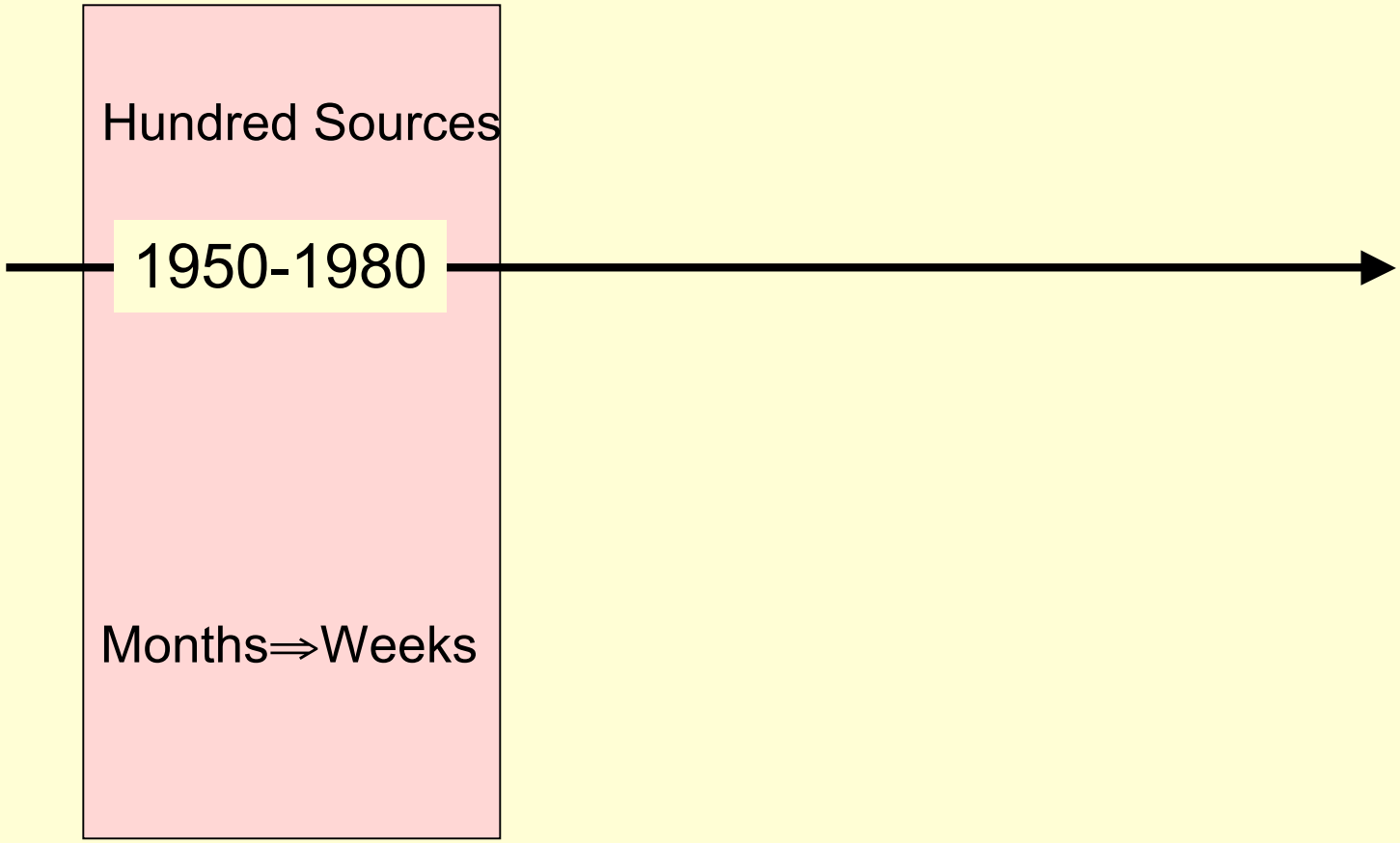
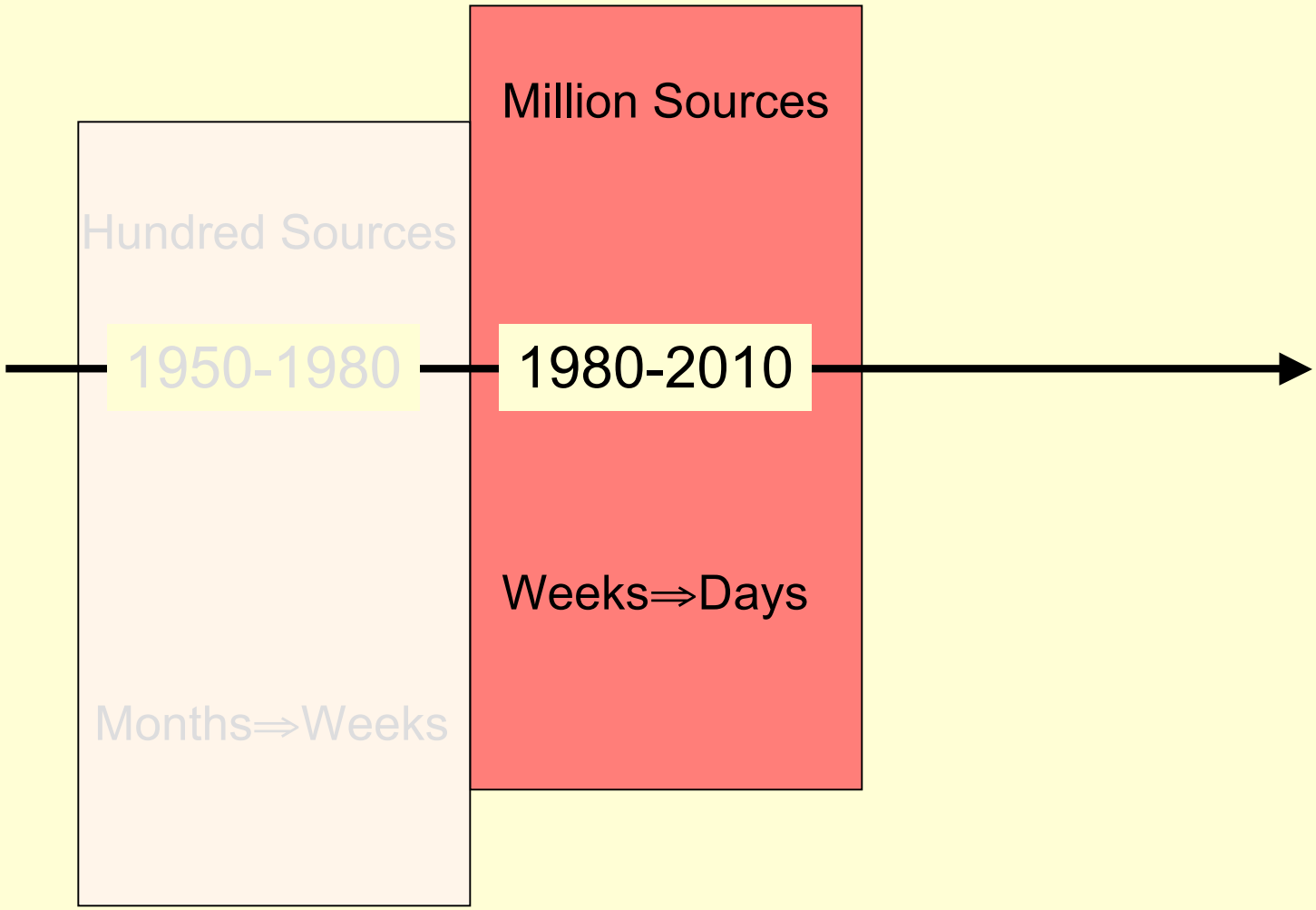
A Model for the Systems Architecture of the Future

