLP-based product and has been incorporated into a number of projection display products. We discuss the DMD and its operating

New Search finds words and phrases in article text even if not in abstract

# IEEE Enterprise Basis for IEEE Xplore Release 1.8

- July 2004
- Three levels of document purchases
  - 350 documents for $4,995
  - 800 documents for $9,995
  - 1,750 documents for $17,500
- Documents are stored in an electronic file cabinet
  - Shared access as long as subscription is active

# IEEE Enterprise Leverages Provides Electronic File Cabinet

# IEEE Xplore Release 2.0 in Development Now

- Planned release for end of 2004/early 2005
  - A new graphical design
  - Free basic search for guests
  - Publication branding
  - Comprehensive training sessions planned in advance of release
- Lays foundation for future releases
  - User profiling
    - Saved searches, subject email alerts
  - OpenURL compliance
  - Consolidation of conference titles
  - Integration of IEEE Press books content

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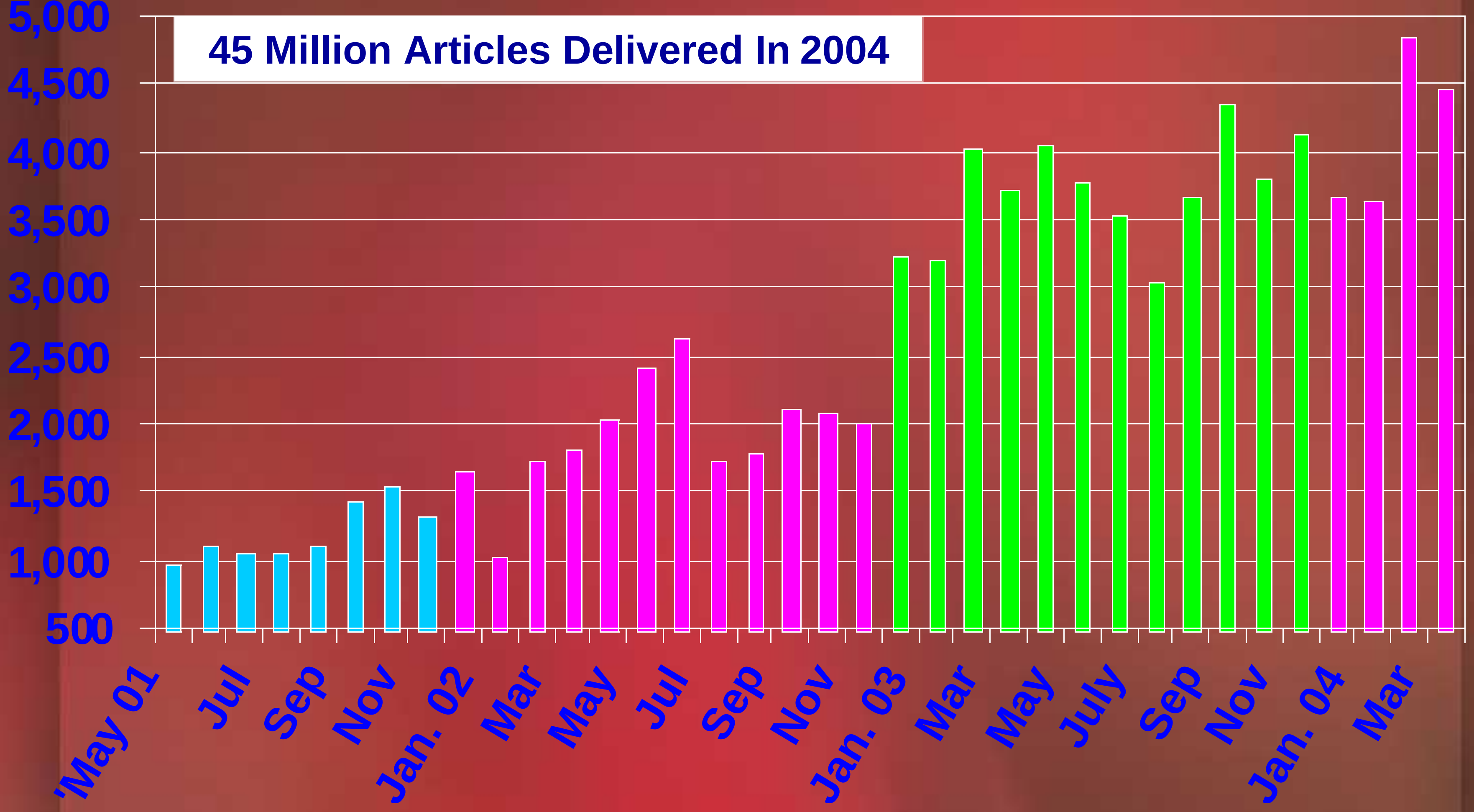
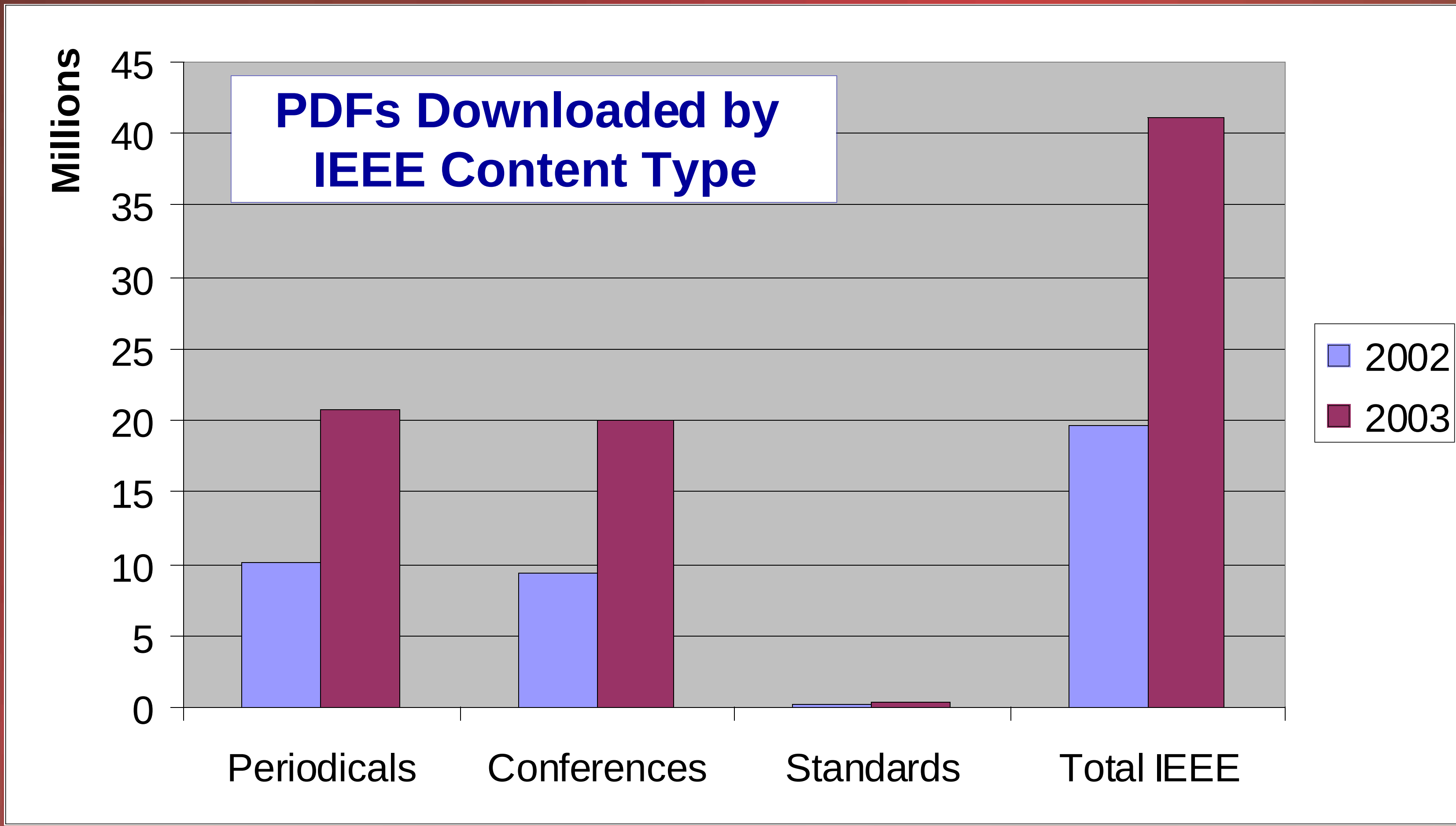
# Updates on OpenURL

