

Hitachi Dynamic Provisioning Software at United Airlines

Game-changing Hitachi Dynamic Provisioning Technology Dramatically
Improves Storage Utilization and IT Efficiencies

Case Study

By Rick Freedman

March 2008



Executive Summary

In today's world of unprecedented growth of storage and storage demands, companies are faced with the rapidly increasing size and complexity of storage area networks (SANs). Yet, due to provisioning layouts for optimal application performance along with efforts to streamline storage administration tasks, most companies only utilize 30 to 50 percent of their usable storage resources. With little or no corresponding increases in IT staff, the burden on storage administrators is to manage an ever increasing amount of storage per person, making efforts to improve utilization even more difficult. What if there was a way to improve storage utilization, optimize performance and improve IT efficiencies at the same time?

Hitachi Dynamic Provisioning software is a dramatic step toward improving utilization and automation in SAN storage. As described in this case study, the virtualization capabilities of the new Hitachi Universal Storage Platform™ V with Hitachi Dynamic Provisioning software improve storage utilization to new levels. The automated capabilities to balance the load across many more of the physical resources of the system remove a significant burden of storage management and optimization from the IT storage administrator and deliver on a next generation promise of self-managing, self-optimizing SANs.

"The Hitachi Universal Storage Platform V and Dynamic Provisioning software will dramatically improve our ability to respond to our users' storage demands and at the same time simplify the management of our storage infrastructure. We intend to allocate all new storage using Dynamic Provisioning."

Gary Pilafas, Managing Director, Enterprise Architecture, United Airlines

The ability to allocate disk space independent of the physical space used ("thin provisioning"), the performance improvements of wide-striping across many more disk drives, and the advantages of being able to provision storage without regard to physical location all contribute to spreading the I/O demand over more storage resources (disks, cache, ports, etc.), thereby minimizing "hot spots" and improving the overall utilization of the storage system. In prior generations of storage systems, storage administrators had to manually assign data volumes to drive groups, determining how to balance the system load (or simply not do any balancing and keep their fingers crossed that they were not putting too many volumes, or volumes with widely varying I/O profiles, on the same drive group). Hitachi Dynamic Provisioning provides the capability to automatically spread I/O loads over a maximum number of disk drives and array groups. As additional physical capacity is required, it is added to the pool and allocated to specific volumes. And the Dynamic Provisioning software automatically spreads the I/O load over the now larger number of disks for optimal performance.



Dynamic Provisioning software changes the game for storage management — managing at a macro level rather than micro-managing storage. Instead of provisioning and managing performance characteristics of the storage system volume by volume, the software now allocates individual volumes within a small number of large dynamic “pools” on the storage system and the storage administrator needs only to monitor capacity and performance of each pool. The storage system will dynamically allocate physical disk space as needed and optimize across a large number of disk spindles for best performance.

Dynamic Provisioning software:

- Simplifies storage management
- Self-balances resource utilization and optimizes performance
- Maximizes physical disk utilization

It's little wonder that a leading industry analyst firm has declared that thin provisioning software is no longer a leading edge technology, but should be considered a best practice for storage that customers should demand from their vendors.

Prior to implementing Dynamic Provisioning software in a production environment, United Airlines wanted to run a series of tests using some of their applications to learn how to use it effectively and understand how they would benefit from it. The company selected a key Microsoft® SQL Server application and copied the data to their Universal Storage Platform V. Working with Hitachi Data Systems, United set up a series of tests to exercise the storage system and monitor the impact of Dynamic Provisioning on disk usage, performance and storage management. The results were even better than they expected. When the data was copied from standard volumes to Dynamic Provisioning volumes, the disk used by the data volumes was reduced by almost 50 percent. United had been concerned that there might be application performance degradation but was pleasantly surprised to see a 30 percent performance improvement. Finally, United was able to see first-hand how Dynamic Provisioning was a much easier way to manage storage. It provided them with a way to reduce disk usage, improve performance, improve storage administrators' productivity and optimize the overall utilization of their storage systems. “There is no question,” says United Airlines Managing Director of Enterprise Architecture, Gary Pilafas, “it's the way to go.”



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Introduction

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Hitachi Universal Storage Platform™ V and Services Oriented Storage Solutions

Reaching previously unattainable levels of consolidation, the Hitachi Universal Storage Platform™ V has once again redefined the storage industry. Its predecessor, the Universal Storage Platform, redefined tiered storage by introducing virtualization in the storage controller itself. The Universal Storage Platform V builds upon that innovation by incorporating the world's first implementation of a large scale, enterprise-class virtualization layer combined with thin provisioning software. That means the full virtualization of internal and external heterogeneous storage under one storage system has finally been achieved. Organizations can obtain the consolidation benefits of external storage virtualization with the efficiencies, performance, power and cooling advantages of thin provisioning in one integrated solution.