Prof. Paul A. Strassmann
George Mason University, December 5, 2005

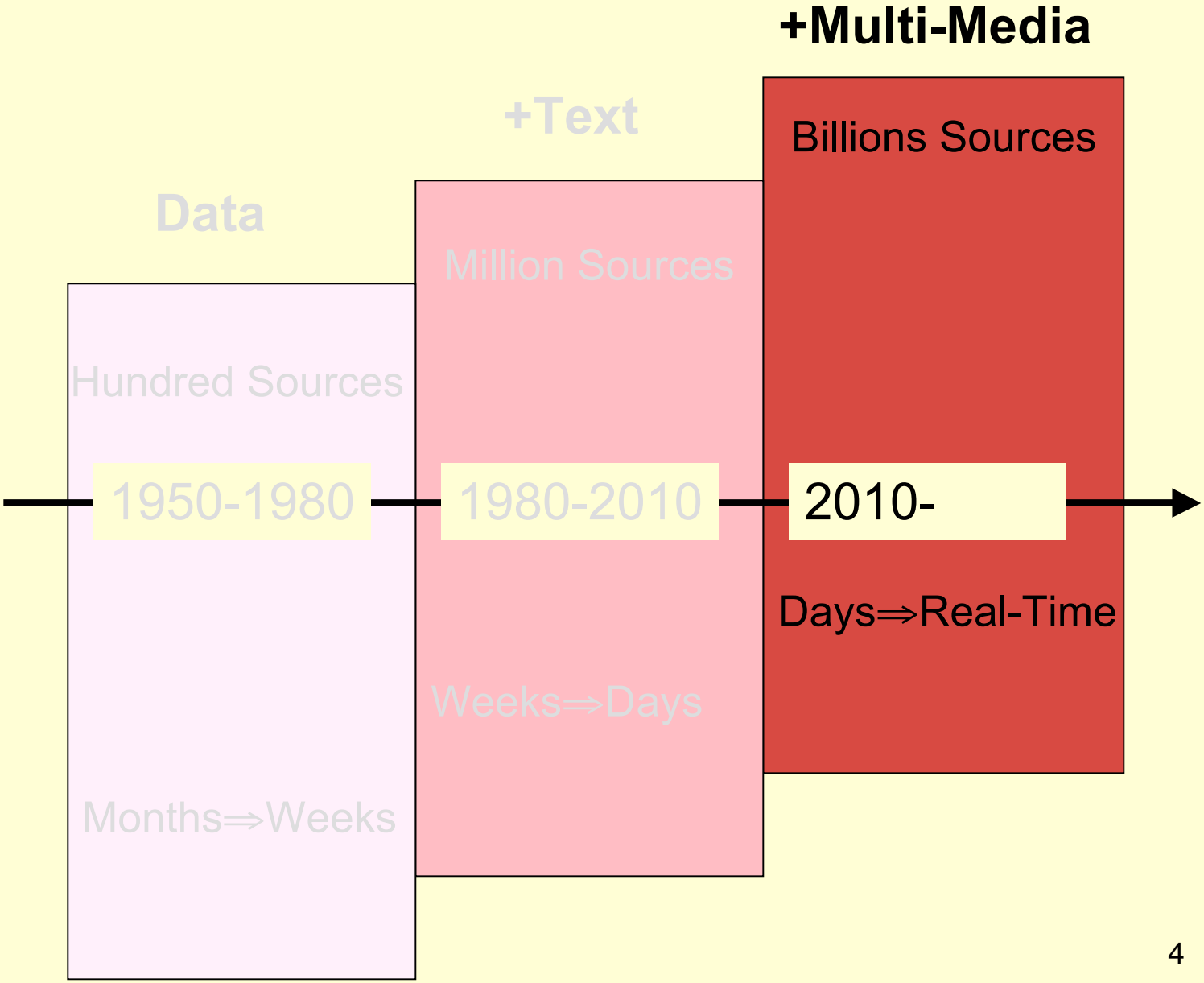
Data-Centric Era; IBM Dominates



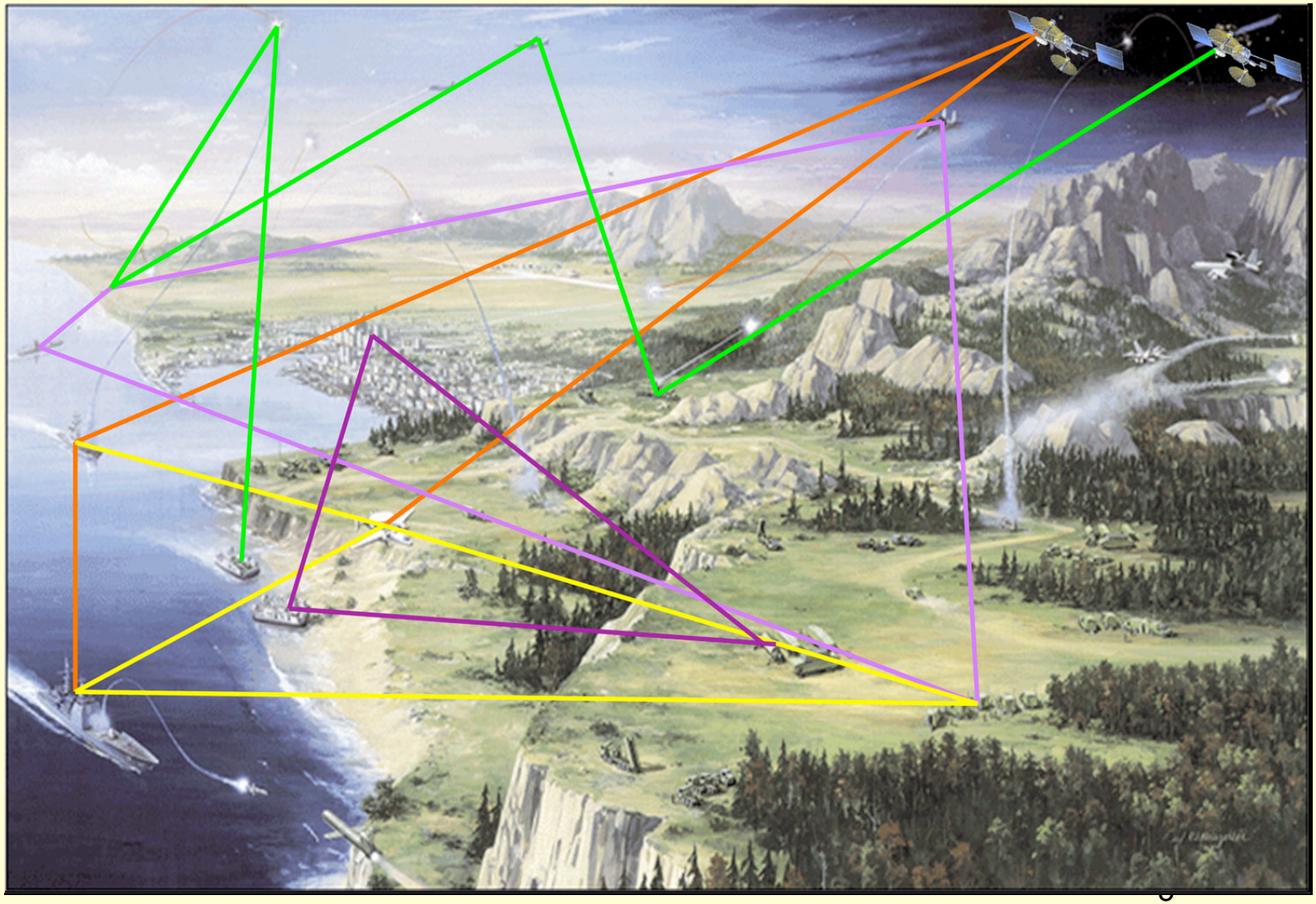
Workgroup-Centric Era; Microsoft, INTEL Dominate



Network-Centric Era; Google and Cisco?



Example of a Network-Centric System



Network-Centric Requirements (2010)

- Downtime (< 5 min/yr);
- Display (200 Billion ops/sec);
- Connectivity (> 1 Gigabyte/sec);
- Access (< 0.25 sec);
- Innovation (< 1 day);
- Security (> 8 sigma).

Performance (2005)

- Infrastructure = > 50% of spending;
- Security = ?;
- Integration = > 50% of applications;
- Network downtime = > 1 hour/year;
- Innovation = > 1 year.

Conclusion

- Network-Centric systems cannot be built on Workgroup-Centric architecture.

Network-Centric Principles (Google)

1. Build & operate protected information network;
2. Offer universal connectivity for:
   - Collection, processing and storing of information;
   - Provide secured communications.
3. Maintain shared data models;
4. Require continued upgrading & innovation.

