The Future of Data Storage Devices and Systems

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SLIDES COURTESY Giora J. Tarnopolsky, TarnoTek

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Alternative Talk Title

Autonomic, Secure, Private, Pervasive, Long-term, Application-aware, Active Storage

Specifically, the Research Advances Necessary to Get Us There...





DS2 Talk Contents

- Introduction to INSIC
- The DS2 Research Roadmap Process
- DS2 Roadmap
 - -Precompetitive Research
- DS2 Research Thrusts and Proposals
- Next Steps





WHO WE ARE...

INSIC the <u>Information Storage</u> Industry Consortium ... the collaborative technology research consortium for the worldwide



information storage industry







WHO WE ARE...

What INSIC is:

- An international storage technology research consortium

What INSIC does:

- Organizes & manages high-risk, pre-competitive, collaborative research projects
- Develops & publishes <u>long-range</u> storage technology and applications <u>roadmaps</u>
- Coordinates & obtains <u>funding for university research</u> in storage technology





INSIC Members ...

and Universities

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Example – HAMR Program

Project Goal – Demonstrate 1 Tbit/in² Heat Assisted Magnetic Recording

- \$21.6 million 5 year program started in 2001
- 50% funded by Dept. of Commerce's Advanced Technology Program (ATP)
- Balance of money comes from company match spending



























DS2 Roadmap

Roadmap of Data Storage Devices and Systems Research

INSIC INFORMATION STORAGE INDUSTRY CONSORTIUM

Data Storage Devices and Systems (DS2) Roadmap



January 2005

http://www.insic.org/2005_insic_ds2_roadmap.pdf









"Devices and Systems"

- In the context of this program, "devices" go together with "systems"
- "Devices" here are a managed storage independent devices
- "Systems" may not refer to devices at all, but to issues such a includes software, middleware it-addressable and architectures...
 that are not directly linked to a device











Information Storage Industry Consortium

DATA STORAGE DEVICES & SYSTEMS (DS2) RESEARCH PROPOSALS





Research Thrusts

	Thrust	Issues addressed	Leaders			
•	Active Storage Devices	General purpose data processing by the storage device	Erik Riedel Seagate Research			
•	Application-aware Storage	Device or system behavior depends on data or users' characteristics	Michael Mesnier Intel & CMU			
•	Autonomic Storage	Storage system manages itself	Remzi Arpaci-Dusseau U. Wisconsin			
•	Long-term Storage	Preservation of digital assets	T. Ruwart/ G.Tarnopolsky U. Minnesota / INSIC			
•	Pervasive Storage	Devices everywhere, data consistency, preservation, security	C. Harmer/ P. Massiglia VERITAS			
•	Privacy and Security	Data access rights, data integrity, IP, security	James Hughes StorageTek			

Research Thrusts



 Application-aware storage devices are those which possess knowledge about the environments in which they operate, and enhance their performance as a result of that knowledge.

> Examples: - aggregation information - relationships among data, users, apps

Application-aware Storage Opportunities

- Spatial and temporal access patterns
 For better data layout and organization
- Relationships among data, users and apps
 For improved indexing, searching, organizing
- Data replication factors
 - For higher availability and data reconstruction
- Access control lists and what I/O is "normal"
 - For device-resident anomaly detection
- Caching hierarchies
 - For exclusive and/or cooperative caching
- Application goals (e.g., latency, availability)
 - For autonomic storage

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 Active storage devices are those which run application-specific processes to perform application-specific functions upon the data. These devices apply their own capabilities to improve application performance.

Active Devices Research Issues

A model of distributed computation

 a theory of how to flexibly distribute the functionality in a system around a computing environment.

Resource management for active functions

handling multiple executing active functions at the same time

Internal device API (Application programming interface)

how active functions interact with the local hardware environment

Correctness/reliability/stability

 in disk or disk array, most corner cases are tested and interface is limited; in active storage, now many more dimensions to the problem.

Specialized hardware for fixed functions

- hardware-optimized functions in some settings.