As an integral component of the Services Oriented Storage Solutions architecture from Hitachi Data Systems, the Hitachi Universal Storage Platform V provides the foundation for matching application requirements to different classes of storage. The Universal Storage Platform V packages and delivers critical services, such as:

- Thin provisioning
- I/O load balancing
- Volume management across heterogeneous storage systems
- Nondisruptive data migration
- Security services (immutability, logging, auditing, data shredding)
- Business continuity services
- Content management services (search, indexing)
- Data de-duplication
- Data classification
- File management services



Services Oriented Storage Solutions enable IT organizations to present business clients with a menu of storage attributes (such as performance, availability, cost and security) and charge for those services based on the client's selection. Services Oriented Storage Solutions can lower costs, extend lifetime value and simplify management activities. The Universal Storage Platform V enables organizations to deploy applications within a new framework, fully leverage — and add value to — current investments and more closely align IT with business objectives.

What Is Dynamic Provisioning?

Hitachi Dynamic Provisioning software provides “virtual storage capacity” to eliminate application service interruptions, simplify administration and reduce costs. For companies with ongoing growth of their data storage requirements and expenses, Dynamic Provisioning can greatly simplify the application storage provisioning process and help defer costs on storage capacity purchases.

Dynamic Provisioning software allows disk capacity to be allocated to an application without actually being physically mapped and used until it is written. Decoupling the provisioning of storage to an application from the physical addition of storage introduces flexibility into the storage allocation process, eliminating the guesswork often involved in capacity planning. Dynamic Provisioning monitors shared storage resources and alerts administrators when the need occurs for additional capacity, which can be added nondisruptively with no application downtime.

Dynamic Provisioning simplifies performance optimization by transparently spreading many hosts' individual I/O patterns across many physical disks, thereby reducing performance management concerns and optimizing performance and throughput.

Goals and Requirements

What Are Organizations Looking to Gain from Dynamic Provisioning?

Benefits from Dynamic Provisioning most commonly fall into three areas:

- “Thin” savings — reduced disk requirements because physical disk space is not used until data is actually written to the blocks of the data volumes
- Performance and utilization improvements — resulting from the distribution of data volumes over a much larger number of storage assets (for example, physical disk drives or “wide striping”)
- Ease of storage management — simplifying storage administrators' burden for storage provisioning

Thin Provisioning

A storage system that supports thin provisioning allows administrators to create virtual volumes larger than the amount of physical disk capacity that is actually being used. Large data volumes can be allocated and provisioned without actually consuming that amount of physical disk capacity, whether the disks are physically in the storage system or not. With thin provisioning disk capacity is not consumed until the host or application actually writes to that part of the volume. Using this, technology administrators can create large data volumes to allow for future growth without having to use up or waste “real” physical disk capacity until it is needed.

With the old capacity planning model, using traditional volumes, a storage administrator might have chosen to provision enough “real” physical space to accommodate 12 or 18 months of projected growth. This choice involved paying for all the allocated space up front, at the price per gigabyte (GB) that prevailed at the time. Invariably, some of these growth projections were not realized, leaving the extra space captive, while in other cases the growth was under-projected, requiring an early disruption to the application to allocate net new physical space (once again over-provisioning physical space, but also without the capability to re-utilize the captive space from the over-projected allocations). With the new capacity planning model afforded by Dynamic Provisioning software, the allocation of virtual space can be specified to accommodate three, four, five or more years of



projected growth, thereby postponing future disruptions for expansion, but at no physical cost. Furthermore, there is no captive space — the “real” physical space is utilized when and where it is needed.

Thin provisioning addresses the problem of over-allocated and under-utilized capacity by improving storage allocation efficiency and dramatically simplifying storage provisioning. Using virtual storage volumes, applications are given access to as much storage capacity as they can use, without requiring matching physical resources. Behind the scenes, the storage infrastructure provides just enough physical capacity to satisfy today’s data requirements. As demand grows, the application is assigned more capacity from a common pool of physical resources. The provisioning of new capacity takes place automatically, without requiring application downtime, or storage administrator/operator intervention.

Some “thin friendly” file systems and applications are more likely to provide significant disk capacity savings using thin provisioning than others. These thin friendly applications only write blocks to the volume when data is written to them. In some cases, options can be set that will limit the application from writing to the storage volume until data is actually written (for example, SQL Server auto-extend option). Other applications or file systems, such as the UFS file system on Sun Solaris, write data to much of the entire volume when they are initially created and formatted and therefore do not take advantage of the thin provisioning capabilities.

Will Applications that Are Not “Thin Friendly” Still Benefit from Dynamic Provisioning Software?

Yes, absolutely. Applications that are not thin friendly may provide little or no savings from reduced disk capacity utilization, but they will still benefit from performance and load-balancing improvements, as well as from simplified storage management. Many organizations are implementing Dynamic Provisioning with no expectation of disk capacity savings.

Wide Striping and Storage Performance

Dynamic Provisioning software eliminates the need for outside experts to fine tune application I/O performance. The Universal Storage Platform V controls the precise location of each physical allocation in a thin provisioned storage volume. Using wide striping techniques, the storage system automatically spreads the I/O load of all applications accessing the common pool of storage across the available spindles. This process eliminates hot spots and optimizes I/O response times, leading to consistently high application performance.

