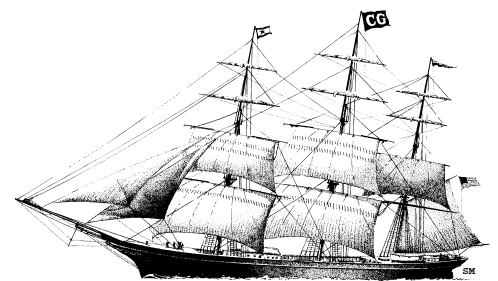


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## *E Pluribus Unum* — The Oneness of IBM Storage

Analysts: Mike Fisch, Mike Kahn, and Anne MacFarland

### Management Summary

On the backside of a U.S. dollar bill is the Latin phrase “E Pluribus Unum”, or “*Out of many, one*”. It refers to the unity of the member states – many, diverse elements unified under a common framework. Interestingly, this same motto can apply to the future of information technology. **Much of the industry is converging upon a similar vision of where everything is headed: *The Computing Utility* – where many, heterogeneous elements of computing are integrated into a unified infrastructure for servicing applications and users, for the betterment of all.**

Functionally, the idea is similar to a public utility like water or electricity. Customers “turn it on” and receive the service in an on-demand, typically pay-per-unit manner. In the case of computing, customers specify the resources required (processing, storage, and network) as well as qualities of service (performance, reliability, and cost). **Then, the utility automatically and transparently delivers and accounts for the needed resources. It just flows! The result is high resource utilization, greatly simplified management, and a superior TCO.** This is a far cry from the disparate point systems and “silos” of computing that dot the landscape of enterprises today, breeding complexity and cost.

**Storage is an essential, and possibly easier-to-supply-and-manage component of this grand vision.** While the industry is making progress in the storage arena, it is not yet close to declaring victory. **Several capabilities are required:**

- **Consolidated, networked storage** – block and file services, converged SAN and NAS,
- **Automation** – devices monitor and manage themselves to meet user-defined service levels,
- **Centralized management** – single point of control,
- **Open standards and interoperability** – broad interoperability and integration of components, including multiple vendors and existing equipment, and
- **Intelligence expanded into the network** – to encompass all servers and storage devices.

A storage infrastructure that combined all of these capabilities *in full* would be much closer to the utility world of the future. In fact, IBM is busily working in that direction. It is betting heavily on the computing utility vision, in general. **From the starting point of its range of storage hardware, software, and services, IBM is executing on a credible and comprehensive plan to deliver a storage utility.** Read on to find out how it intends to create “out of many, one” storage.

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## Looking Back to See the Future

Few understand it (yet), few accept it as inevitable (yet), many can't see it happening at all (many won't see it till it's over), but to those of us who have been around for two, three, or more decades of computing evolution, it truly seems like "*déjà vu* all over again"!<sup>1</sup> **The need for cost containment and control for enterprise IT infrastructure has never been greater.** We hear from enterprise management that:

- **Users have got to understand the relationship between desires, needs and costs** (i.e., they have to be aware and accountable) and
- **IT departments have got to get their runaway trains under control** (i.e., isn't there a better way to do what you are doing?).

We're talking about *utility computing*, of one sort or another. While very few public utilities can be described as huggable, and most of us have a number of rational complaints about them, most utilities do serve a purpose of reliably delivering a commodity service or set of commodity services to a large population that pays (largely) based upon the services ordered or consumed. While the industry has been moving in this direction for years (i.e., running IT like a business), many were taken by surprise when IBM President Sam Palmisano declared that "e-business on demand" was to receive the highest priorities with the company, including a \$10 billion investment.

We'll save the historical lecture and "I told you so attitude" for another bulletin, but mainframes have been doing much of this for a long time. IBM has been moving key elements of its mainframe technology to its other *eServer* platforms for a number of years and has recently driven intelligence into the equation under its autonomies banner. Hardware is becoming commoditized in many ways and for many reasons. **We don't really care, any more, about the technology inside, as elegant as it might be; we care about what the technology will do for us** (i.e., how many transactions are processed in a second, how fast

<sup>1</sup> Many thanks to baseball legend Yogi Berra, whose mastery of English is truly a treasure.