- IEEE Xplore already behaves as a target for link servers
  - Utilizing DOI as the primary linking tool
- As a source
  - To be developed as part of Release 2.1
  - Will enable customers to link from IEEE Xplore linked references via link servers

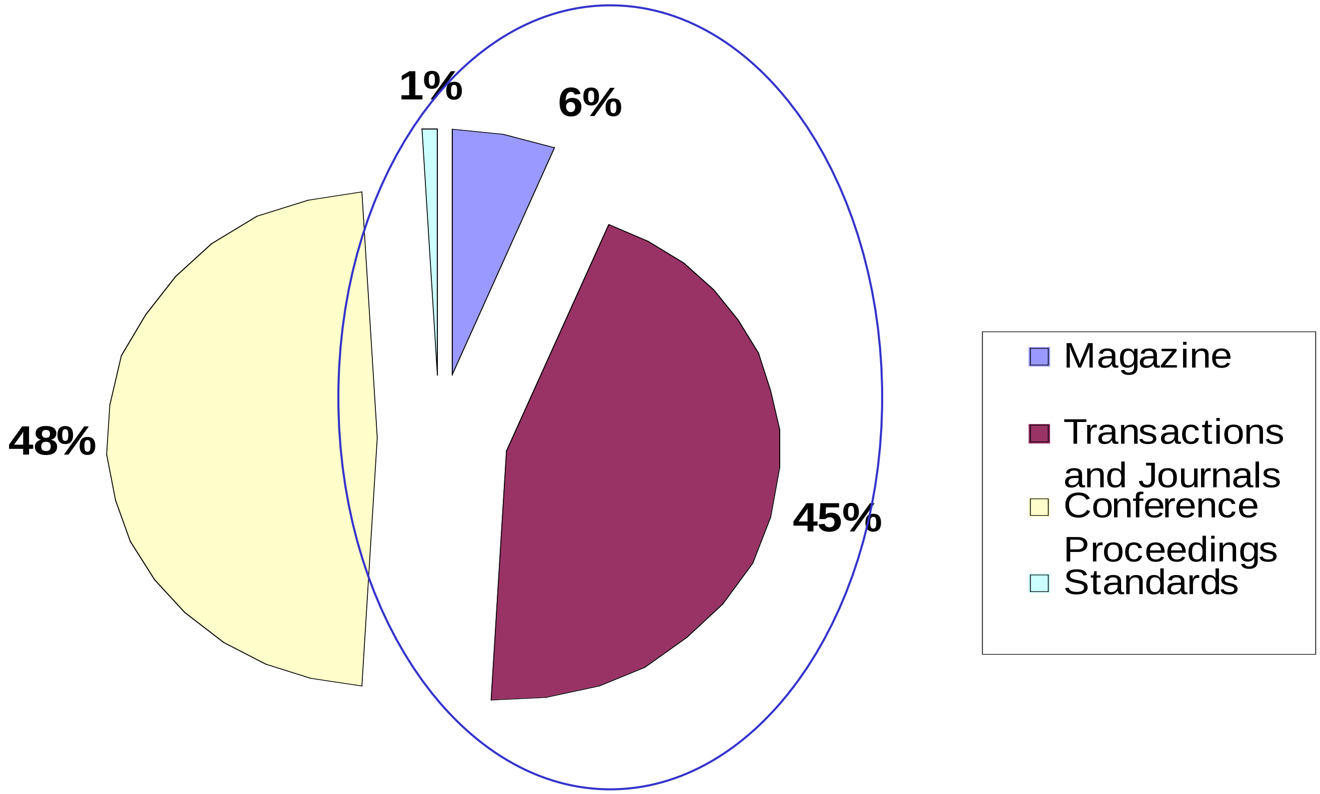
# Use Of IEEE Xplore By Users Doubles from 2002 to 2003