The Fear of Running Out of Space

An industry poll showed that the number one concern that users had about using thin provisioning was running out of disk space. If an application tried to write to a thin provisioned volume and no additional physical disk space was available, it would cause an I/O error and the data could not be written to disk. Clearly, this is a condition that no storage administrator wants to see occur. Therefore, every effort needs to be taken to ensure that there is always some unused disk capacity in the Dynamic Provisioning pool. But this concern is no different than being worried about an individual server running out of its physically allocated space using a traditional volume. However, with the traditional model the administrator will be monitoring hundreds or thousands of servers instead of a handful of storage pools.

The most common solution is to have alerts set so that the storage administrator gets an alarm when a pool is nearing capacity. Individual alarms can also be set for those data volumes that are most critical, or most likely to grow rapidly, alerting the storage administrator to sudden changes or possible risks of shortfall in a pool. In addition to the standard pool and volume alarms provided with the Dynamic Provisioning software, Hitachi HiCommand® Tuning Manager software offers a broad range of customizable alarms on pool and volume metrics.

The range of alarms available provide a series of checkpoints and thresholds that help storage administrators manage the Dynamic Provisioning pools and minimize the risk of unexpectedly running short of disk capacity.

United Airlines – Case Study

About United Airlines

United Airlines operates more than 3,600 flights a day on United®, United Express® and TedSM to more than 210 U.S. domestic and international destinations from its hubs in Los Angeles, San Francisco, Denver, Chicago and Washington, D.C. With key global air rights in Asia and the Pacific Rim, Europe and Latin America, United is one of the largest international carriers based in the United States. United is also a founding member of Star Alliance, which provides connections to 842 destinations in 142 countries worldwide.

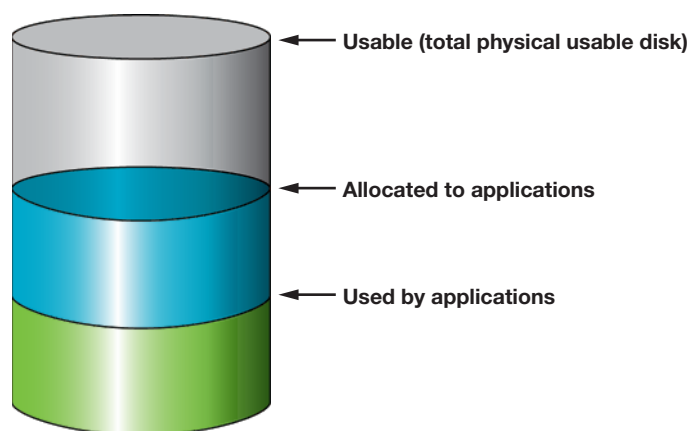
United's data centers are critical to the airline's operations. They maintain the company's reservation systems, Web sites, cargo operations, staff and equipment scheduling, real time maintenance information and accounting and finance records as well as office functions. Reliability, availability and high-performance access to their data are all critical. United Airlines maintains several hundred terabytes (TB) of data storage to support these operations, most of which is on Hitachi storage systems. United was one of the first customers to adopt the Universal Storage Platform and implement tiered storage using its virtualization capabilities when the platform was first introduced in 2004. Not surprisingly, United elected to participate in the Early Adopter Program for the Universal Storage Platform V and Dynamic Provisioning software when they were introduced in the summer of 2007.

Objectives for Dynamic Provisioning Software

As with most enterprise storage customers, United Airlines is faced with a rapidly growing demand for storage capacity and increasing pressure to minimize IT expenditures. To do this, they are constantly looking for ways to improve efficiencies and utilization of storage, defer purchases and improve productivity, allowing storage administrators to manage more and more storage per person.

Since the introduction of the Universal Storage Platform, United Airlines has taken advantage of this platform's virtualization and tiered storage capabilities to improve its storage utilization. The company has made significant improvements by being able to use the storage capacity of the Universal Storage Platform and externally attached midrange storage systems. These improvements have primarily been in effective utilization of the usable storage (the gap between "Allocated" and "Usable" in Figure 1). With Dynamic Provisioning they expect to further improve on what they've already accomplished and begin to attack the gap between actual capacity "Used" by databases and applications and capacity "Allocated." In addition, the ability to dynamically grow volumes will reduce the number of times that applications need to be taken offline to increase the size of standard, static data volumes.

Figure 1. Disk Utilization





United Airlines estimates that after accounting for allocated but unused space and free space embedded within databases, current storage systems are 54 to 60 percent utilized. Internal customers request large amounts of storage capacity that they expect to grow into. Typically, the amount requested is much more than actually used. Most often this is done because they know that their storage requirements will increase, though they are uncertain by exactly how much and how fast, and because increasing their storage allocation will require downtime for the application. For many applications that is inconvenient, and for some it can affect airline operations, which run 24/7. The result is that a large amount of allocated disk space is for anticipated growth that may not actually be used for many months or years.

Many of United's applications are mission critical and storage performance is essential. In order to maximize performance, the data volumes are strategically placed on the storage system so that they are located in array groups with few or no other high-demand applications that might conflict with their performance. This careful layout of data, however, tends to result in array groups that are not fully utilized (having excess, unallocated storage capacity). In addition, this can be a significant burden to the storage administrator. The allocation of disk space for these applications requires manual analysis of volume placement and performance and can require re-shuffling of existing volumes to provide space and optimize distribution on the storage system.