## Why Utilities May Have A Negative Image

Think, for a moment, about the reasons that many utilities have a negative image. At the top of the list may be **a lack of responsiveness in meeting customer needs and the customers inability to replace the offending utility with another**, due to the monopolies granted by the states and municipalities, or difficult to duplicate (massive) physical infrastructure. Lock-in of any kind is offensive, and any apparent IT vendor inclination to do so will be met by great resistance in today's world of open systems.

With open systems, the utility supplier's grip (ability to lock you in) is weakened greatly. While there is always a pain and a cost to move applications and data to another utility, escape is always an available option in the IT arena, because applications and middleware are portable (and not limited to a hard-to-duplicate infrastructure, like underground gas lines). **Though your initial, knee-jerk reaction to an IT utility may be unfavorable, most of the fear is unwarranted.**

a query is answered, how much data can be stored and retrieved, etc.) **and the quality of the service** (i.e., how available, secure, protected from disaster, etc., are the resources). At the same time, management has changed its attitude about IT services from

*Give me all that I might need, at the highest qualities of delivery at any cost*

to

*Let me tell you exactly what I need and what it's worth.*

The IT world has grown rapidly (and to many excesses) and now it's time to return to the management and service delivery disciplines of the mainframe era that never ended, but definitely got overshadowed by many generations of "open systems".

For the purposes of this bulletin, let's not argue about the force of the march to utility computing, nor whether it will be done within the enterprise or by service providers; we'll

discuss these in detail in later bulletins<sup>2</sup>. Instead turn your focus to a piece of the IT technospace loosely called *storage*, and let's see why storage will be an early proving ground for the utility-like concepts and then see how IBM plans to cover this territory very broadly.<sup>3</sup>

### Storage Provisioning and Management is Part of the Shift

In spite of the difficult economy, or maybe because of it, storage management has been a hot topic in the industry and at Clipper.<sup>4</sup> **There are many components of storage management, but the bottom line is control and optimization of assets through better management.** Reducing the burden on storage administrators is often the ROI justification with the most immediate payback, but your objectives should be broader. All of these related efforts work on two fronts: the assets, and the people that use them. Once all of the fog has cleared, the next step is to tie the people (organizations) to their ownership and use of the assets. Then accounting<sup>5</sup> enables deployment and use to be measured and charged back to the organization. Receiving that first accounting is like getting the big bill when you, for the first time, check out of a first-class hotel. You are surprised at the cost, of course, but also the level of detailed itemization (and what seems disproportionately expensive, from your youthful perspective). Most of us on a budget then decide to deploy or use resources more carefully. **This is the first critical**

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<sup>2</sup> OK, so you don't want to wait. Here's a taste of what's to come. There are many reasons and conditions that make running an IT utility within the enterprise very attractive (including control, targeted optimization, security, and cost-containment). But there are also many reasons to consider outsourcing this to a trusted third party (including insufficient internal scale to optimize costs, insufficient differentiation between what an enterprise requires and the requirements of many other enterprises, and lower long-term costs). As you will see, it is not who runs the utility that is the first question, but **whether the utility can better meet enterprise requirements at a lower cost.** We will have a lot more to say about all of this in future bulletins.

<sup>3</sup> We will have more to say on other parts of the utility, such as servers, in later issues.

<sup>4</sup> See **The Clipper Group Explorer** dated June 25, 2002, entitled *Storage Resource Management - Conducting a Symphony of Storage* as well as other related publications at <http://www.clipper.com/publications.htm>.

<sup>5</sup> See **The Clipper Group Explorer** dated October 31, 2002, entitled *The Accounting Pendulum Swings at Storage (or, Why The Taxman Cometh?)* in at <http://www.clipper.com/publications.htm>.

**revelation: a decision to manage the use of procured resources to optimize costs.**

**The second revelation usually follows quickly: not all needs are the same.** When you never see the detailed accounting, you are inclined to think about the entire bill as a necessary expense, and you feel comfortable paying for first-class services – in the aggregate – because you need *some* first-class services. But now that you have seen the bill, you know that, maybe, you should have done your copying at the around-the-corner print shop, and that you should have eaten some of your meals elsewhere.

**The final revelation is that you want to specify your needs,** probably by some tiered scheme according to the quality of what is being provided, **and get as much quality as your restricted budget will afford.** This is why we are so focused on tiered-levels of storage, where you specify what is required, and pay for what you deploy and use.<sup>6</sup>

With these three revelations in hand, plus a general order from management to squeeze as much out of the IT budget as you can, you go off **in search of the best stratified, tiered-storage solution that you can get for your money.** Most definitely there will be stress in your life, trying to decide how to rank the users, applications, files, and databases, in terms of importance according the criteria that you must determine, knowing well that you do not have enough money to go first class all of the time. But you have no choice, once you see the itemized bill; you can't ignore it! Your pump has been primed, and you know what you must do as a responsible manager.

