VIGILANT INFORMATION SYSTEMS FOR MANAGING ENTERPRISES IN DYNAMIC SUPPLY CHAINS: REAL-TIME DASHBOARDS AT WESTERN DIGITAL[1]

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Executive Summary

This article describes how Western Digital (WD), a global hard-drive manufacturer that supplies over 100,000 hard drives a day, built a vigilant information system (VIS) that includes both sensing and responding capabilities. The system includes an underlying layer of business intelligence applications that analyze data from numerous sources, and management dashboards that automate the alerting process and provide the means for responding. Its operational costs have been reduced almost 50% due both to the VIS and to revamping WD's business processes so that the right people are alerted and have the means to respond correctly and quickly.

Seven lessons were learned from this effort:

1. *Design the real-time management dashboards to be the nerve center for managing the enterprise.*
2. *Plan and schedule the coordination among teams to use the dashboards to manage enterprise-wide.*
3. *Build a learning loop around each OODA (observe, orient, decide, act) loop to foster group learning because the faster the loop, the more important the learning reviews*
4. *Match the time latency of each OODA loop to the organization's needs and capabilities to become truly vigilant. Do not indiscriminately chase zero latency.*
5. *Provide the building blocks for the "sense-and-respond" real-time enterprise through a vigilant information system and real-time management dashboards.*
6. *Justify vigilant information systems on a basis other than return on investment.*
7. *Make implementation of an enterprise-wide VIS a management initiative (not a technology initiative) because it requires "active, collaborative engagement" from all top management to instill the needed organizational transformation.*

VIGILANT INFORMATION SYSTEMS [2]

In a cost-conscious and turbulent economy, operating effectively in a lean and high-velocity supply chain is demanding, especially for high-volume suppliers whose large customers change their requirements often. In such dynamic supply chains, *vigilant information systems* are needed to respond quickly.

To be vigilant means to be alertly watchful. A vigilant information system (VIS) includes both sensing and responding capabilities. *Sensing*—to detect changes and enhance managerial visibility from the factory shop floor to corporate headquarters—comes through real-time dashboards with automated alerting. *Responding* comes through capabilities that help decision makers at each organizational level reach decisions and take action.

The dashboards at Western Digital are called "real time," which means they are "sufficiently vigilant for the process being monitored." In other words, "real

time" for the factory means "as close to real time as possible," while "real time" for executive management means "once the information has been validated and synchronized among data feeds so that noise has been filtered out."

To understand VIS, it's helpful to understand how these systems differ from traditional information systems, and how the concept of OODA loops is useful in designing VIS.

How Vigilant Systems Differ From Traditional Systems

Vigilant information systems integrate and distill information and business intelligence[3] from various sources to detect changes, initiate alerts, assist with diagnosing and analyzing problems, and support communication for quick action.[4]

A vigilant information system differs from a traditional system as shown in Figure 1. In a traditional information system, a user initiates a process, by, say, querying an application, causing a database to be accessed. As shown, the database—whether it stores transactions, events, or other data— is passive.

In contrast, in a vigilant information system, the system initiates the process. As shown, the database is active. Each time its data is updated, the data is reanalyzed. If preset conditions are met, the system alerts the user. Thus, vigilant information systems provide sense-and-respond capabilities.[5]   VIS are meant to provide proactive mechanisms and are designed from strategic and operational plans.

OODA Loops and Their Applicability to Vigilant Information Systems

The requirements for vigilant information systems can be viewed as coming from the concept of an OODA loop (Observe, Orient, Decide, Act). See Figure 2.

US Air Force Colonel John Boyd developed the concept of the OODA loop in 1986.[6] He wanted to understand how fighter pilots flying aircraft with inferior maneuverability won air combat engagements (dog

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[3] Business intelligence is granular information about the business and its supply chain that line-of-business managers seek when they are analyzing key performance metrics of their enterprise.

[4] Walls, J., Widmeyer, G., and El Sawy, O. "Building an Information System Design Theory for Vigilant EIS," *Information Systems Research*, March 1992, pp. 36-59.

[5] Haeckel, S. *Adaptive Enterprise: Creating and Leading Sense-and-Respond Organizations*, Harvard Business School Press, 1999.