United Airlines is in a very competitive business and is under tremendous pressure to minimize IT costs. The company has made great strides in reducing costs, increasing the number of terabytes managed per storage administrator to well above industry averages. Currently United's storage administrators spend an estimated 50 percent of their time allocating, provisioning and zoning storage to meet customer demands. Through Dynamic Provisioning, United hoped to significantly reduce that burden by eliminating the time required to manually analyze and place data volumes within specific drive groups and minimize the re-provisioning and re-allocating of storage for applications as their capacity requirements increased.

United had already implemented the use of tiered storage, using the Universal Storage Platform, as a way to reduce their storage costs by using less expensive, midrange storage systems for less critical applications and backup volumes as well as testing and development. Implementing Dynamic Provisioning software across a tiered storage environment would give them the combined benefits of both technologies: reduced capital expenditures for lower-cost hardware, common management tools across multiple tiers, improved disk utilization and load balancing across multiple storage systems, and simplified storage management. Backup copies of "thin" data volumes would also benefit from the reduced disk capacity, compounding the total disk savings.

A leading technology innovator, United Airlines saw the potential for Dynamic Provisioning in their environment to:

- Improve the utilization of disk space and thereby reduce and/or delay future disk, cache and port purchases
- Balance the load on the storage system more evenly and improve overall storage performance (for example, throughput, response time, minimization of "hot spots", etc.)
- Reduce the burden on storage administrators, eliminating the need for manual volume placement and dramatically reducing time provisioning storage

United's Concerns: What's the Cost?

The IT team at United Airlines is a veteran team that understands their business requirements and is conservative about adopting new technologies too quickly. They understand that every new technology has its advantages — and its costs. Before moving existing storage to the Universal Storage Platform V and into Dynamic Provisioning volumes, United wanted to understand the requirements and implications in migrating to this new environment. How difficult would this be to set up? Will it be so difficult to create and administer that it offsets the savings? What will they save in disk space? Are United's applications thin friendly? What sort of benefit could they expect to see? Is the overhead for the system to manage the Dynamic Provisioning going to affect application performance? What's involved with migrating data to Dynamic Provisioning?



To answer these questions, Hitachi Data Systems provided United Airlines data on testing and performance results that it had performed. The United Airlines team also wanted to set up its own test environment with some existing production applications to find out.

Implementing Dynamic Provisioning at United Airlines

The Hitachi Data Systems Global Solution Services (GSS) team developed a Dynamic Provisioning design and implementation service specifically to help customers like United Airlines to get started. A “kickoff” meeting was held with GSS, Hitachi Data Systems Advanced Technical Consulting, the United Airlines storage administration team and their applications development team, specifically their SQL Server applications developers.

The Design and Implementation Service for Hitachi Dynamic Provisioning Software creates an operational Dynamic Provisioning software infrastructure aligned with applications best suited to its use. GSS will install and configure Dynamic Provisioning software, integrate threshold alerts into the customer’s existing systems monitoring processes, and conduct knowledge transfer on the operations and threshold alerts of Dynamic Provisioning software.

The service provides an infrastructure design that is optimal for each unique IT environment, determines pool(s) sizes and best virtual volume characteristics, and identifies existing applications that will benefit from the thin provisioning aspect of the Dynamic Provisioning software. As a result, administrators can eliminate the traditional and time-consuming procedure of provisioning storage volumes on a per-application basis, or without adding more physical disks. Alternatively, administrators can simply draw from the Dynamic Provisioning software pool when more storage is required.

The review included the white paper “Hitachi Dynamic Provisioning Software — Best Practices Guide,”¹ which explains recommended practices for implementing Dynamic Provisioning, with particular emphasis on Microsoft® Exchange, Microsoft SQL Server and Microsoft SharePoint applications.

Following the kickoff, it was agreed that following the initial setup of Dynamic Provisioning on the Universal Storage Platform V in the United Airlines test labs, they would start with a SQL Server application: a data mining application for price modeling and analysis. The application data would be migrated to the platform using traditional data volumes, test cases run as a baseline and then the data would be migrated to Dynamic Provisioning data volumes for comparative testing.

In order to take advantage of the “thin” provisioning, the SQL Server database had to be changed to use the “auto-extend” capability. Instead of initially formatting the SQL Server database, which would extend the database to the full size of the allocated storage volume, auto-extend only writes out data as the database is populated. The United Airlines team was concerned that the overhead to create new blocks as the database was extended, rather than when the database was created, would affect the database performance. For the application being tested, they would be willing to trade off some nominal performance degradation in exchange for saving a significant amount of disk space and simplifying their storage management, but for other, mission critical applications that might not be acceptable. They wanted to know what the performance “cost,” if any, of moving to Dynamic Provisioning would be.