Note that nothing has been said about where you go to get your services – within your department or enterprise data center, or from some outside provider. For the purposes of this bulletin, it doesn't really matter because each of those possible sources is or soon will be running itself as a utility, giving you choices, and charging you accordingly. These sources can no longer say *here it is, take all you want, and someone else will pay for it.* They, too, are now accountable, and must figure out how to

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<sup>6</sup> See **The Clipper Group Explorer** dated August 29, 2002, entitled *Tiered Storage Classes Save Money - Getting The Most Out Of Your Storage Infrastructure* at <http://www.clipper.com/publications.htm>.

successfully run their utility.

**To do this, the utility providers need a different set of storage resources, and tools to automatically manage them, than before.** Of course they will want (and will have) to use some of the assets in place. It's taken a while to get you here, but this is a broad undertaking. It is in the context of achieving the storage utility that we look at how IBM is enhancing its storage hardware and software offerings, what products are planned, and what future capabilities are indicated by some of IBM's research initiatives.

### IBM Builds the Storage Utility

**IBM has stressed its commitment to bringing about the computing utility, and specifically in storage, it has laid out concrete plans to deliver on the storage component.** Something this big is not achievable in one felled swoop – for IBM or the industry in general. Progress comes incrementally over time. However, there are a number of important milestones along the way, and we see IBM driving towards them all.

#### *Consolidated, Networked Storage*

Just as an electrical utility must have a grid for distribution, a storage utility must have a network. **A network allows storage to be consolidated into a single pool and connected to the entire enterprise.** The result is much higher utilization and easier management. It is a more-efficient architecture. Furthermore, a storage utility must provide block services (“raw” storage) and file services (more structured storage) since applications and users access data at one level or the other. **This implies a converged SAN and NAS infrastructure.**

Today, IBM offers SAN-attached storage with its *Enterprise Storage Server (ESS or “Shark”), 7133*, and *FASiT* storage arrays. Certain models of tape drives, tape libraries, and the *Virtual Tape Server* also connect to SANs. IBM offers a line of NAS appliances and a NAS gateway that acts as a front end to SAN storage, providing a measure of convergence today.

**IBM is continuing its efforts to change the nature of storage hardware and software. Its goal is to reduce costs and increase value of the delivery vehicles.** (See

### Storage Bricks — Very Cool

This future storage product is worth mentioning for the *wow factor* alone. IBM storage already comes in many sizes and form factors. **In the future, it may come in dense bricks – a radical departure from anything on the market today.**

The prototype is about 7 inches on a side, each brick contains 12 disk drives comprising more than 1 TB of storage. **There is no external cabling, and the units cannot be opened – a proverbial black box.** The bricks stack on vertical power-and-cooling rails, and they communicate with adjacent bricks via wireless (capacitive) interfaces on all six sides, creating a true 3-dimensional mesh. (*Beam me up, Scotty!*) Each connection in this mesh has a bandwidth of 1 gigabyte/second, for a total bandwidth of approaching terabytes/second in a large configuration of bricks.

When a brick fails, it is left where it is. **This “fail-in-place” strategy is a key aspect of the architecture.** Long-term experience in data centers has shown that humans trying to repair a system can cause as much damage as they fix. For example, accidentally removing the wrong disk during a hot-swap repair is a dominant cause of data loss. In such a cube system, administrators may add fresh, new bricks on top of the existing layers, but they should not need to remove existing bricks during the 5-7 year lifetime of the system. Autonomic software will reconstruct data stored in a failed brick from data in other bricks and put it in an unused one.

The cube approach is currently in development at IBM's Almaden Lab and is expected to deliver simplified management and exceptional scalability. **Its dense, three-dimensional stacking allows a large amount of capacity in a small form factor.**

*Storage Brick* box above for an example of hardware being developed in IBM labs.) While hardware like Storage Brick is critical to changing the nature of storage, **software is the key to improving the management of storage.**

IBM's next-generation *Virtualization Engine* and *Storage Tank*<sup>7</sup> technologies represent a more dramatic fulfillment of consolidated, networked storage. **Virtualization Engine is an intelligent, block-level storage platform that resides in the SAN and joins together heterogeneous servers and storage arrays.** It will abstract all attached disk arrays and present them as a pooled resource to servers, allowing them to be securely shared, reallocated, and scaled without disruption and without regard to brand of storage. It will also offer advanced features like point-in-time copy, remote replication, clustered failover, and data migration across all connected devices.