# All Content Types Grow Usage in 2003



# Periodicals Represent 51% of Total IEEE Xplore Usage

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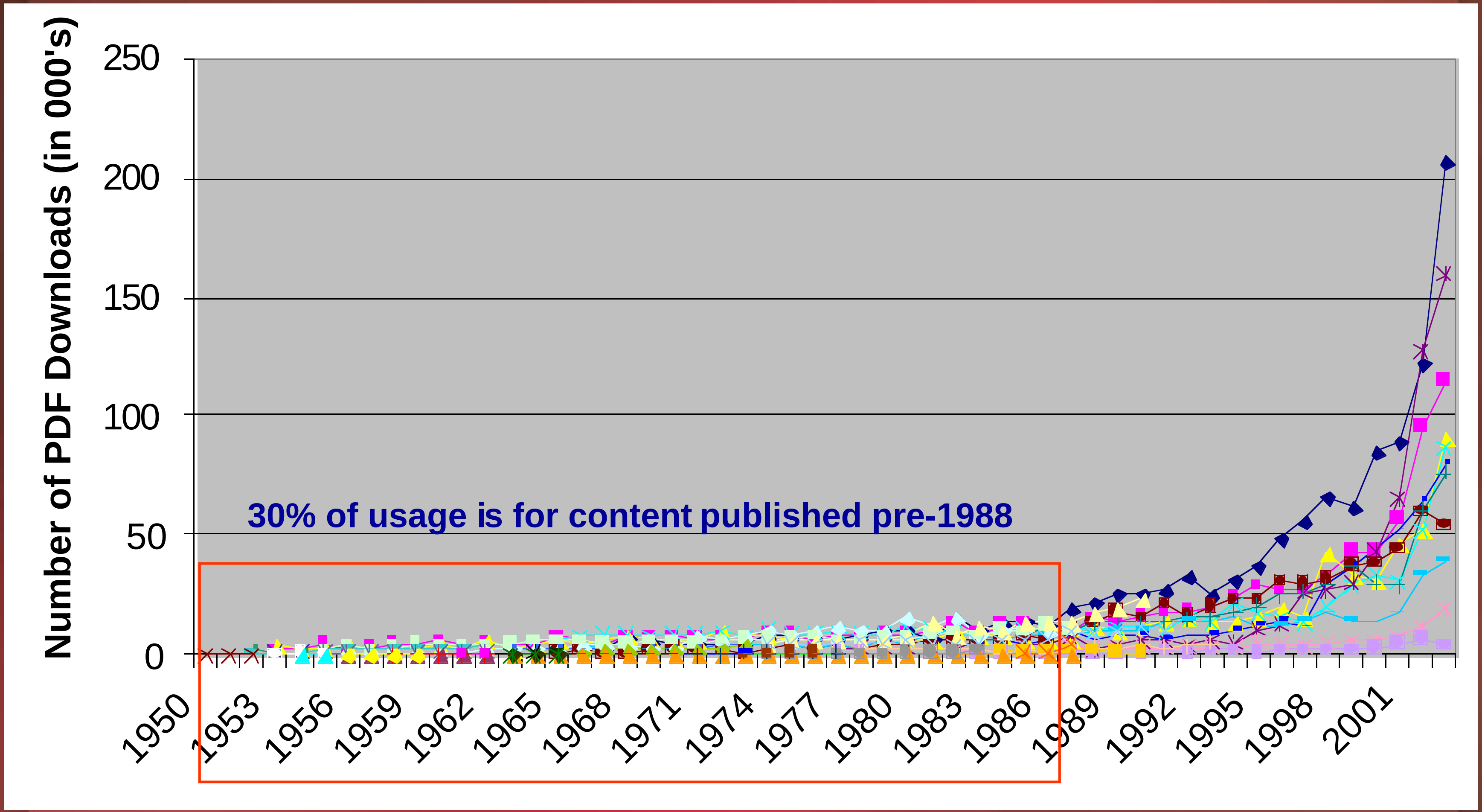
# Pre-1988 Content is Used