Google Principle #1

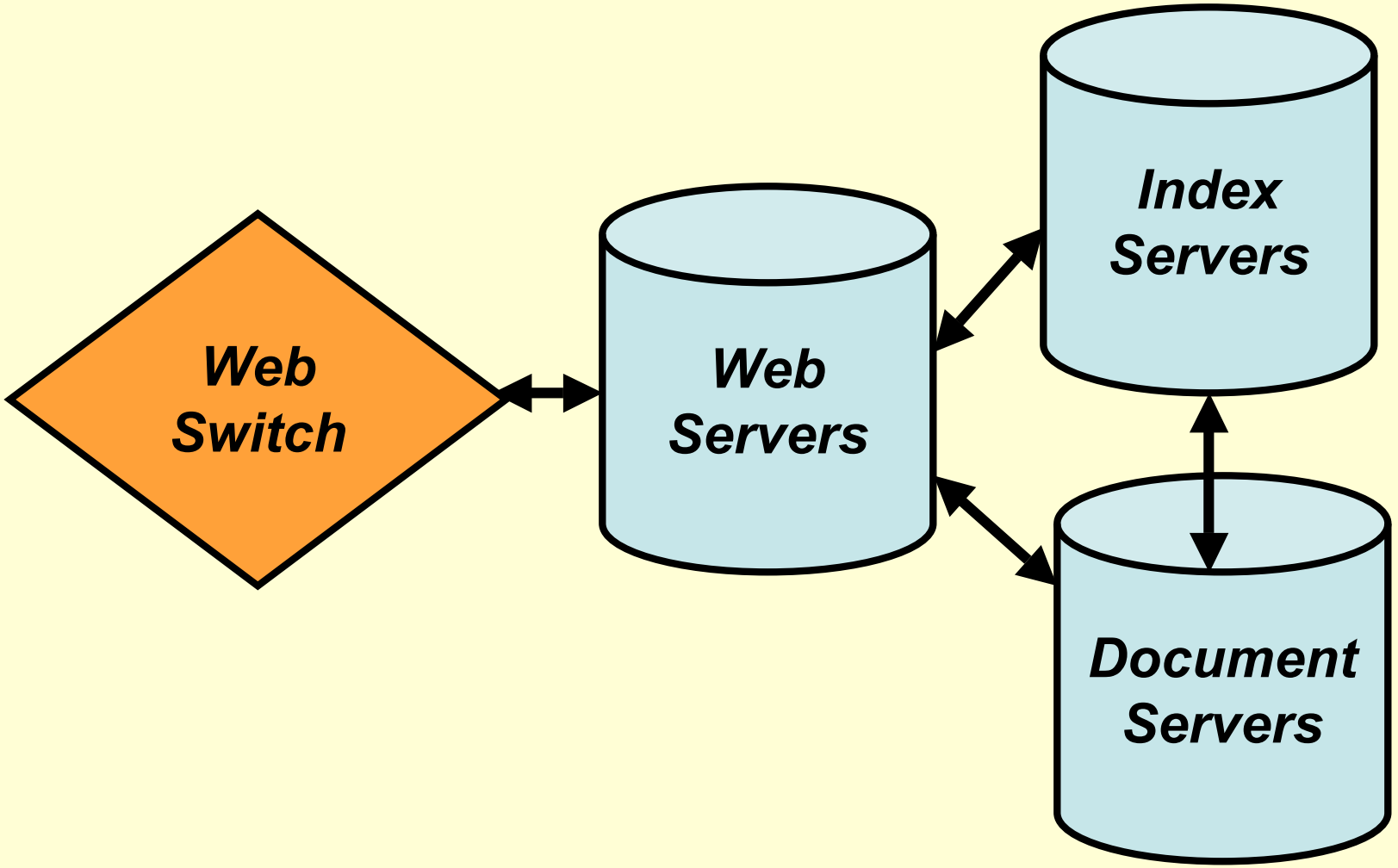
Build & operate protected information network

Standard Google Clusters Operate Net

- 359 racks
- 31,654 machines
- 63,184 CPUs
- 126,368 Ghz of processing power
- 63,184 Gb of RAM
- 2,527 Tb of Hard Drive space

- Appx. 40 million searches/day

Clusters Have Identical Architecture



Google Cluster Set-Up = Three Days

Google Infrastructure: Key to Growth (1)

- **>200,000 custom-built commodity servers;**
- **Acting as one parallel supercomputer;**
- **Fault tolerant hardware.**
- Storage capacity >5 petabytes; low response latency (0.2 sec); >80GB per server, distributed;
- Indexed >8 billion web pages; Indexing is computationally complex (>500M * > 2B matrix)
- Capital and operating costs at fraction of large scale commercial servers; traffic growth 20-30%/month; data centers (>12); in US, Europe and Asia.

Google Infrastructure: Key to Growth (2)

- >200,000 commodity Linux servers built to custom specifications; distributed cluster architecture; acting as one parallel supercomputer; scaleable;
- >50,000 requests/sec; fault tolerant (no single point of failure); diverse hardware; stripped version of Red Hat;
- **Storage capacity >5 petabytes;**
- **>80GB per server;**
- **Indexed >8 billion web pages;**
- **Indexing is complex (500M x 2B matrix)**
- Capital and operating costs at fraction of large scale commercial servers; traffic growth 20-30%/month; data centers (>12); in US, Europe and Asia.

Google Infrastructure: Key to Growth (3)

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- Storage capacity >5 petabytes; low response latency (0.2 sec); >80GB per server, distributed;
- Indexed >8 billion web pages; Indexing is computationally complex (>500M * > 2B matrix)
- **Capital and operating costs a fraction of commercial servers;**
- **Traffic growth 20-30%/month;**
- **Data centers (>20), in US, Europe and Asia.**

Architecture for Reliability

- Replication (3x+) for redundancy;
- Replication for proximity and response;
- Reliability with software and architecture, not with hardware.

Indexing for Response

- Dynamic indexing of 8B+ pages;
- Dynamic indexing of 1B+ images;
- Indexing of 1B+ messages;
- Index broken into “shards” and distributed across data centers.

Query Serving Infrastructure

- Processing a single query may involve 1000+ servers;
- Index Servers access Index Shards;
- Document Servers access Doc Shards;
- Response times monitored to assure <0.25 sec latency.

Google MapReduce System (1)

- **Coordinates servers in real-time;**
- **Automates distribution of workload;**
- Fault tolerance and service reconstitution;
- Systems-wide I/O cluster scheduling;
- Status and performance monitoring.

Google MapReduce System (2)

- Coordination of servers in real-time;
- Automates distribution of workload;
- **Fault tolerance & service reconstitution;**
- **Systems-wide cluster scheduling;**
- **Status and performance monitoring.**