**Storage Tank is an advanced SAN file system with aspirations for inter-SAN and wide-area applications.**<sup>8</sup> Traditionally, servers access files over the LAN through a file server or special-purpose NAS appliance. **With Storage Tank, heterogeneous servers will be able to access and share files in a common name space directly over a high-performance SAN.** It is designed for speed, availability, and scalability.

**The goal of Virtualization Engine and Storage Tank is to hide complexity and consolidate resources.** They abstract and simplify storage at both block and file levels. **Together, they will form the foundation of a unified, high-performance and cost-effective networked storage infrastructure.**

### *Automation*

Through automation, machines can perform tasks and take care of themselves without much human intervention. This saves labor, usually the most costly component of TCO equation. For example, thanks to automation, phone operators no longer need to manually connect every call placed. Otherwise, half the population would have to work as operators nowadays! **In the same way, a storage utility must be able to scale without adding an outrageous and cost-prohibitive number of people to staff it. It also must be able to dynamically adapt to meet service levels, re-deploy assets, and optimize their use. Automation is a key ingredient to running a**

<sup>7</sup> Both Storage Tank and Virtualization Engine are expected in 2003.

<sup>8</sup> These features are expected in later releases.

### **storage utility.**

IBM is pursuing automation through a company-wide initiative called "autonomic computing". **It seeks to instill technology with the ability to configure, protect, optimize and heal itself, much like the human body.** The idea is to strip away the unnecessary complexity and cost from information technology. **Autonomic computing is a future-oriented vision, like the computing utility, but we see the fruits of IBM's progress today.** For instance, the recently-revised ESS command line interface (CLI) lets administrators automate routine operations.<sup>9</sup> They run locally on the ESS storage processor without having to be invoked by an external server, making life easier for the administrator.

A future capability in development at IBM is the *Performance Assured LUN* (logical unit number). Traditionally, the LUN is merely a unit of storage capacity within a storage array. The Performance Assured LUN takes it a step further by guaranteeing performance in terms of user-defined access times. It does this on the storage processor through I/O scheduling, *ALIS*<sup>10</sup>, cache management, and virtualization. It can enable tiered storage classes within a single array and contributes to the higher objective of managing quality of service based on policy.

These features may seem like technical minutia, **but they build upon one another and ultimately enable an automated storage utility to be self-managing and self-optimizing.**

### *Centralized Management*

Like automation, centralized management is also a labor-saving device. A side effect of distributed, networked computing is the plethora of interfaces and consoles for managing all of the devices and software layers. Trying to manage the infrastructure with them can be like herding cats, and storage

<sup>9</sup> Like asset monitoring, LUN masking, space monitoring, volume identification, host connections, audit log, parallel access volumes, and copy services.

<sup>10</sup> ALIS, Automatic Locality Improved Storage, is an automated routine that monitors I/O to find pattern of data access and then repositions the data on the disk to produce more sequential reads, giving faster and more consistent throughput.

networking, in its present state, is no exception. **To minimize the administrative burden, the storage utility must have a single point of control, or at least as few as possible.**<sup>11</sup>

**IBM is developing software that will direct a heterogeneous, networked storage environment from a top-down perspective, like a conductor in front of an orchestra. The goal is to provide centralized, simplified, automated management.** Currently, IBM offers three storage management software products:

- **Tivoli Storage Resource Manager** – identifies, measures, and reports ownership and utilization of storage assets at a granular level and enables charge-back,
- **Tivoli SAN Manager** – discovers components and maps topology of SAN fabric, and constantly monitors availability and changes in the fabric; and
- **Tivoli Storage Manager** – performs enterprise tape backup and recovery, archiving, and hierarchical storage management, using a flexible hierarchy of storage media including disk and tape.

**The long-term plan is to integrate these products into one framework that manages storage capacity, assets, events, availability, and performance.** In turn, it will hook into the higher-level Tivoli systems management solutions. The objective is to centrally manage the entire IT infrastructure, including the storage component.