SQL Server Testing at United Airlines

The existing data mining SQL Server database, including over 50 million records, consisted of data and log-file volumes. The primary database volume had been allocated to 500GB. The current database was 389GB, including almost 100GB of free space, and was expected to grow to 2TB within a year. This was an ideal

¹ The white paper “Hitachi Dynamic Provisioning Software — Best Practices Guide” is available on the Hitachi Data Systems Web site (www.hds.com) or from a Hitachi Data Systems representative.

candidate to take advantage of the over-provisioning capabilities of Dynamic Provisioning software. Storage administrators could create virtual volumes of 2TB knowing that, initially, at most they would use the 500GB currently allocated (and quite likely less as excess free space was eliminated). The log file was 100GB, but this was a fixed size used in a circular fashion so that the oldest log records would be overwritten by the newest records. This volume would remain at 100GB as before, using their fully allocated disk space, but as noted above would still benefit from the performance benefits and simplified management of Dynamic Provisioning.

The data and log file volumes were simply copied, using Hitachi ShadowImage® Heterogeneous Replication in-system volume mirroring software, directly to the Universal Storage Platform V into “standard” volumes for the baseline testing. Each of the volumes was created in its own dedicated drive group. Though this would not be representative of a production environment where it is unlikely that drive groups would be dedicated to individual volumes, the tests would show “best case” scenarios and an apples-to-apples comparison (see Figure 2).

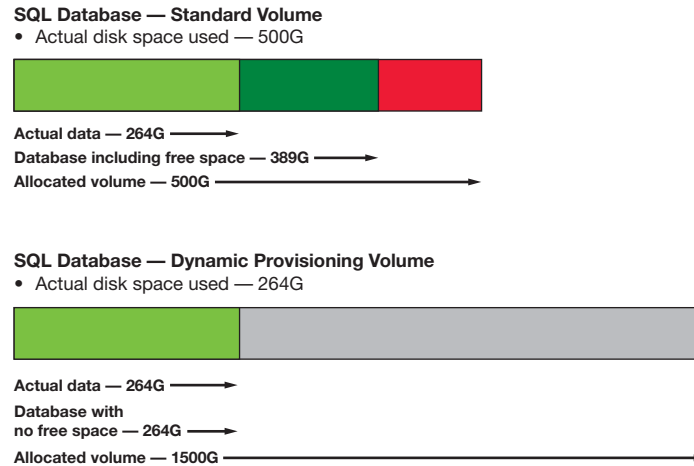
A test procedure was set up that would insert 6 million records into the database. The initial performance testing, comparing the Universal Storage Platform V, using standard volumes, to the previous generation Universal Storage Platform, was “remarkable,” according to United: the test routines ran in 23 minutes, as compared to 2 hours on the Universal Storage Platform (an 80 percent improvement).

Figure 2. Drive Group Busy Rates for Insertion Test: Universal Storage Platform V with Standard Volumes



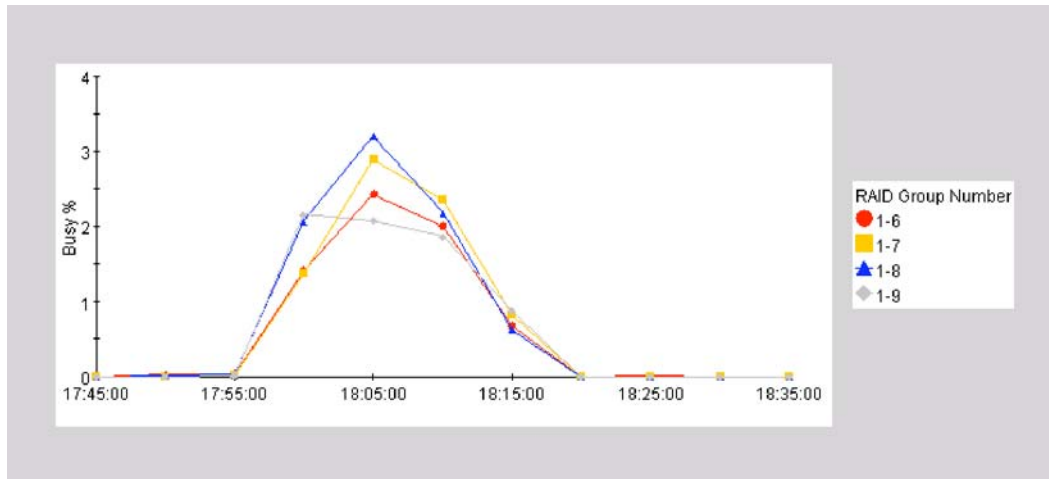
In order to extract the existing free space from the database and shrink it to its actual usable space, the data had to be extracted and then re-loaded into a new database volume created from the Dynamic Provisioning pool. The new database was created with the auto-extend feature turned on so that blocks would only be written to the volume as data is loaded into the database. This only needed to be done this one time to extract existing free space, reducing the database volume capacity from 500GB down to 264GB, an almost 50 percent reduction in actual disk consumption (see Figure 3). For additional databases United will change to use auto-extend, but it will evaluate whether the savings (that is, used versus allocated capacity) would be worth the effort to shrink the databases, extracting embedded free space.