Google Principle #2

Universal connectivity

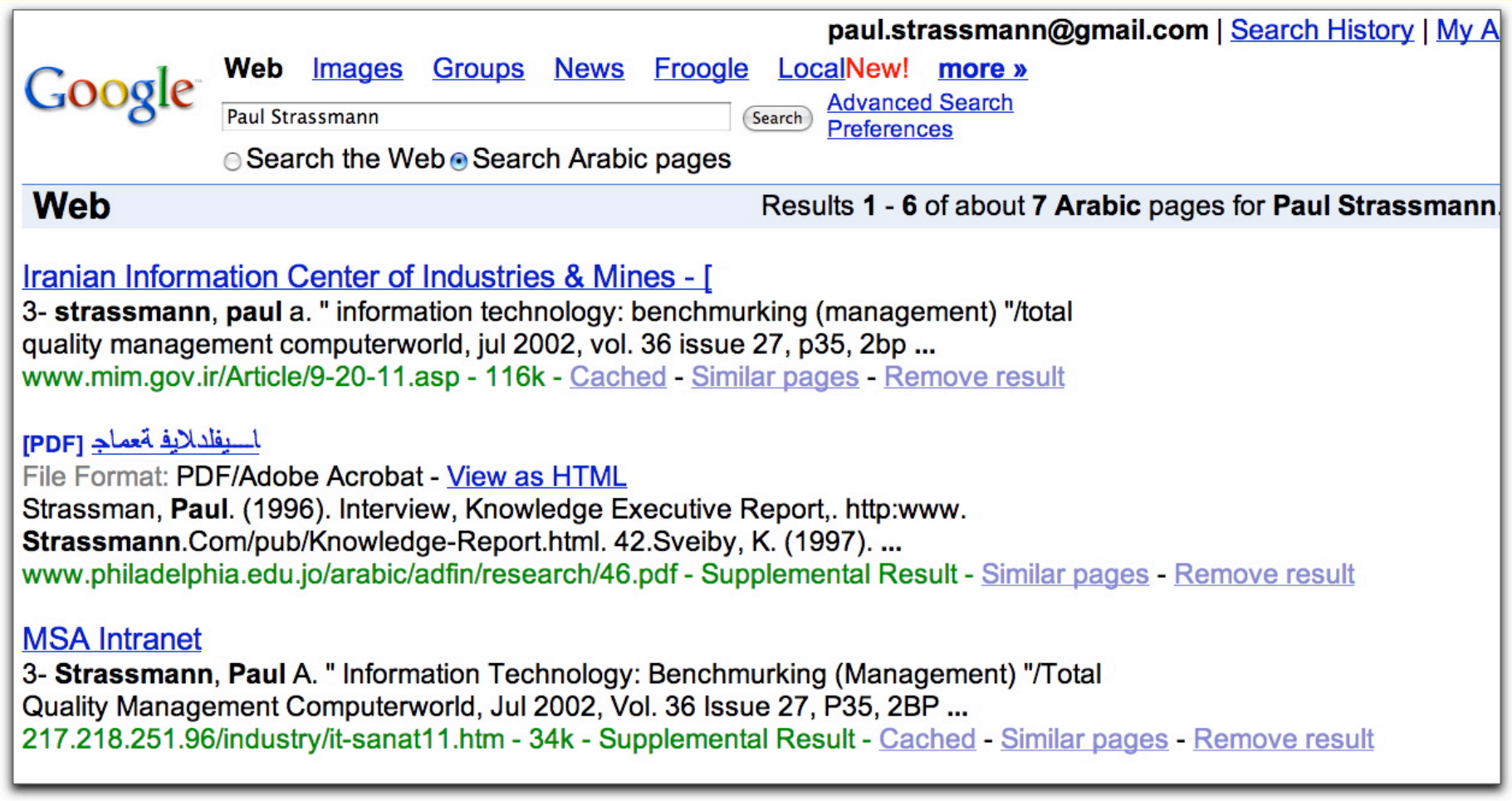
Multi-Lingual Services

Use the Google Interface in Your Language

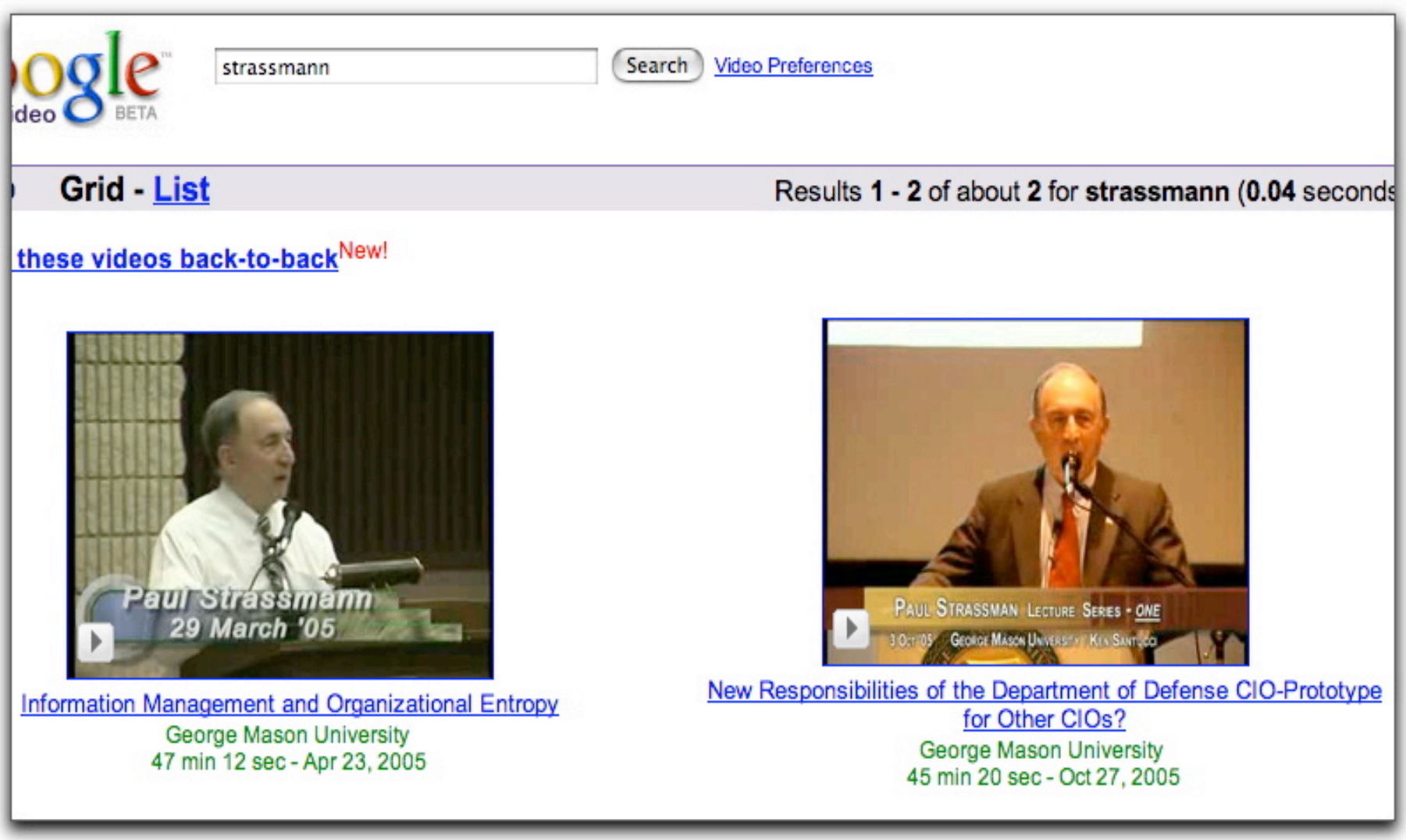
Set the Google homepage, messages, and buttons to display in your selected language via our Preferences page. Google currently offers the following interface languages:

- Afrikaans
- Albanian
- Amharic
- Arabic
- Armenian
- Azerbaijani
- Basque
- Belarusian
- Bengali
- Bihari
- Bork, bork, bork!
- Bosnian
- Breton
- Bulgarian
- Cambodian
- Catalan
- Chinese (Simplified)
- Chinese (Traditional)
- Corsican
- Croatian
- Czech
- Danish
- Dutch
- Elmer Fudd
- English
- Esperanto
- Estonian
- Faroese
- Filipino
- Finnish
- French
- Frisian
- Galician
- Georgian
- German
- Greek
- Guarani
- Gujarati
- Hacker
- Hebrew
- Hindi
- Hungarian
- Icelandic
- Indonesian
- Interlingua
- Irish
- Italian
- Japanese
- Javanese
- Kannada
- Kazakh
- Klingon
- Korean
- Kurdish
- Kyrgyz
- Laothian
- Latin
- Latvian
- Lingala
- Lithuanian
- Macedonian
- Malay
- Malayalam
- Maltese
- Marathi
- Mongolian
- Nepali
- Norwegian
- Norwegian (Nynorsk)
- Occitan
- Oriya
- Pashto
- Persian
- Pig Latin
- Polish
- Portuguese (Brazil)
- Portuguese (Portugal)
- Punjabi
- Quechua
- Romanian
- Romansh
- Russian
- Scots Gaelic
- Serbian
- Serbo-Croatian
- Sesotho
- Shona
- Sindhi
- Sinhalese
- Slovak
- Slovenian
- Somali
- Spanish
- Sundanese
- Swahili
- Swedish
- Tajik
- Tamil
- Tatar
- Telugu
- Thai
- Tigrinya
- Tonga
- Turkish
- Turkmen
- Twi
- Uighur
- Ukrainian
- Urdu
- Uzbek
- Vietnamese
- Welsh
- Xhosa
- Yiddish
- Yoruba
- Zulu

Search in Arabic Media



Video Searches



Google Base - Connecting Diverse Sources

Semantic Parsing

- Tools parse millions of documents;
- Automated learning for related information.
  - Query: **"Bay Area Cooking Classes"**
  - Finds: **"*San Francisco College Classes*";**
    "*The Magic of Thai Cuisine*"