### ***Open Standards and Interoperability***

An era of distributed computing brought the blessings of flexibility and choice of technology and vendor, but with it came the curse of interoperability issues. For a whole system to function, the components must interconnect and work together. With so many vendors and products and versions, this is a huge and never-ending struggle in the open systems world. **In the large-scale and more interconnected environment of the storage utility, it becomes all the more important to interoperate**

**without hassle.** Limitations and vendor lock-in are not acceptable. **The best way to achieve broad interoperability is through open standards.**

IBM has committed to the Storage Management Interface Specification (SMIS) and its predecessor CIM/Bluefin for open storage management. SMIS is a broadly-accepted specification for identifying, monitoring, and controlling storage resources that is being developed by the Storage Management Initiative within the Storage Networking Industry Association (SNIA). **It is essentially a common language that everything can speak – a storage lingua franca.** SMIS is partially complete, at this point, and being rolled out in phases. In the end, it will cover everything from storage and networking devices to volume managers, file systems, and databases. The industry will release a slew of products in 2003 with SMIS support.

IBM will make its managers and devices SMIS-compliant. Tivoli managers will be able to manage third-party storage devices, and third-party managers will be able to manage IBM storage devices. IBM will also deliver proxy agents that allow existing devices to support SMIS, and in some cases as a stopgap measure it will incorporate proprietary APIs (application programming interface). The net result is:

- **More powerful, cost-effective products** – In the industry in general, SMIS will remove proprietary interfaces as a means to lock in customers. Instead, vendors will have to compete only by virtue of their feature set and price, ultimately resulting in better products all around.
- **Enterprises retain choice and flexibility (heterogeneous support)** – While IBM has and will have a comprehensive set of building blocks for a storage utility, enterprises will be free to choose the components that best meet their needs, regardless of vendor.
- **Support for legacy systems** – Many enterprises have invested a great deal in their storage infrastructure to date. A realistic storage utility solution should be able to incorporate legacy systems, and IBM will provide this capability through SMIS proxy agents, Virtualization Engine, and other means.

<sup>11</sup> A single point of control does not necessarily mean a single point of execution (i.e., it runs on a single server) or a single point of access (there is only one point of entry for management). A single point of control means that most/all of the information about the objects and operations under management is available from one place.

### *Intelligence in the Network*

Storage intelligence (i.e., software features) will expand into the network. This is not so much a storage utility requirement as it is an inevitability as storage evolves.<sup>12</sup> **It will happen because intelligent storage networking is a superior architecture that delivers greater value to enterprises.** Here's why:

- **The network provides a common ground through which all data passes** – The application of intelligence requires examining, routing, and manipulating data. Intelligence and data must cross paths, and the network is the most logical point for many (but not all) features.
- **The scope encompasses all servers and storage devices** – Rather than limit software features to particular servers and storage devices, why not make it available to everything, regardless of vendor and operating system? Software value is maximized, and enterprises are free to use any new or existing equipment they want. No more proprietary lock-in.
- **Storage management is simplified** – With one or few instances of the same network-resident software, management is centralized and simplified. This is easier than managing instances on a multitude of servers, or managing different, vendor-specific software on storage arrays.
- **It's more economical** – All of the above characteristics work to lower TCO, especially as the infrastructure scales. Acquisition costs are likely to be lower (especially if using tiered storage classes), and operating/ management costs will certainly be lower.

**Simply, it is a more-efficient approach.** Many storage features like volume management, data replication, storage management, and others will find their way into the network. For its part, IBM is pushing forward this trend with the Storage Tank, Virtualization Engine, Tivoli storage management, and other offerings.

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<sup>12</sup> See *Intelligent Storage Networks – Creating A More Cost-Effective Storage Infrastructure* in **The Clipper Group Explorer** dated February 22, 2002, at <http://www.clipper.com/publications.htm>.

### *Putting It All Together*

**At the end of the day, the storage utility is about delivering storage service levels to multiple users in an economical manner.** The characteristics and requirements described above are a rough blueprint of what it will look like and how to get there. **While the industry makes incremental progress toward this ideal, enterprises must answer the more immediate question: *How do I meet my storage requirements today?***

**First, keep in mind that a storage purchase is more than an isolated event that satisfies an immediate need. It is also the foundation on which you will build the future.** Knowing that the industry – and ultimately your enterprise – is evolving toward the storage utility, it is therefore important to see the big picture and think from the future backwards to the present. **Decisions made today about products, architecture, and vendors will enable or hinder this transition over time.**

Therefore, look for products, architecture, and vendors that meet today's requirements *and* position your enterprise well for the future. **If you have not already, consider networked storage (i.e., SAN and NAS).** This is now mainstream technology with a proven ROI. Depending on your enterprise's risk-reward profile, you might also **consider some of the next-generation storage resource management and intelligent storage networking solutions.** There are significant benefits to be had. Finally, **engage in partnerships with vendors that can satisfy your needs today and help bring your enterprise into the future, as it unfolds.** In an industry evolving as rapidly as storage, choice of vendor takes on a greater, strategic significance.