- Long-term preservation assures the availability of tangible data records, digitally stored, over periods of time that vastly exceed the lifetime of the physical and logical system used to store and retrieve the record initially.
- A *tangible data record* is information that is sensorially evident to all users, visually or in natural languages, although certain information, such as hyperlinked documents, may require machinery for its display.

- *Digital information lasts forever" or five years, whichever comes first.*" Jeff Rothenberg

Preservation Cost Issues & ROI Models

 Comparison of costs between the Harvard Depository film vault and the Online Computer Library Center, Inc., Digital Archive(2003). (Chapman, 2003)

April 2006 # 30

- Factor 200 in favor of film plate
- Digital costs include extant bit preservation and exclude long-term preservation
 - Raw capacity cost of disk 229 MB: \$0.069 (2004)

Preservation of Digital Assets

- Preservation of an extant bit stream
 - Hardware, firmware, software means of assuring data integrity, including disaster recovery, within a single technology generation
- Preservation of a bit stream representative of the tangible data record over generations of hardware and software migrations. Invariant or adaptive.
- Preservation of the ability to re-create the sensorial representation, the tangible data record itself
 - Semantic continuity
 - Record aggregation, curatorial metadata
 - Emulation: future computer emulates O/S, application
 - Universal Virtual Computer approach

Pervasive Storage

Nokia N91 4GB phone

500 M units @ 10 GB = 5 Exabytes

- Pervasive access to informa-tion, supports either "disconnect-ed" or connected operation.
- Pervasive storage refers to the widespread availability of storage resources of practically unlimited capacity, over unbound geographic areas, concurrent with the consistent management of the stored assets and their immediate accessibility

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Pervasive Storage Research Issues

- Storage cells vs. pure storage farms
- Name space management
 - universal, unique identifiers regardless of home location for O(10¹⁵) objects
- Privacy and security
- Architecture of the required metadata
- Data consistency
 - multiple users share data object
- Intermittent connectivity operation

Economics - mass deployment of storage

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- Privacy refers to the denial of access to stored records by unauthorized clients concurrently with the assurance of access by authorized ones
- Security refers to the assurance of the integrity of stored records concurrently with efficient access by multitudinous clients

Privacy & Security Research Opportunities

- Data Integrity: protection and recovery
- Data Privacy access controlled by creator
- Data Destruction when data no longer needed
- Intrusion Detection
- Key Management enterprise, distributed
- Authorization
- Authenticity and integrity of data
- Operational risk
- Economic issues risks vs. costs

Autonomic Storage

- Autonomic storage is:
 - \rightarrow Self-configuring
 - \rightarrow Self-optimizing
 - \rightarrow Self-healing
 - \rightarrow Self-protecting
 - → "Self-*": important computing operations can run without the need for human intervention

Example: Detection, diagnosis, and avoidance of service interruption or system failure

Some Research Directions

- Transparency
 - How to "explain" autonomic decisions to system manager?
- Evaluation and Metrics
 - How to compare how "autonomic" systems are?
- Study of Processes and Practices
 - What are the processes that we are automating?
- Management Policies
 - What are the policies and support machinery needed?
- Evolution, Growth, Scale
 - How to adapt over time as systems change?
- Specialized Storage Systems

- How to build less general systems that are more autonomic?

April 2006 # 38

DS2 Thrusts & Business Interest

	Thrust	Business Opportunity				
•	Active Storage Devices	Massively parallel database search and data mining	Massive indexing and searching	ILM & automatic destruction of data	Sensor networks	
•	Application- aware Storage	QoS, efficient I/O	Reliability	Security	System management	
•	Autonomic Storage	TCO (operational)	Predictability	Data integrity	Self-healing	
•	Long-term Storage	TCO (over time)	Data integrity	Language development	Consumer markets	
•	Pervasive Storage	Consumer markets	Record preservation	Consistency	Distributed storage utilities	
•	Privacy and Security	Assurance of service	Dispersed storage systems	Consumer markets	Record management	
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April 2006 # 43

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