Google Principle #3

Shared data models

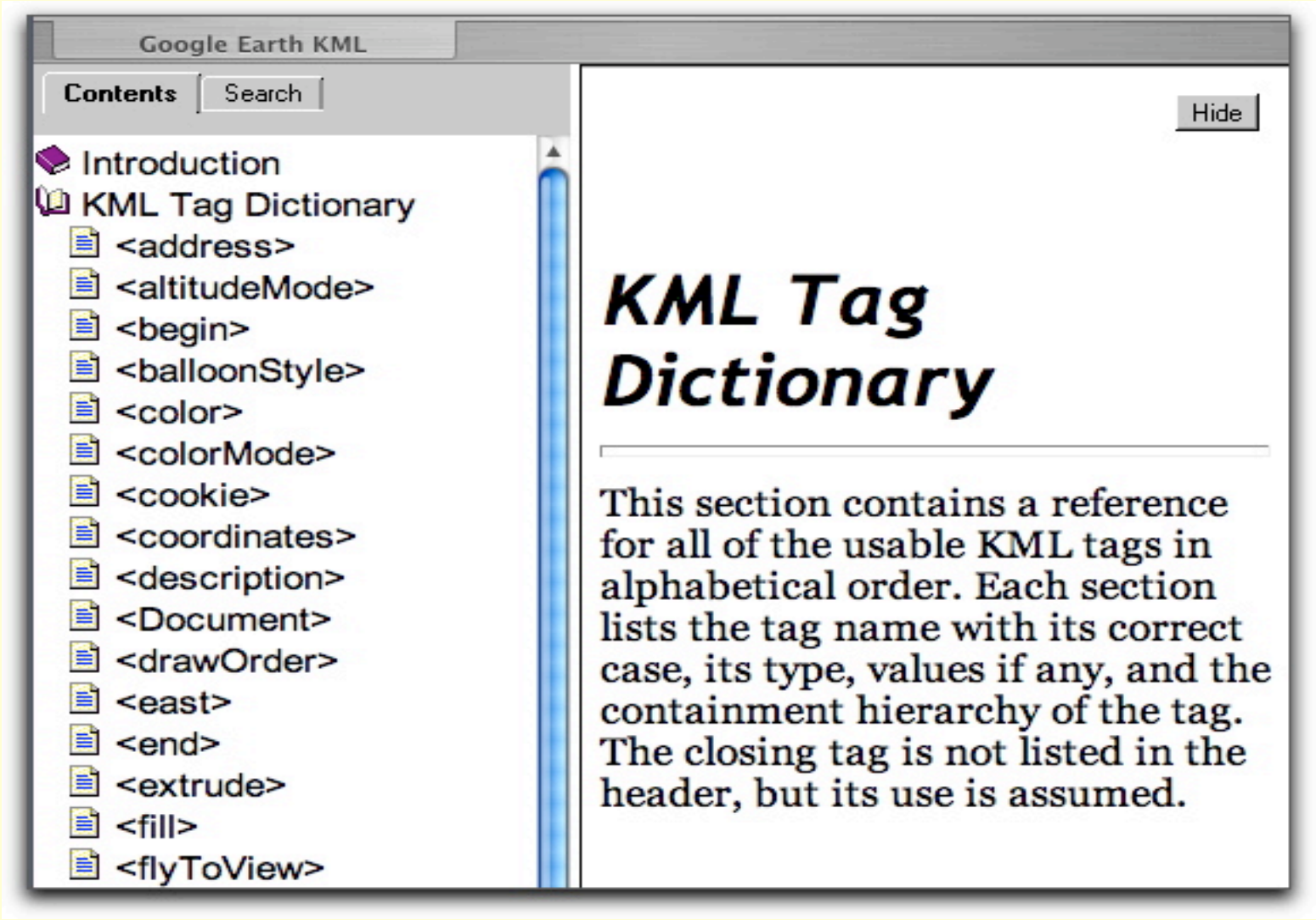
Data Engineering

- Standard file management: The Google File System (GFS);
- Standard job scheduling: The Global Work Queue (GWQ);
- Standard network management: The Google MapReduce system.

Google File System (GFS)

- Replicated Masters manage MetaData directories;
- Data transfers directly at the machine level within 2,000+ clusters;
- File broken into 64 MB chunks for 2000+ MB/second read/write load;
- All file chunks at least triplicate for safety.

Data Dictionary for Interoperability



Application Interfaces

Google Principle #4

Upgrading & Innovation

Deliver On-Line Services

Google Services


[Alerts](#)
Receive news and search results via email


[Answers](#)
Ask a question, set a price, get an answer


[Blog Search](#)
Find blogs on your favorite topics


[Book Search](#)
Search the full text of books


[Catalogs](#)
Search and browse mail-order catalogs


[Directory](#)
Browse the web by topic


[Froogle](#)
Shop smarter with Google


[Groups](#)
Create mailing lists and discussion groups


[Images](#)
Search for images on the web


[Labs](#)
Try out new Google products


[Local](#)
Find local businesses and services


[Maps](#)
View maps and get directions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[SMS](#)
Use text messaging for quick info