[6] Boyd, J. Patterns of Conflict, Unpublished manuscript, USAF, 1986. Also see Curts, R. and Campbell D. "Avoiding Information Overload through the Understanding of OODA Loops," *Proceedings of the Command & Control Technology Research Symposium*, 2001.

fights) against pilots with superior aircraft. He found that the winning pilots compressed the cycle of activities in a dog fight and completed them more quickly than their adversaries. Boyd's OODA loop included:

- *Observe* (see the situation and adversary)
- *Orient* (size up the vulnerabilities and opportunities)
- *Decide* (choose the combat maneuver to take)
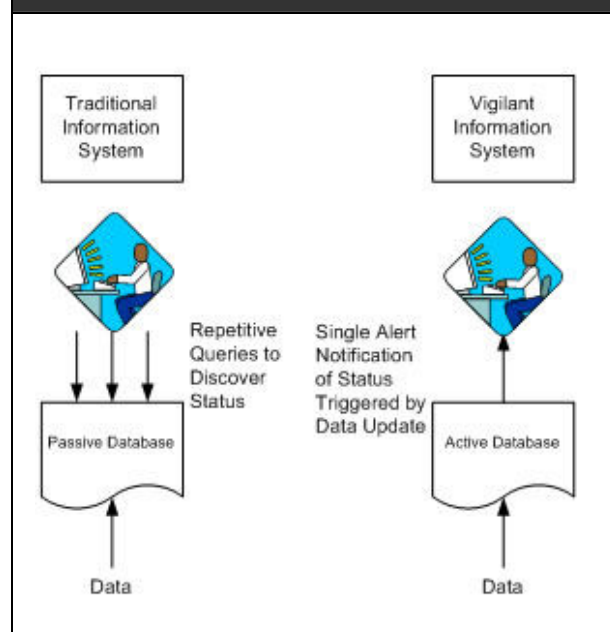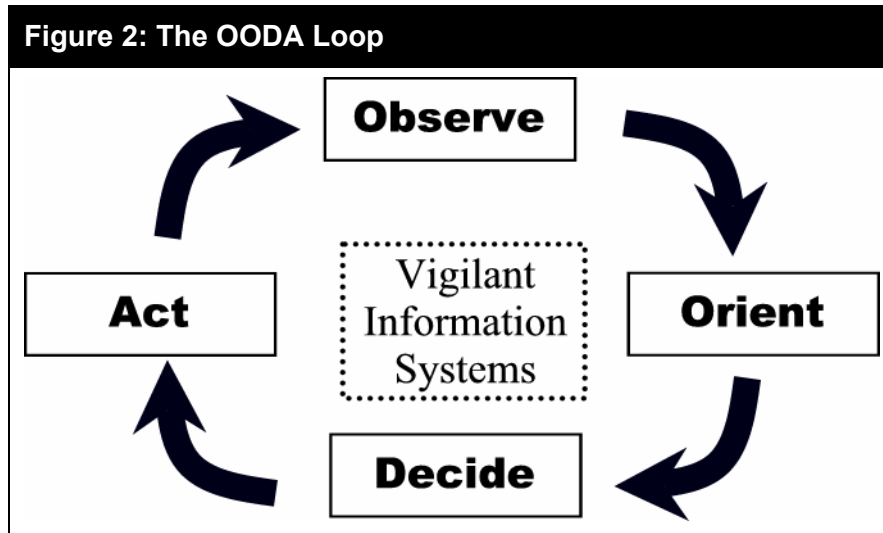- *Act* (execute the maneuver)

In 1990 and 1993, respectively, Stalk and Hout[7] and Haeckel and Norton[8] converted the idea to business use. Haeckel and Norton's four activities are:

- *Observe* (see change signals)
- *Orient* (interpret the signals)
- *Decide* (formulate an appropriate response)
- *Act* (execute the selected response)

When changes occur in the business environment, enterprises that can complete OODA loops faster than competitors improve their ability to survive. OODA loops should not only be executed quickly but they should also be flexible and responsive to environmental changes.

Western Digital's corporate managers use OODA thinking to react quickly to customer changes. In fact,

Figure 1: Vigilant Versus Traditional Information Systems

Figure 2: The OODA Loop

the goal is to initiate a change in the factories within the same work shift in which WD receives requests from customers; being the fastest to respond to new customer requirements in the hard drive business can increase WD's market share.

The OODA loop translates into the following four requirements for VIS:

- **Capabilities for observing:** Provide visibility into the critical business processes in the enterprise's supply chain. Capture key performance indicators (KPI's) in real time. Integrate information from various sources and systems;

- **Capabilities for orienting:** Provide graphical dashboards that display data. Send alerts to managers. Permit drilling down in data. Allow users to slice-and-dice the data. Provide traffic-light alerts. Report trends.