Figure 3. Database Disk capacity Utilization: Universal Storage Platform V with Standard Volumes versus Dynamic Provisioning Volumes



The data and log files volumes were created out of a common Dynamic Provisioning pool, which comprises four array groups. Four array groups is the recommended minimum allocation for a Dynamic Provisioning pool. The database insertion test was then re-run using the Dynamic Provisioning volumes; it ran in only 16 minutes, 30 percent faster than with standard volumes (see Figure 4).

Figure 4. Drive Group Busy Rates for Insertion Test: Universal Storage Platform V with Dynamic Provisioning Volumes, 420MB Extent Size



Because the test was based on the sequential insertion of database records, United surmised that increasing the auto-increment size might speed the insertion test even further. Note that Hitachi best practices are to set the database extents in multiples of 42MB. The initial test was run with auto-extents of 420MB, the final test was run with an auto-extent of 4200MB (see Figure 5). While it ran faster than with standard volumes — 20 minutes (13 percent faster) — it ran slower than with the smaller database extent size. In examining the processor utilization of both the front-end directors (FED) and back-end directors (BED) it was evident that the overhead to do the larger extent size was slightly higher than doing more frequent smaller extent sizes (see Table 1).

Figure 5. Drive Group Busy Rates for Insertion Test: Universal Storage Platform V with Dynamic Provisioning Volumes, 4200MB Extent Size

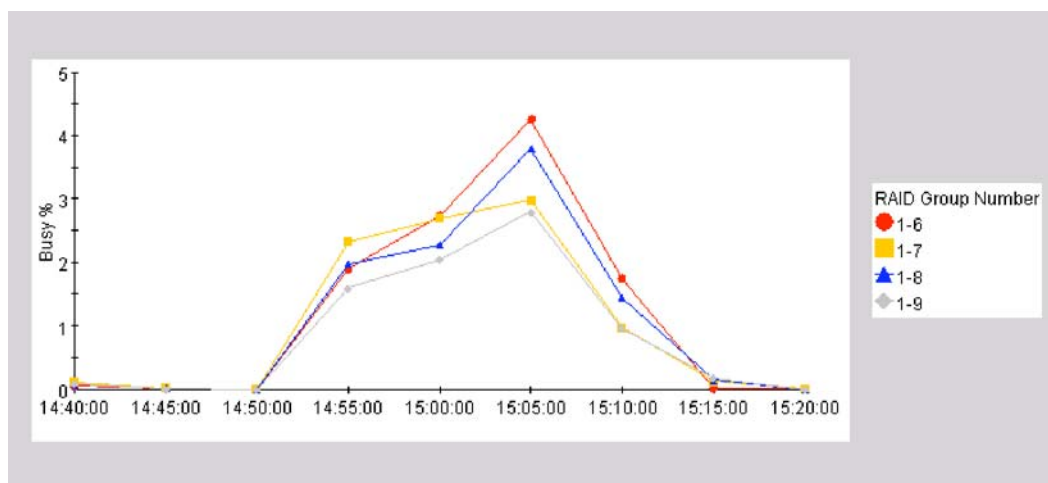


Table 1. Database Insertion Test Results

	Standard Volumes	Hitachi Dynamic Provisioning Volumes (420MB increments)	Hitachi Dynamic Provisioning Volumes (4200MB increments)
Test run time	23 min.	16 min.	20 min.
Average Drive Group Busy percentage	3.9%	1.2%	1.8%
Increase in FED processor load	11.29%	11.19%	12.19%
Increase in BED processor load	0.85%	0.63%	0.83%

“The database application performance improvement was remarkable. And, using Dynamic Provisioning will eliminate the need for us to allocate more space than is needed today or to worry about having to shut down our applications to allocate additional space.”

Eugene Kagan, Sr. Database Applications Developer, United Airlines

United Airlines Conclusions

The SQL Server testing demonstrated numerous benefits to United Airlines in disk capacity, storage utilization, improved performance and ease of management.

Disk Space Reduction

In order to get immediate capacity savings from database files with embedded free space, as well as file systems with a large amount of free space, the United Airlines team would need to use host-based, application tools to copy the data between standard and Dynamic Provisioning volumes. The test database migration resulted in an almost 50 percent reduction, from 500GB allocated to 264GB used. For databases that have been significantly over-provisioned, it will be worth the time and effort to reclaim the disk space, but many will be migrated without reclaiming free space. United’s storage administrators will work with the applications developers and database



administrators to evaluate individual applications to determine if sufficient disk capacity can be saved. For other databases and applications where free space isn't reclaimed, the Hitachi Data Systems GSS team can help United quickly and easily migrate them to larger Dynamic Provisioning volumes, thereby allowing for future growth without taking up the additional disk space until actually consumed. United does not expect to see an immediate, major reduction in disk usage as a result of the introduction of Dynamic Provisioning, but it does expect to see a significant reduction in the growth of storage requirements deferring incremental disk purchases.

The major benefit will come from new applications and those that have significant expected growth where the storage administrators can allocate very large, virtual data volumes knowing that they won't actually consume all of that disk space until some time in the future. Of course, with new databases no migration would be required; they would simply be configured initially with Dynamic Provisioning software. Going forward, United Airlines knows that they will be able to minimize wasted space (allocated for future use). As a result they expect a reduction in the rate of growth in disk capacity purchases that they have been seeing. They estimate that overall storage capacity utilization should increase by at least 20 to 30 percent within the first year, with corresponding reduction of new disk purchases and quite possibly much more in the long run.