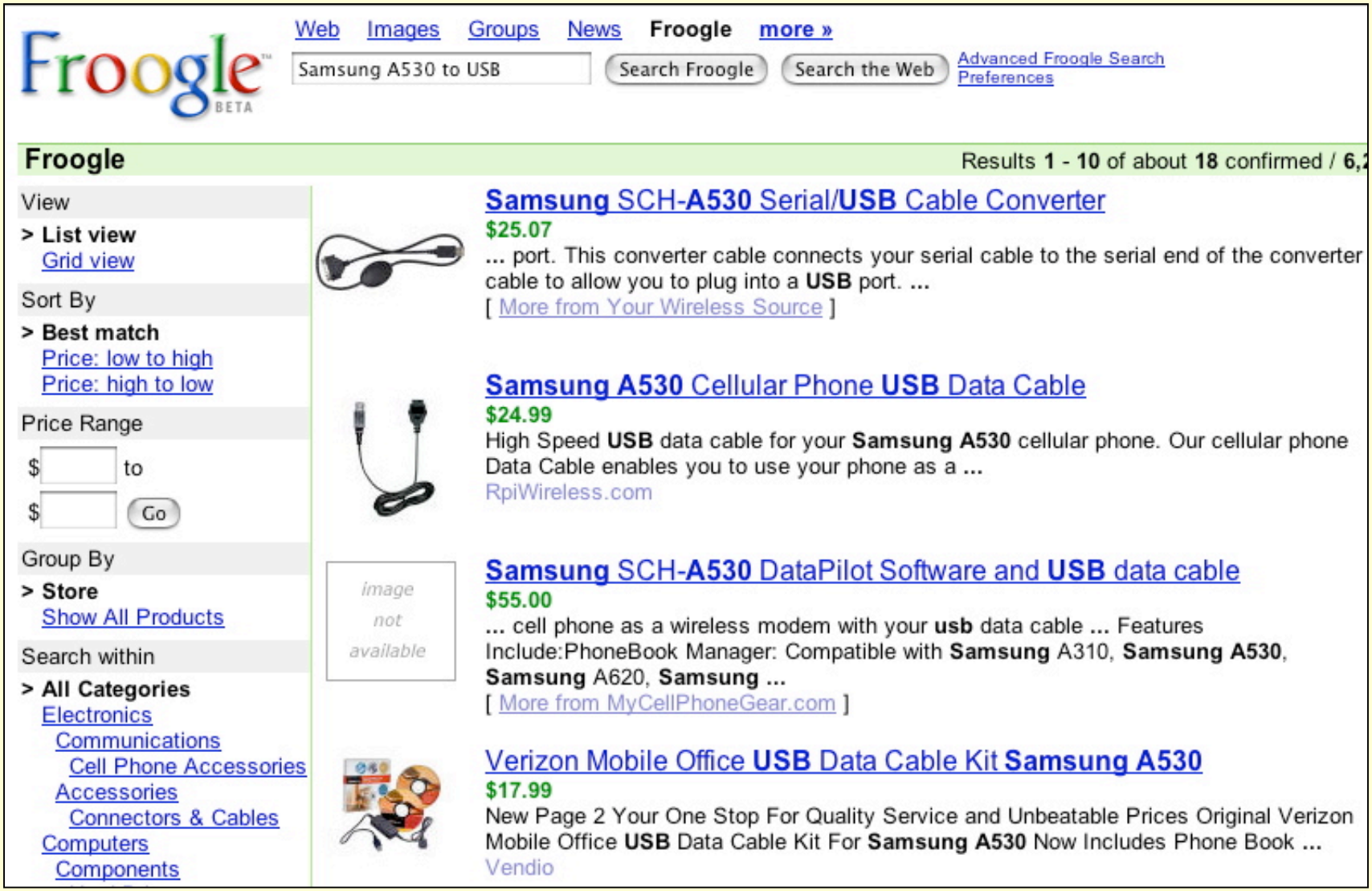

[Special Searches](#)
Search within specific topics


[University Search](#)
Search a specific school's website

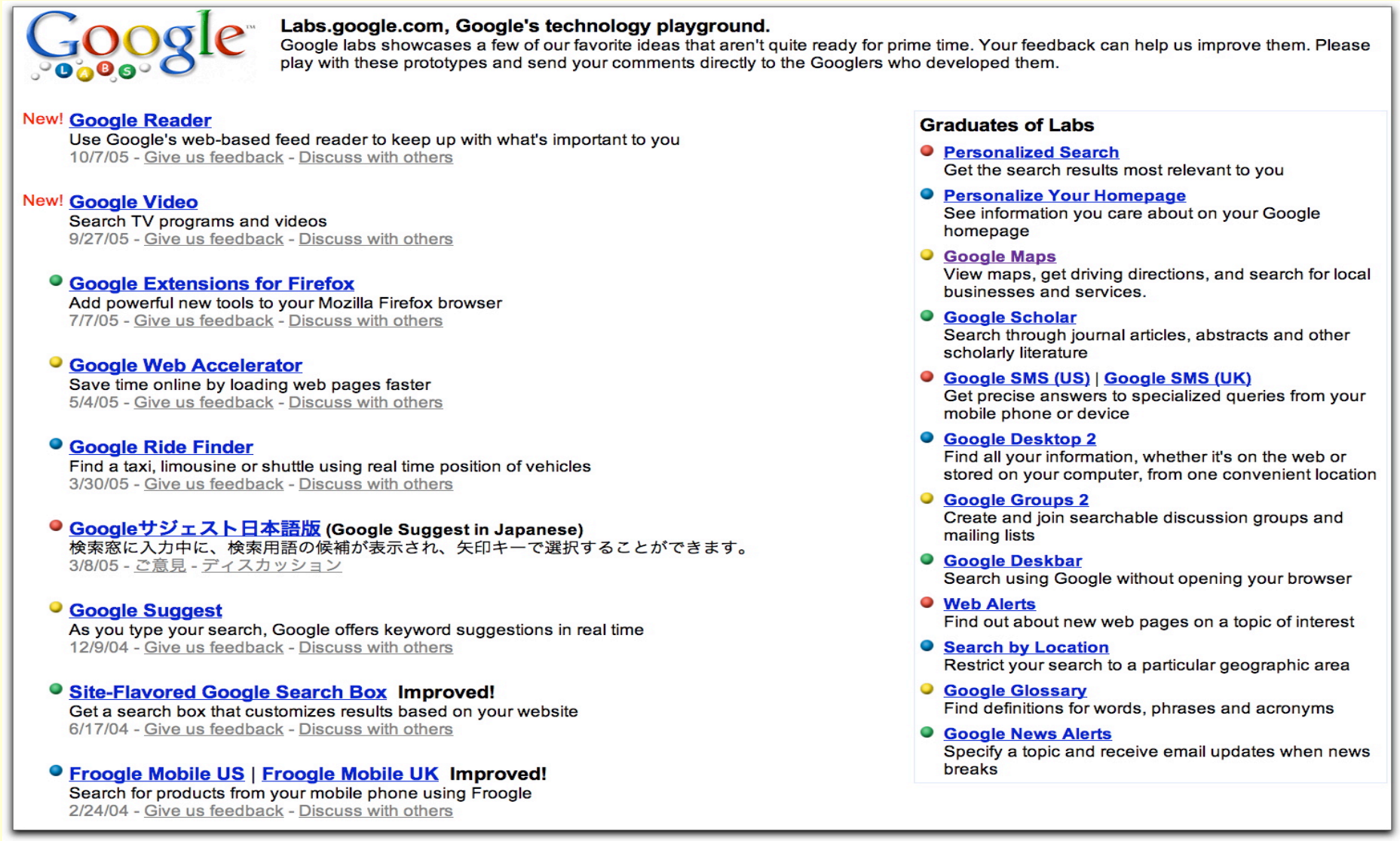

[Web Search](#)
Search over billions of web pages


[Web Search Features](#)
Do more with search

Shopping Services



Environment for Rapid Innovation



Google Labs

Labs.google.com, Google's technology playground.
Google labs showcases a few of our favorite ideas that aren't quite ready for prime time. Your feedback can help us improve them. Please play with these prototypes and send your comments directly to the Googlers who developed them.

New! **Google Reader**
Use Google's web-based feed reader to keep up with what's important to you
10/7/05 - Give us feedback - Discuss with others

New! **Google Video**
Search TV programs and videos
9/27/05 - Give us feedback - Discuss with others

Google Extensions for Firefox
Add powerful new tools to your Mozilla Firefox browser
7/7/05 - Give us feedback - Discuss with others

Google Web Accelerator
Save time online by loading web pages faster
5/4/05 - Give us feedback - Discuss with others

Google Ride Finder
Find a taxi, limousine or shuttle using real time position of vehicles
3/30/05 - Give us feedback - Discuss with others

Googleサジェスト日本語版 (Google Suggest in Japanese)
検索窓に入力中に、検索用語の候補が表示され、矢印キーで選択することができます。
3/8/05 - ご意見 - ディスカッション

Google Suggest
As you type your search, Google offers keyword suggestions in real time
12/9/04 - Give us feedback - Discuss with others

Site-Flavored Google Search Box **Improved!**
Get a search box that customizes results based on your website
6/17/04 - Give us feedback - Discuss with others

Froogle Mobile US | **Froogle Mobile UK** **Improved!**
Search for products from your mobile phone using Froogle
2/24/04 - Give us feedback - Discuss with others

Graduates of Labs

Personalized Search
Get the search results most relevant to you

Personalize Your Homepage
See information you care about on your Google homepage

Google Maps
View maps, get driving directions, and search for local businesses and services.

Google Scholar
Search through journal articles, abstracts and other scholarly literature

Google SMS (US) | **Google SMS (UK)**
Get precise answers to specialized queries from your mobile phone or device

Google Desktop 2
Find all your information, whether it's on the web or stored on your computer, from one convenient location

Google Groups 2
Create and join searchable discussion groups and mailing lists

Google Deskbar
Search using Google without opening your browser

Web Alerts
Find out about new web pages on a topic of interest

Search by Location
Restrict your search to a particular geographic area

Google Glossary
Find definitions for words, phrases and acronyms

Google News Alerts
Specify a topic and receive email updates when news breaks

A New Application Launched in 15 Minutes

About Me

View my profile

Visit my site

archives

02/01/2005 - 02/28/2005
03/01/2005 - 03/31/2005
04/01/2005 - 04/30/2005
06/01/2005 - 06/30/2005
10/01/2005 - 10/31/2005

Commentaries

Comments and observations by Paul Strassmann

Friday, October 14, 2005

Are Federal and Corporate CIO Positions Comparable?