**Note: Usage of 41 periodicals with legacy content**

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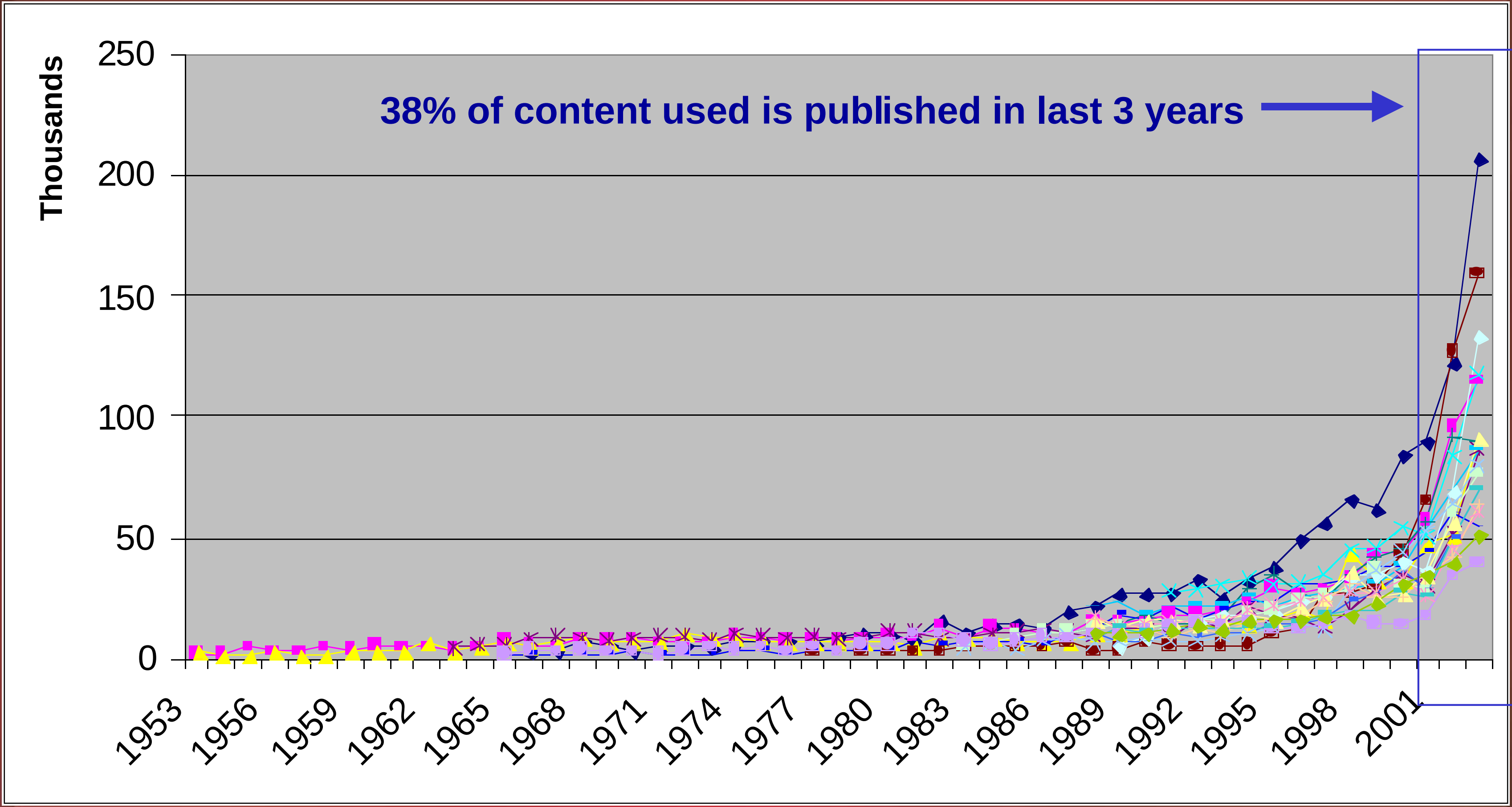
# High Usage on IEEE Xplore Benefits Current Content