Performance

The United Airlines storage team was pleasantly surprised to see that instead of a performance degradation, moving to Dynamic Provisioning improved storage performance by 30 percent over standard volumes (23 minutes versus 16 minutes). The overhead of mapping the data blocks for Dynamic Provisioning was more than offset by the improved efficiency of the wide striping. The benefit of spreading the I/Os over a much larger number of physical disk drives and spreading the dynamic data mapping over the Universal Storage Platform V BEDs (with their load balanced across multiple processors) takes full advantage of all of the processing power of the storage system rather than isolating processing to individual components and relying on manual allocation and management of the storage resources. While not every single application will necessarily run faster, they are confident that, overall, their applications will run much faster and the storage system resources will be used more efficiently, thereby reducing incremental storage purchases.

Ease of Management

Perhaps the biggest, though most subjective, benefit of Dynamic Provisioning is in how much easier it will be to manage storage. No more micro-management, worrying about moving data volumes around to allow adequate disk space for new data volumes, re-allocating and re-provisioning of existing data volumes as they run out of space, putting too many volumes on the same drive group that might affect application performance or using up disk space for planned growth that's not likely to occur for months or years.

"Once it was explained, creating and maintaining an HDP pool is quite simple. Creating Hitachi Dynamic Provisioning volumes is as easy as a standard data volume, but without having to be concerned about how much space is available in individual array groups or worrying about how much capacity is being wasted due to over-provisioning for future growth. All I need to do is check the total available capacity in the pool."

Marina Sterner, Storage Administrator, United Airlines

Moving forward, United Airlines plans to put all data on the Universal Storage Platform V into Dynamic Provisioning volumes. Many will benefit from disk capacity savings, most will benefit from performance improvements and all will make allocating and provisioning storage much simpler and easier.



Monitoring Growth — Minimizing Risk

A critical priority for United Airlines is to make sure that the Dynamic Provisioning pools don't run out of space as the Dynamic Provisioning volumes grow. The built-in warning and critical alarms were implemented to notify the storage administrators when the used space in a Dynamic Provisioning pool approached capacity. Individual alarms can also be set on any Dynamic Provisioning volumes where high growth is a concern.

Because the United Airlines IT team supports such a broad spectrum of applications, they don't have a lot of visibility to their expected growth patterns. Using Hitachi HiCommand Tuning Manager software, United Airlines will be able to monitor and report on the Dynamic Provisioning volumes and pools with greater detail. The software will also provide trend and forecasting reports on the pools and individual volumes. These reports will help them make sure that they proactively monitor the growth and be prepared to add to the pools before shortfalls could occur.

Initially, United Airlines will set the alarms conservatively to be absolutely certain that none of their pools run out of capacity. As they gain experience with managing the pools and confidence based on the growth trend reports they expect to raise the alarm thresholds and reduce the total amount of reserve capacity. But even with the initial levels the excess reserved capacity will still be significantly less than the total free capacity in all the data volumes currently allocated and unused.

Improved Utilization — Balancing the Storage Load

Overall, Dynamic Provisioning gives United Airlines the confidence that all of the Universal Storage Platform systems are being used efficiently. No longer will there be pockets of unallocated disk space in a drive group that can't be utilized effectively. Furthermore, the wide striping of data across the entire pool will mean a much more effective utilization of all of the disks in the storage system rather than a smaller number of array groups being "hammered" while others are accessed much less frequently.

Financial Benefits — Return on Investment

As they have just begun their implementation of Dynamic Provisioning it is premature to fully determine the actual savings to United Airlines. The first place that most organizations look for savings is related to reduced disk capacity. As noted above, United Airlines expects to see some short-term reduction in disk capacity usage, but significant savings in future growth and a reduction in planned disk purchases. The reduction in disk purchases will save United Airlines not only in the cost of the disks, but also in power, cooling, software license and maintenance fees.

The performance improvements derived from implementing Dynamic Provisioning will benefit United Airlines financially, primarily in deferred storage purchases. Because of the improved performance, United Airlines will eliminate, or defer the acquisition of additional disks, cache, ports and other storage assets that would have otherwise been purchased to support the ever-increasing storage demands.

The biggest benefit will be in the improved ease of storage management, allowing their storage administrators to manage more storage per person. The ongoing requests for additional storage will take much less effort to allocate and provision. Because administrators will be much freer to allocate larger storage volumes, without concern for wasting large amounts of unused disk capacity, they should expect to see fewer requests for increasing volume sizes. Ongoing monitoring and reporting on storage capacity will change from micro-management of individual volumes to simply managing the entire storage system as one entity. United Airlines estimates that as a result they should be able to increase the amount of storage managed per administrator by 20 to 30 percent.