### **IBM As a Storage Utility Provider**

In this context, IBM stands out because of the completeness – or *oneness*, if you will – of its storage offering. It includes:

- **The broadest lines of storage hardware and software,**
- **A credible and concrete vision** for achieving a storage utility in the future,
- **The ability to integrate solutions** through IBM Global Services, whether for storage alone or a broader IT infrastructure,

- **The ability to finance utility construction and operation** through IBM Global Financing, and
- **The ability to approach the storage utility part of a larger business transformation**, with the assistance of PwC Consulting.

**The total sum of the parts is what makes IBM unique.**

**Product leadership alone is transitory in the competitive, fast-paced storage industry.** One minute Vendor A has the fastest box; the next minute it's Vendor B, and so on. It's like watching cars jostle for position midway through the *Indy 500*. While IBM's current storage line is broad, and certain products and features are best of breed, this is only part of the equation.

**IBM is also able to be a long-term, strategic partner for the storage utility.** Its announced plans for achieving it, as previously described, are thorough and innovative. Exciting things are coming down the pike. IBM is capable of bringing your enterprise along the journey to the storage utility, one step at a time.

**Finally, IBM has strong capabilities in systems integration.** You have three choices for deploying information technology:

1. **Amalgamate many resources and tools** from many providers to assemble and run your own system, or
2. **Seek one party to deliver all of the parts** as part of a coherent offering, or
3. If this all seems too much, you can **find someone else to provide the services** on a pay-for-service basis, and get out of the infrastructure business.

IBM can sell you the pieces (#1, above). Your enterprise (or an independent integrator) then assumes responsibility for testing and integration, which takes time and carries an element of risk. For those who do not want the hassle, IBM is well-prepared to deliver an integrated and tested storage or even broader IT solution (#2). This is where IBM Global Services comes into play. **In many ways, IBM is a vertically-integrated integrator, making/providing many of the component parts itself (servers, storage, managementware, middle-ware, etc., – even solutions), thus allowing it to deliver an integrated offering that is pre-**

**tested (first) with its own components, but can also incorporate third-party hardware or software.** Other, less-complete IT vendors cannot take you this critical, last mile. Furthermore, IBM can deliver all of this as an outsourced service (#3) on pay-as-you-use terms. Depending on your chosen path, IBM Global Finances also has a variety of options for financing acquisition and operations.

**In short, the oneness of IBM storage provides one-stop shopping without one-size-fits-all.** It can deliver the whole storage utility, today (in parts) and tomorrow (in full).

## Conclusion

The evolution of computing began many years ago with the mainframe. It was (and is) centralized, largely self-contained, and highly efficient, if somewhat unhuggable. History buffs: think in terms of a monarchy. Next came the proliferation of distributed, networked systems of all sorts and colors, like a myriad of fiefdoms and city-states. They met local needs well but became costly, chaotic, and inefficient in aggregate. **The Computing Utility envisions something in between – the best of both worlds.** It will have efficiency with flexibility, self-contained yet heterogeneous, and tunable to individual requirements without unnecessary waste and complexity. **It will be various, distributed components united under a common framework for management and delivery: diversity within unity, *E Pluribus Unum*, “out of many, one”.**

**IBM gets it – for computing, in general, and storage, in particular.** Although the world is not there yet, IBM has the vision, resources, and desire to achieve it. They have a broad and compelling story for storage – both for today and for the future. **Enterprises looking for a long-term storage partner would do well to consider where IBM can take them.**



### **About The Clipper Group, Inc.**

**The Clipper Group, Inc.**, is an independent consulting firm specializing in acquisition decisions and strategic advice regarding complex, enterprise-class information technologies. Our team of industry professionals averages more than 25 years of real-world experience. A team of staff consultants augments our capabilities, with significant experience across a broad spectrum of applications and environments.

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