**Note: Usage of the top 20 periodicals in IEEE Xplore**

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# Updates on Usage Statistics

- Currently, delivering aggregated PDF counts for each customer
- Internally, we can view aggregate usage at publication level
- Now, investigating work involved in providing customer reports at title level
  - To be COUNTER compliant

# IEEE Conducts Audit of Usage Statistics Gathering Process

- PricewaterhouseCoopers conducts audit to verify accuracy of gathering process
- PWC conducted audit Oct-Dec 2003
- PWC attests to IEEE's processes and accuracy of PDF download measurement

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# Process Audit is Important

- Assures customers, volunteers and management that reports are valid and accurate
- Institutes control improvements that could reduce any misstatement risks
- Sets standard for complying with industry initiative, COUNTER

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# PricewaterhouseCoopers Attests that IEEE Xplore Processes are Valid

"Internal control provides reasonable assurance that statistics related to PDF downloads summarized in reports generated from the System completely and accurately reflect IEEE Xplore usage …"

PRICEWATERHOUSECOOPERS

"We rarely see control consciousness and interest in controls and accuracy as strong as we have seen from this group."

-- David Kohl
Pricewaterhouse

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# What will the Digital Library of the Future Look Like

- Include more content types
  - Patent data, author profiles, tutorial content
- Include non-traditional content
  - Interactive and searchable math formulae
  - Multimedia
  - Visualization tools for showing relationships
- Engage information retrieval software
  - May replace the need for “old-fashioned” index
  - Learn from the symantic web