The financial benefits gained for just this one SQL Server–based data mining application provide a limited sample, but a good indication of the magnitude of the potential savings. This application had been allocated 500GB and was expected to grow to 2TB within the next year. Based on the 50 percent capacity savings in the current database (500GB to 264GB), United Airlines expects that the actual disk usage savings will also be 50 percent or 1TB. Using a fully loaded cost estimate — including hardware, software, maintenance, building and utility costs — of US\$18,000² per TB, the company estimates a savings of more than \$50,000 over the next three years. In addition, United Airlines conservatively estimates a savings from storage management efficiencies that will reduce the amount of time for ongoing storage provisioning by 5 hours per week for their storage administrators, equating to approximately \$16,000 per year. The savings from this one application alone will offset the cost of the Dynamic Provisioning software. The savings from converting hundreds of applications to Dynamic Provisioning will be dramatic.

In order to provide their users with incentives to save the company money, the United Airlines IT organization is looking at ways to implement a chargeback system for storage that is based on actual used capacity, as opposed to its current practice of charging back for allocated capacity. By tracking storage demands in this way, United can provide the savings back to the users and departments based on actual usage.

The Bottom Line

“We were sold on the concept of Dynamic Provisioning before we got it,” says Managing Director of Enterprise Architecture at United Airlines Gary Pilafas. “Now that we’ve completed our initial tests, we can see how much simpler it will be to allocate and provision storage and how it will improve storage performance and disk utilization. We can reduce the mundane, day-to-day provisioning burden on our storage administrators and allow them to proactively manage our storage infrastructure.”

As United continues to move applications to the Universal Storage Platform V, the company’s data will all be migrated into Dynamic Provisioning volumes following Hitachi Data Systems recommended best practices. Wherever possible, new database applications will be implemented using the “auto-extend” features so that databases will not be pre-populated with free space and blocks will only be written to storage when data is written to them, thereby making them thin friendly.

Data for non-critical applications and replicated volume copies for backup purposes will be written to Dynamic Provisioning volumes on cheaper, midrange storage systems externally attached to the Universal Storage Platform V. This will provide a double benefit, using disks that are less expensive to purchase and maintain, as well as using less disk capacity (from thin provisioning savings) and taking advantage of all the benefits of Dynamic Provisioning. With the support of Hitachi HiCommand Tiered Storage Manager software for Dynamic Provisioning, United will be able to migrate Dynamic Provisioning volumes quickly, easily and nondisruptively from the tier-1 Universal Storage Platform V to tier-2 storage systems and vice versa, as needed.

Additional Hitachi Dynamic Provisioning Customer Findings

Several other Hitachi Data Systems customers have also implemented and/or tested Dynamic Provisioning in their environments. Although additional in-depth case studies have not yet been completed, an initial survey of these customers serves to reconfirm and complement the findings at United Airlines.

Surprisingly, a majority of early adopters of Dynamic Provisioning were not motivated to do so for disk capacity savings. All of them saw a major benefit from the simplification of storage management, minimizing the time and effort required for creating and provisioning individual volumes. Most also saw the performance and load-balancing benefit of utilizing all of the disks more efficiently. Several were interested primarily for the performance gains from

² All monetary units are in US dollars unless otherwise noted.



the wide striping. All expected to see significant improvements in disk utilization, performance and storage management efficiencies. All of these Dynamic Provisioning customers intend to move most, if not all, of their storage on their Universal Storage Platform V storage platforms into Dynamic Provisioning pools.

One customer's mission critical application was extremely performance sensitive. They wanted to maximize throughput and, at the same time, maintain a response time of 2 to 3 milliseconds. As part of their testing they initially created a Dynamic Provisioning pool on their Universal Storage Platform V that comprised 128 hard disk drives (spindles). Then they repeated their benchmarks with a pool that comprised 192 drives, resulting in a more than 50 percent increase in throughput at a 3 millisecond response time. For this customer, the ability to increase throughput by spreading the load over an increasing number of drives had a substantial financial benefit.

Summary

United Airlines has been a pioneer in the implementation of advanced storage systems, including the Hitachi Universal Storage Platform family. The Universal Storage Platform V and Hitachi Dynamic Provisioning software offer advanced capabilities not available on any other enterprise-class storage system. The United Airlines IT department, a typical, conservative, risk-averse IT organization, did extensive testing and certification of the Universal Storage Platform V and Dynamic Provisioning, particularly because it is such a game-changing technology. The results not only met but also exceeded their expectations for performance and ease of management.

United Airlines is now proceeding with a plan for implementation to take advantage of these new technologies and integrate them into their IT strategies. All new enterprise storage requirements will be fulfilled on Dynamic Provisioning volumes on the Universal Storage Platform V storage platforms. This also complements the United Airlines tiered storage strategy. They intend to externally attach some of their midrange storage systems to their Universal Storage Platform V systems and create Dynamic Provisioning pools on those systems as tier-2 storage for non-critical applications as well as for development, testing and disk-to-disk backup volumes.

United Airlines recognizes that Dynamic Provisioning software can help them save money and operate more efficiently, now. The power and virtualization of the Universal Storage Platform V and Dynamic Provisioning simplifies their storage management and moves them closer to the reality of storage systems that self-manage and self-optimize.



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WHP-272-00 March 2008