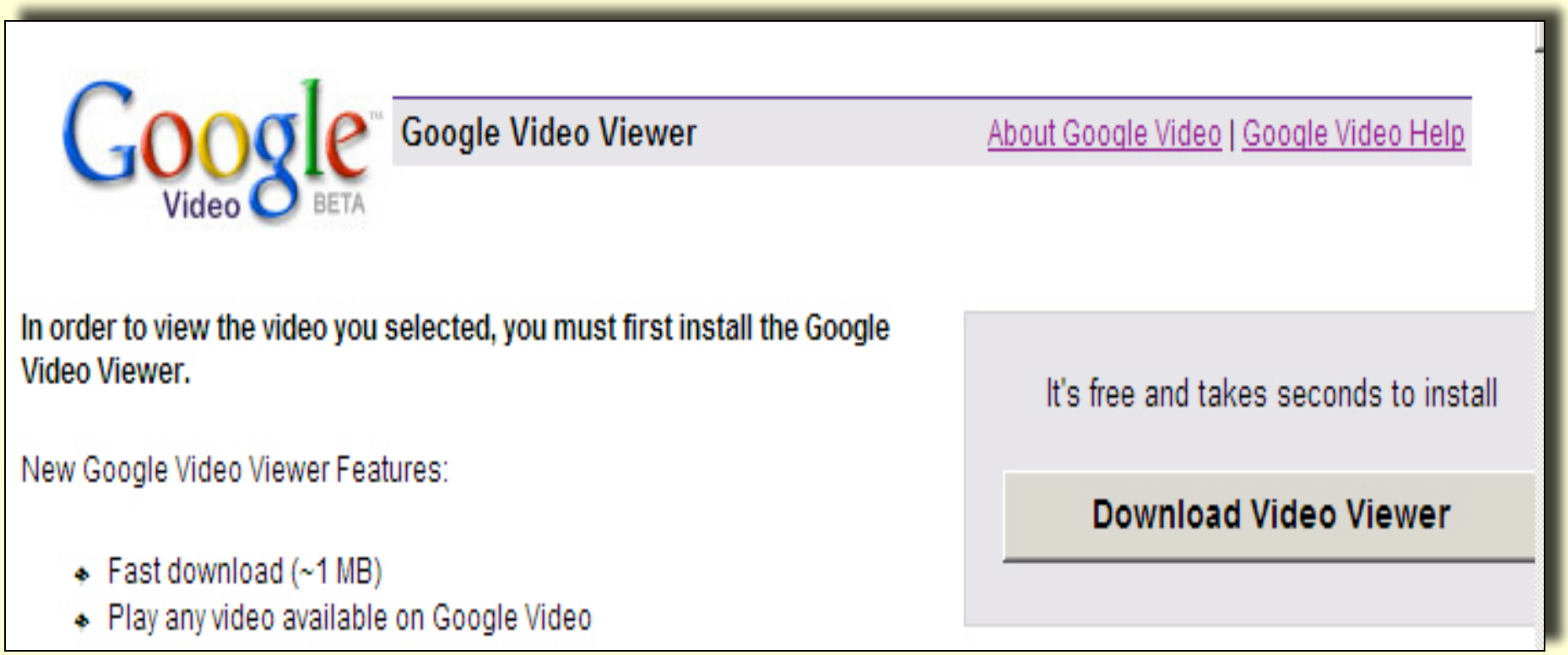
No, these positions are not comparable.

1. The Federal CIO position responsibilities are much more extensive than any corporate CIO roles I know of.

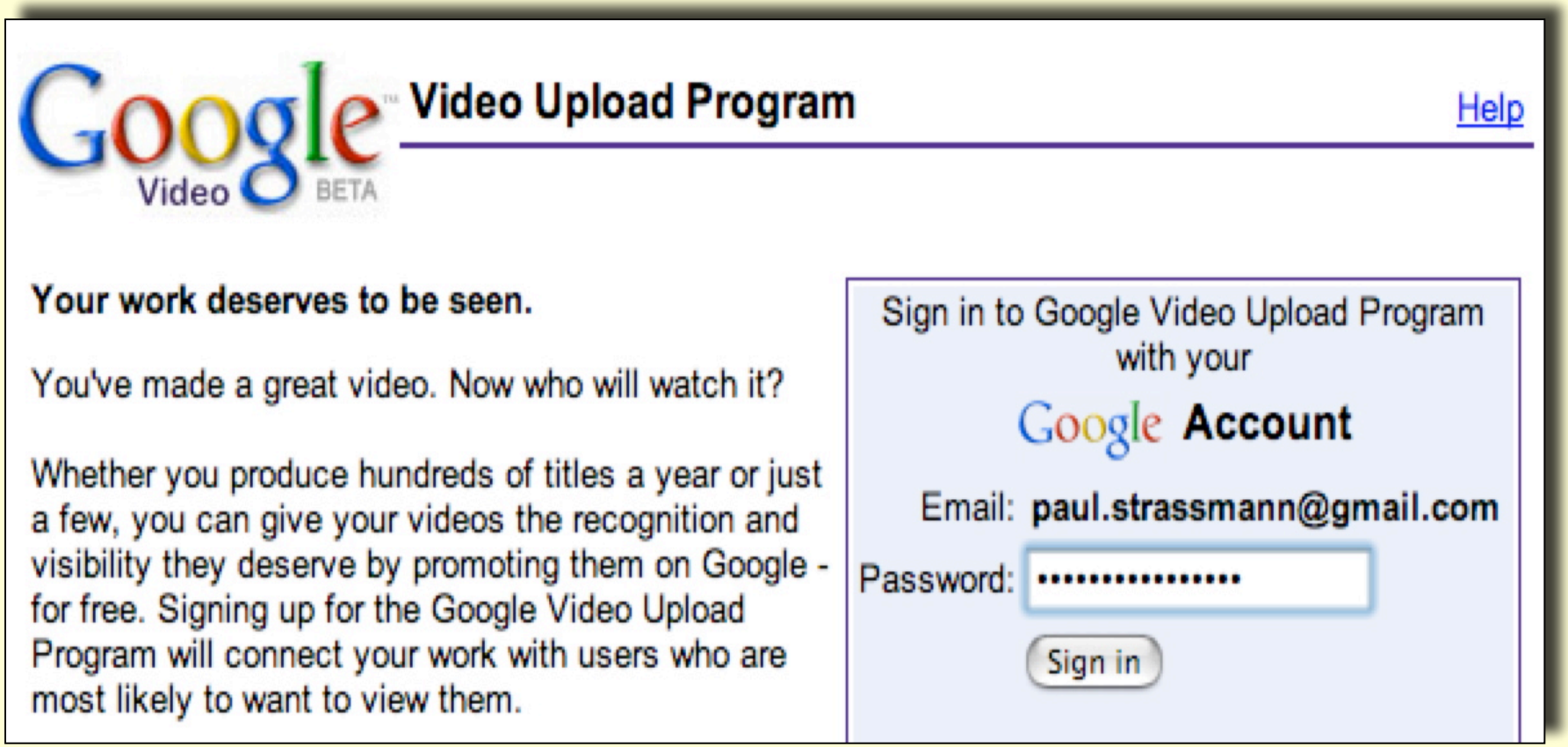
2. The oversight over the work of the Federal CIO is carried out by many more organizations than any corporate CIO is exposed to.

3. The sheer quantity of rules, regulations and laws guiding the conduct of the office of a Federal CIO cannot be even imagined by a corporate CIO.