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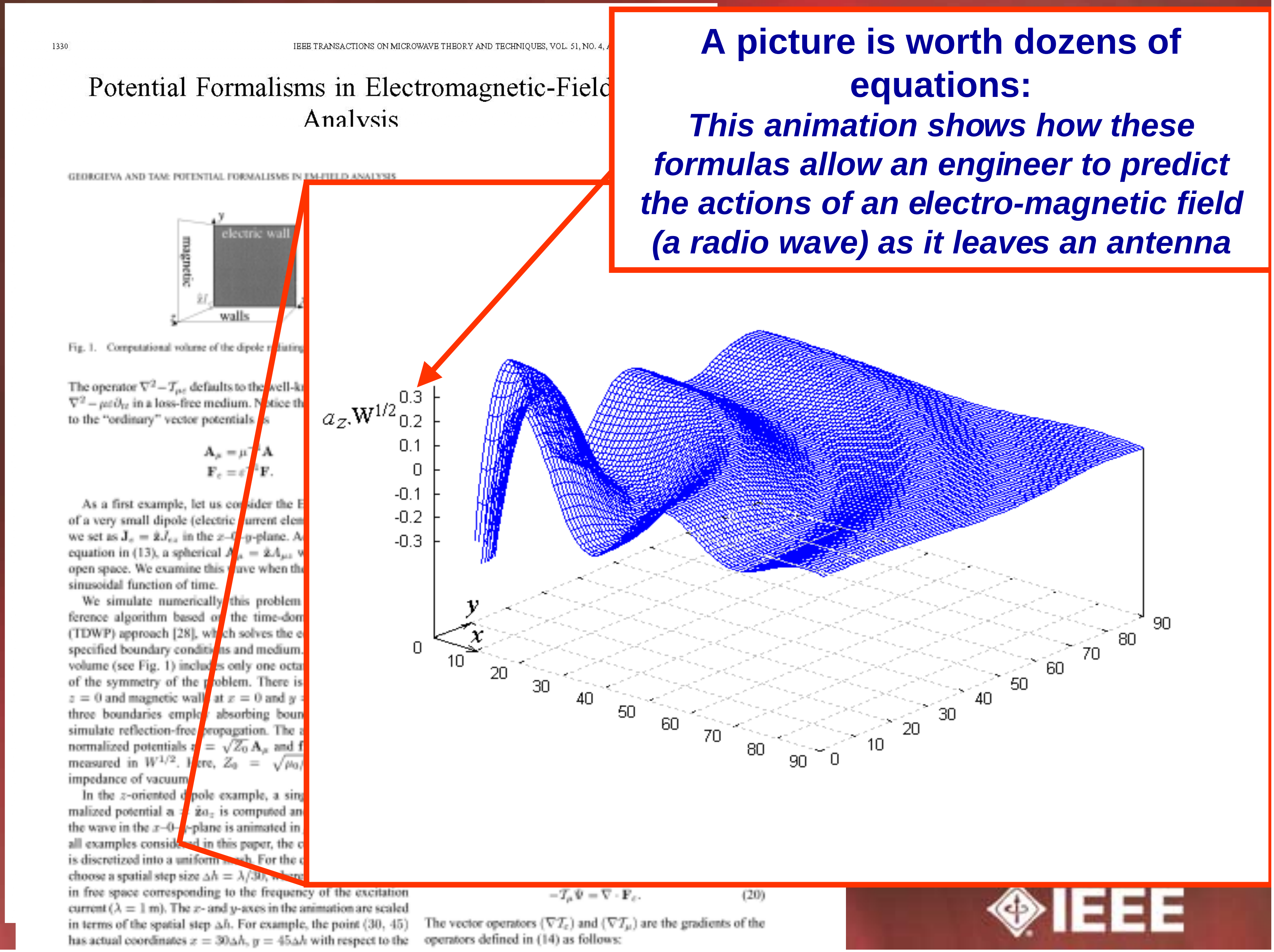
## A picture is worth dozens of equations:

***This animation shows how these formulas allow an engineer to predict the actions of an electro-magnetic field (a radio wave) as it leaves an antenna***



# Tutorials will be a Part of IEEE Xplore Delivery

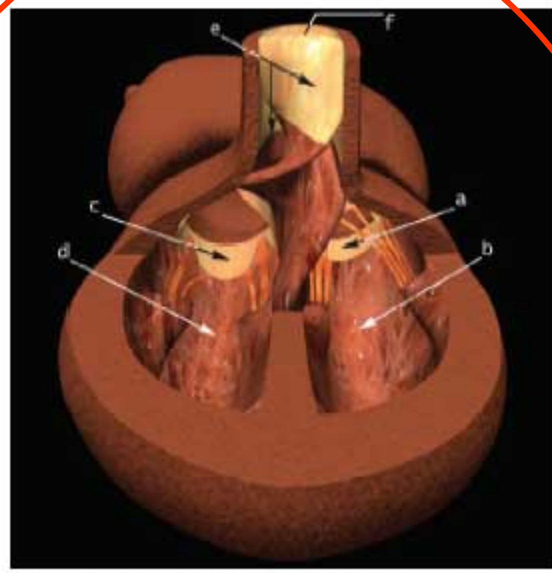

- Subject matter experts prepare content
  - ~30 courses have been identified
- Modules aid in providing practical information to users
- Sample content in testing now, release planned for 2005

# Tables, Graphs and Figures Made Available as Single Elements

there were only a few matte objects. Without losing realism, we chose a rendering without shadows and multiple reflections. LightWave stores the rendered images of the sequence in the Targa32 format. The image resolution is 728 × 576 pixels to match the picture to the European PAL video standard. We used Adobe Premiere to edit the final animation, which is available in AVI format. (You can view two examples at http://virtual-heart-development.univ-rennes1.fr/anglais/generale.htm by clicking on the "Animations" button.) However, this animation isn't always self-explanatory. We post-processed oral explanations and identification signs on the video to describe precisely the anatomy and its mutation and to highlight some particularities of this anatomy or some specific phenomena. The objective of the animation is to teach the normal heart development. The final animation is about 12 minutes long with more than 18,000 frames.