- **Capabilities for deciding:** Analytics for asking "what-if" questions. Descriptive statistics. Time series comparisons.

- **Capabilities for acting:** Architectures for communicating decisions quickly to pre-specified others to take action. Follow-up tracking.

Western Digital Corporation applied these concepts to build their vigilant information system.
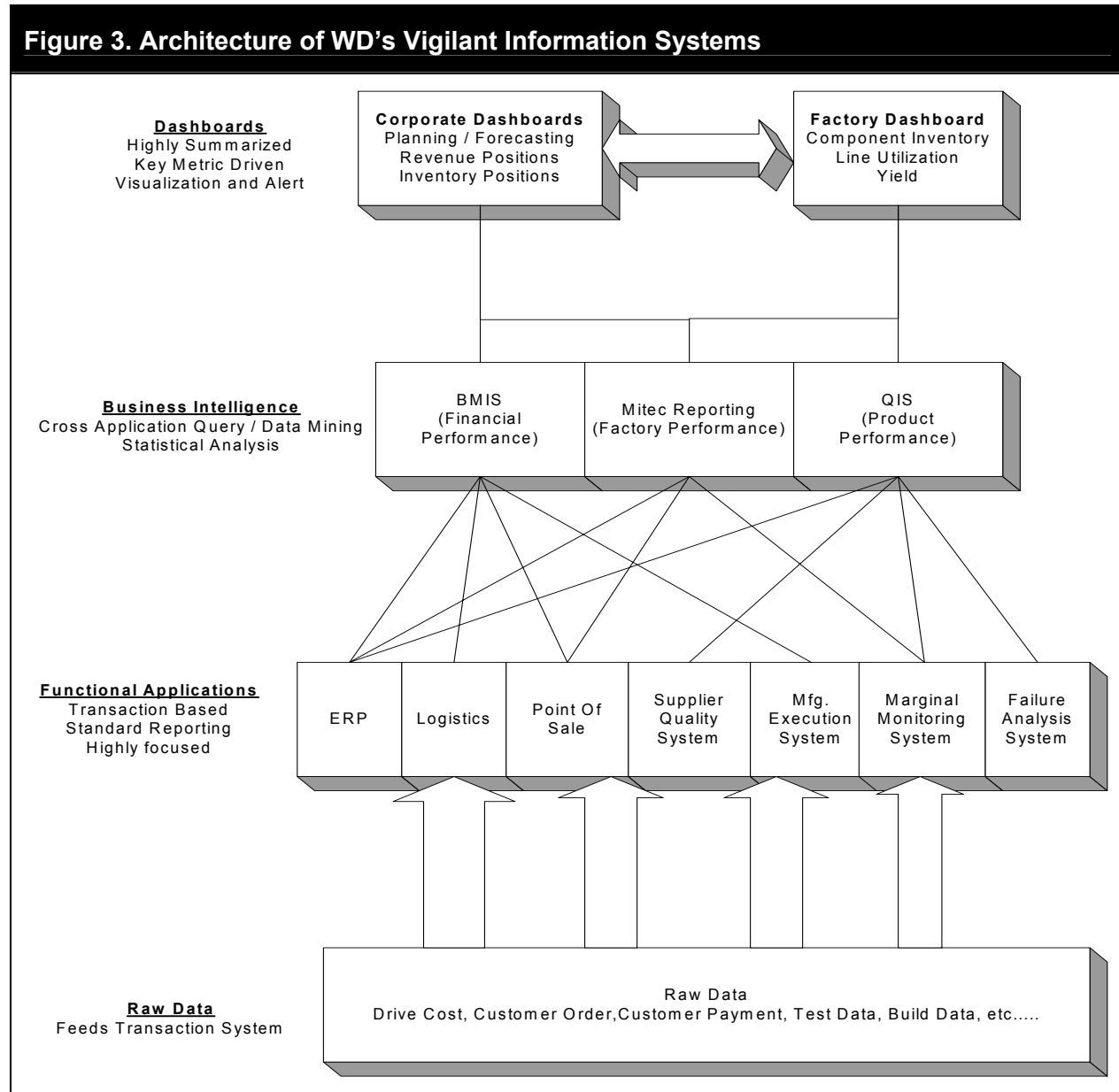
WESTERN DIGITAL AND ITS BUSINESS CHALLENGES

Western Digital is a $3 billion global designer and manufacturer of high-performance hard drives for desktop personal computers, corporate networks, en-

terprise storage, and home entertainment applications. Founded in 1970, WD sells its hard drives to system manufacturers, resellers, and retailers. Headquarters are in Lake Forest, California, about 50 miles south of Los Angeles. Its manufacturing facilities are in Malaysia and Thailand, and it has distribution centers in Europe. WD employs about 18,000 people worldwide.