Occupy the Desktop

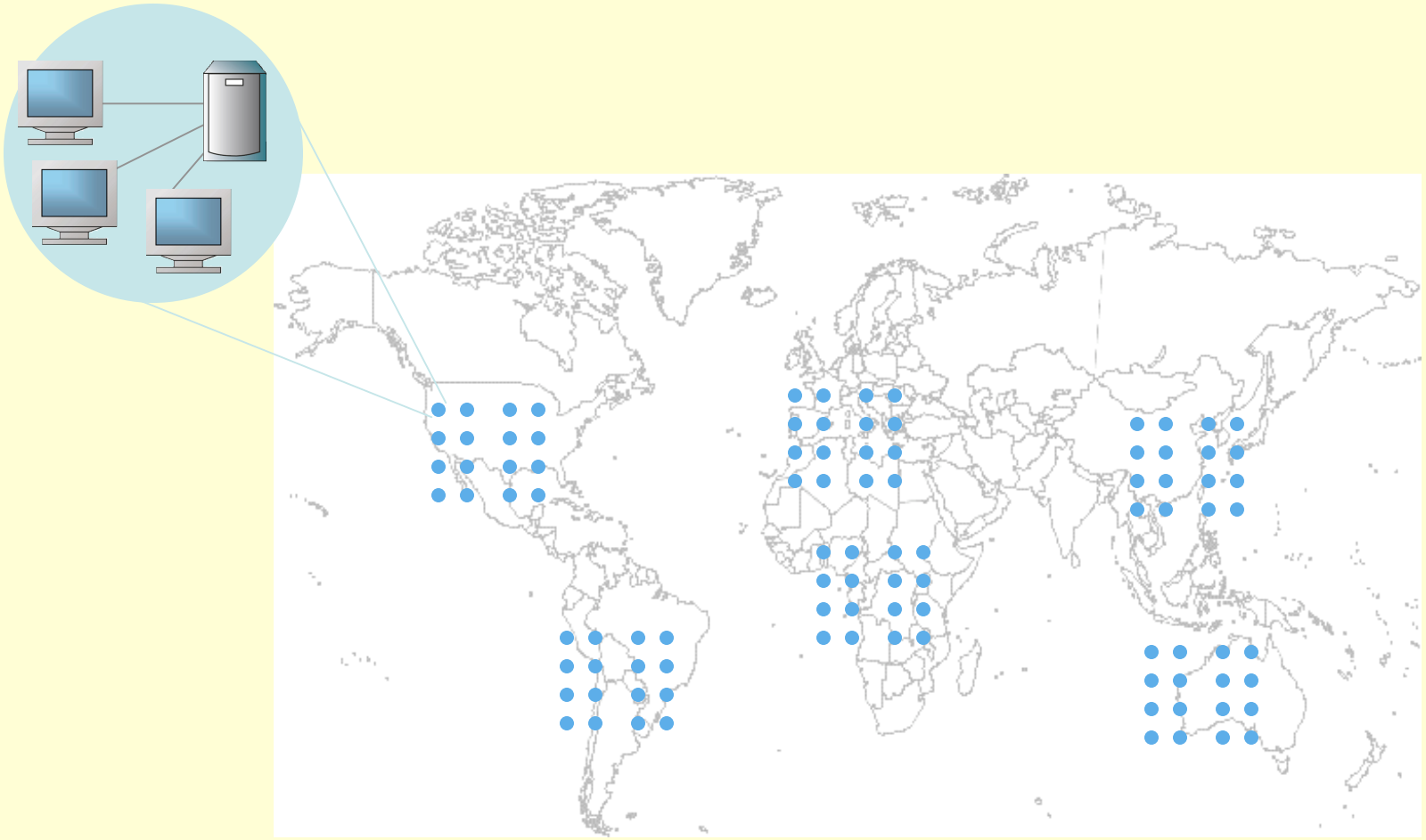


Multimedia Services



Comparison Summaries

Workgroup Computing Today: Millions of Local Applications+Local Data



Work-Groups Vulnerable Today

The 2005 SANS Top 20

The Most Critical Internet Security Vulnerabilities

See *www.sans.org/top20/ for details*

Top Vulnerabilities in Windows Systems

W1. Windows Services
W2. Internet Explorer
W3. Windows Libraries
W4. Windows Office and Outlook Express
W5. File Sharing Applications
W6. Windows Configuration Weaknesses

Top Vulnerabilities in Cross-Platform Applications

C1. Backup Software
C2. Anti-virus Software
C3. PHP-based Applications
C4. Database Software
C5. DNS Software
C6. Media Players
C7. Instant Messaging Applications
C8. Web Browsers
C9. Other Cross-platform Applications

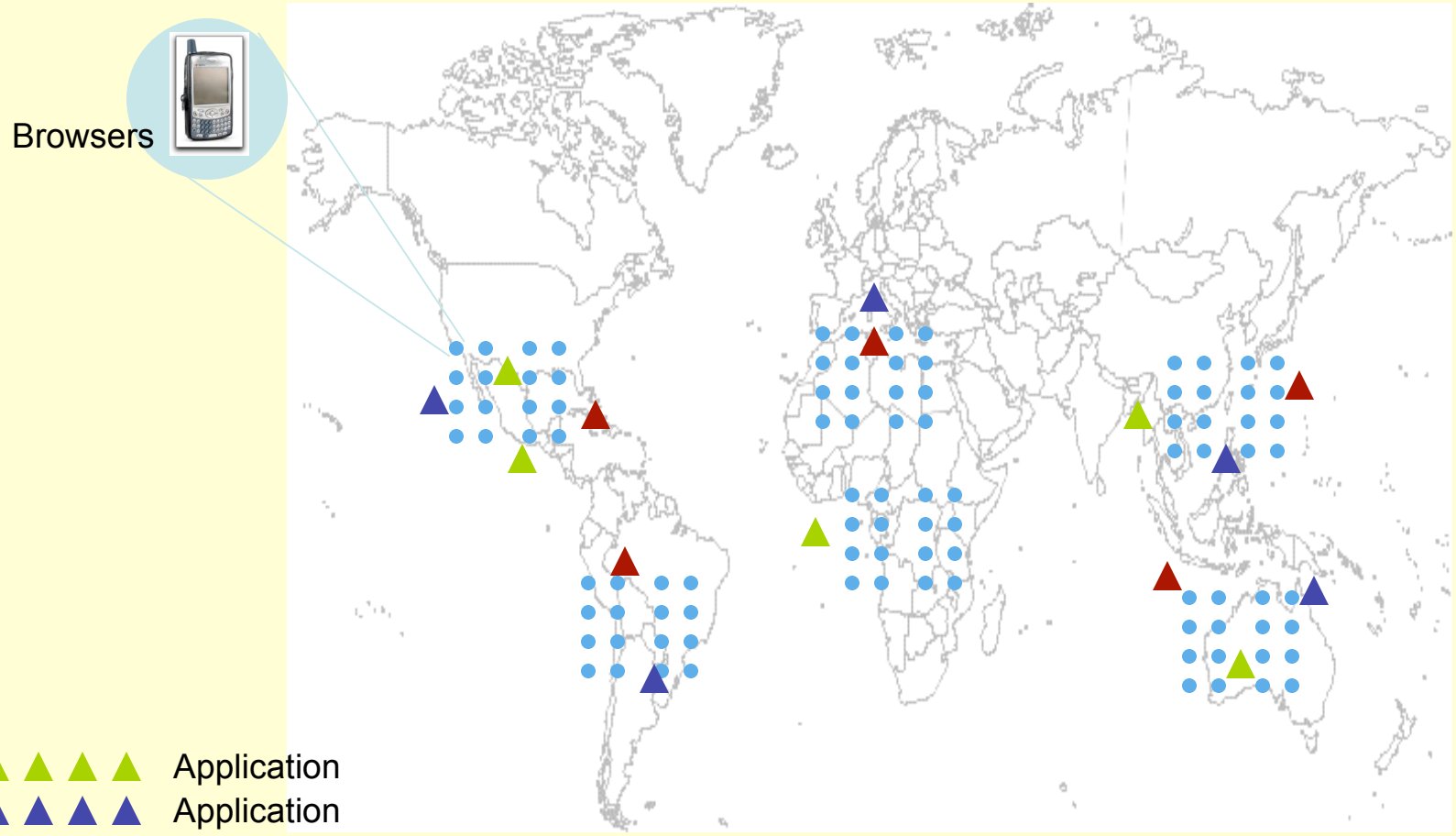
Top Vulnerabilities in UNIX Systems

U1. UNIX Configuration Weaknesses
U2. Mac OS X

Top Vulnerabilities in Networking Products

N1. Cisco IOS-based Products
N2. Cisco non-IOS Products
N3. Cisco Devices Configuration Weaknesses

New Internet: Billions of Browsers, Secure Shared Applications+Data



Workgroup vs. Network Architectures (1)

Workgroup Centric	Network Centric
Strategy: Capture Desktop	**Strategy: Occupy Internet**
Customer's labor and capital	Labor and capital in network
User-specific infrastructures	Infrastructure is universal
Systems controls by user	Network controls in network
Operating system dependency	Open source browsers
License Software	Pay for Use
Data read from files	Data assembled in context

Workgroup vs. Network Architectures (2)

Workgroup Centric	Network Centric
Strategy: Capture Desktop	Strategy: Occupy Internet
Customer's labor and capital	**Labor and capital in network**
User-specific infrastructures	Infrastructure is universal
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Workgroup vs. Network Architectures (3)

Workgroup Centric	Network Centric
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Customer's labor and capital	Labor and capital in network
User-specific infrastructures	**Infrastructure is universal**
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Workgroup vs. Network Architectures (4)

Workgroup Centric	Network Centric
Strategy: Capture Desktop	Strategy: Occupy Internet
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Workgroup vs. Network Architectures (5)

Workgroup Centric	Network Centric
Strategy: Capture Desktop	Strategy: Occupy Internet
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License Software	Pay for Use
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Workgroup vs. Network Architectures (6)

Workgroup Centric	Network Centric
Strategy: Capture Desktop	Strategy: Occupy Internet
Customer's labor and capital	Labor and capital in network
User-specific infrastructures	Infrastructure is universal
Systems controls by user	Network controls in network
Operating system dependent	Open source browsers
License Software	**Pay for Use**
Data read from files	Data assembled in context

Workgroup vs. Network Architectures (7)

Workgroup Centric	Network Centric
Strategy: Capture Desktop	Strategy: Occupy Internet
Customer's labor and capital	Labor and capital in network
User-specific infrastructures	Infrastructure is universal
Systems controls by user	Network controls in network
Operating system dependent	Open source browsers
License Software	Pay for Use
Data read from files	**Data assembled in context**

The Future

Technology

- All electronic devices on Internet.
- Data, voice, video, sensor inputs accessible.
- Phone, TV and print media displaced.

Services

- Systems respond to questions.
- Information is displayed in context.
- Applications for decision-making.

Relevance for National Security Systems

- Workgroups to Network-Centric services.
- Migrate through displacement.
- Invest savings in innovation.