**Results**

The overall process of the model design from the medical definition of the sequence to the final modeling and validation took about three years. The figures presented here highlight some important stages of the overall cardiac morphogenesis. Chronologically, the first visible phase is fertilization (Figure 5). In this sequence,




6 The mitral (a) and tricuspid (c) valves separating, respectively, the left and right atria from the corresponding ventricle. This model of the opened heart shows the mitral valve (a) and left ventricle (b), tricuspid valve (c) and right ventricle (d), aorta (e), and pulmonary artery (f).



In the future, users will be able to download elements from within an article.

2) Functions

$$f_{i,t} : \mathbb{R}^{t-1} \times \{1, 2, \ldots, 2^{T\overline{R}_i}\} \to \mathbb{R}, \quad t = 1, 2, \ldots, T$$

for the source nodes $i \in \mathcal{S}$ and $f_{j,t} : \mathbb{R}^{t-1} \to \mathbb{R}, t = 2, \ldots, T$ for all the other nodes $j \notin \mathcal{S}$, such that

$$X_i(t) = f_{i,t}(Y_i(1), \ldots, Y_i(t-1), \overline{W}_i), \quad t = 1, 2, \ldots, T$$

$$X_j(1) = 0, \quad X_j(t) = f_{j,t}(Y_j(1), \ldots, Y_j(t-1)), \quad t = 2, 3, \ldots, T$$

such that the following total power constraint holds:

$$\frac{1}{T} \sum_{t=1}^{T} \sum_{i \in \mathcal{N}} X_i^2(t) \leq P_{\text{total}}, \quad \text{a.s.} \tag{1}$$

3) $m$ decoding functions

$$g_\ell : \mathbb{R}^T \times \{1, 2, \ldots, |\overline{W}_{d_\ell}|\} \to \{1, 2, \ldots, 2^{TR_\ell}\}$$

for the destination nodes of the $m$ source–destination pairs $\{(s_\ell, d_\ell), \ell = 1, \ldots, m\}$, where $|\overline{W}_{d_\ell}|$ is the number of different values $\overline{W}_{d_\ell}$ can take. Note that $\overline{W}_{d_\ell}$ may be empty.

4) The average probability of error:

$$P_e^{(T)} := \text{Prob}((\hat{W}_1, \hat{W}_2, \ldots, \hat{W}_m) \neq (W_1, W_2, \ldots, W_m)) \tag{2}$$

where $\hat{W}_\ell := g_\ell(Y_{d_\ell}^T, \overline{W}_{d_\ell})$, with

$$Y_{d_\ell}^T := (Y_{d_\ell}(1), Y_{d_\ell}(2), \ldots, Y_{d_\ell}(T)).$$

*Definition 2.3:* The network's *transport capacity* $C_T$ is

$$C_T := \sup_{(R_1, \ldots, R_m) \text{ feasible}} \sum_{\ell=1}^{m} R_\ell \cdot \rho_\ell$$

where for brevity $\rho_\ell := \rho_{s_\ell d_\ell}$ denotes the distance between $s_\ell$ and $d_\ell$, and $R_\ell := R_{s_\ell d_\ell}$.

This is the supremum distance-weighted sum of rates that the network can deliver. The units in which it is measured is bit-meters p… successf… from the… one bit…

This… sons. Th… interest… hauling… man-mi… vides a… deliver… mind.

Secon… that the… to a con… wireless… capacity… example… support… exceeds the upper bound on the transport capacity.

Third, whenever a rate vector is feasible, and is such that its distance-weighted sum of rates is close to the transport capacity, then one can rest assured that the network is being operated close to capacity. We will see that this situation actually holds,

Imagine if the user could find this article by searching a math formulae.

Imagine if the user could download these math formulae and rework problems on his desktop.

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# Thank you for coming to the IEEE Customer Breakfast

Please visit us at Booth 661