WD's top five business challenges are:

1) Constantly changing customer requirements for more storage space, faster access, and better performance

2) A fiercely competitive global industry that exerts pricing pressures

3) Avoiding business disruption, product returns, excess inventory, and bad scheduling

4) Short product lifecycles and rapid obsolescence

5) The need for extremely high quality and reliability in its products

In the early 1990s, the hard drive industry consisted of over 11 manufacturers. It now involves 3 to 5, depending on the product line. WD has not only survived but excelled, becoming the third largest volume producer. In 2002, unit volume rose 30% over 2001 to 29 million drives, and gross margins improved—even though 2002 was one of the toughest years in the IT industry.

Figure 3. Architecture of WD's Vigilant Information Systems

Dashboards
Highly Summarized
Key Metric Driven
Visualization and Alert

Corporate Dashboards
Planning / Forecasting
Revenue Positions
Inventory Positions

Factory Dashboard
Component Inventory
Line Utilization
Yield

Business Intelligence
Cross Application Query / Data Mining
Statistical Analysis

BMIS
(Financial Performance)

Mitec Reporting
(Factory Performance)

QIS
(Product Performance)

Functional Applications
Transaction Based
Standard Reporting
Highly focused

ERP | Logistics | Point Of Sale | Supplier Quality System | Mfg. Execution System | Marginal Monitoring System | Failure Analysis System

Raw Data
Feeds Transaction System

Raw Data
Drive Cost, Customer Order, Customer Payment, Test Data, Build Data, etc.....

As part of WD's survival strategy, management demanded a new mode of information delivery. First, they wanted the ability to react more quickly to changes. Second, they wanted integrated information so that they could manage enterprise-wide in a "follow the sun" manner.[9]

Like many enterprises, information at WD used to be difficult to consolidate because there were no single sources of data. When users ran ERP reports using different filters, they received different results. The data was not accurate nor was it current. Management and end users had no easy way to see trend data, understand the current state of the business, or use a system to take quick action.

Delivering the needed capabilities meant creating an IT architecture that would support not only 24 x 7 system availability but also integrate applications and data. Managers and analysts needed real-time visibility of data in easy-to-use formats. They needed to be notified of changes, when they occurred, in key performance indicators, delays, or supply-demand imbalances. And they needed enough depth of information that different organizational levels could use the same tools. Finally, they needed a way to take action quickly because that is when action makes the greatest difference.

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[9] "Follow the sun" refers to passing work or information across multiple time zones as the workday closes in one and opens in another.

The solution to these needs is WD's vigilant information system and its real-time management dashboards.

WESTERN DIGITAL'S VIGILANT INFORMATION SYSTEM

The VIS is complex, so its description is divided into four sections: its overall architecture, three foundation capabilities, revamping Western Digital's business processes, and the management dashboards.

The VIS Architecture

Figure 3 shows a four-layer schematic view of the architecture of WD's VIS. Starting from the bottom, in Layer 1 is the raw data, which comes from various sources. That data flows into numerous functional applications (ERP, logistics, and so on) in Layer 2 (observe). Business intelligence systems in Layer 3 analyze each new piece of data to determine whether or not it is within its preset boundaries (orient). Out-of-bounds data initiates an alert to Layer 4, the dashboards, at the top (decide-and-act).

Three Foundation Capabilities

Three IT capabilities form the foundation for WD's VIS: the ERP system, the data warehouse, and the Quality Information System (QIS). These systems are considered foundations because together they capture and integrate the data needed for the VIS.

ERP was implemented in 1997, giving managers data about enterprise operations they had never had before. They could, for example, tie together requisitions, purchase orders, sales orders, production runs, and invoices. And they had on-line access to day-to-day workflow and manufacturing processes.

The data warehouse was implemented in 1999 and integrated product data from 12 disparate legacy systems.[10]

The Quality Information System (QIS), also implemented in 1999, is in the business intelligence layer and integrates data to provide insights into quality. It is used to trace each hard drive manufactured at WD through its entire lifecycle, including components, manufacturing, testing, shipment, and returns. WD's
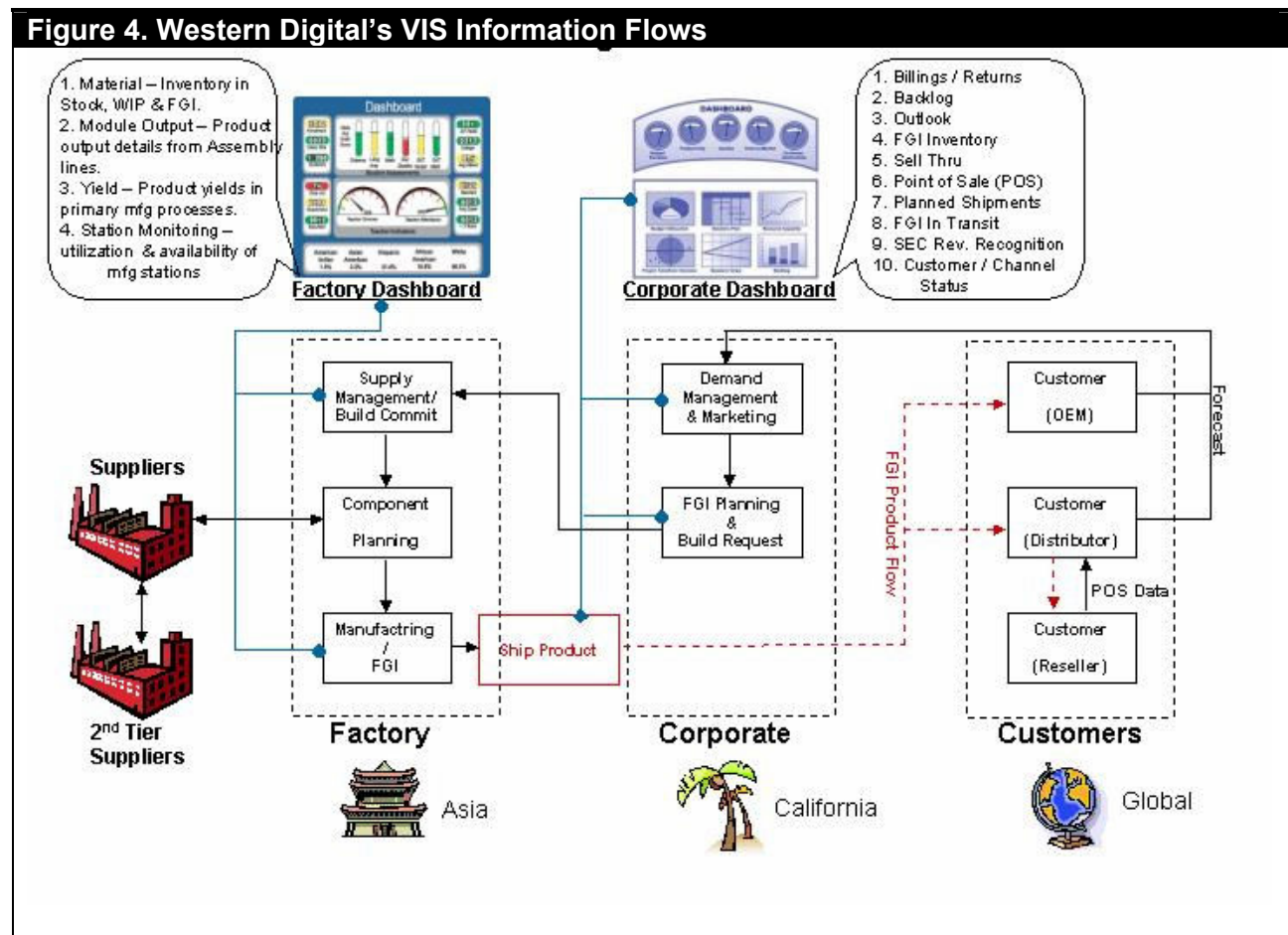

Figure 4. Western Digital's VIS Information Flows

Figure 5. Descriptions of the Factory Dashboards	
Yield dashboard	Yield is the percentage of units that pass inspection. This dashboard shows yields by product, capacity, cache family, and station level. It also reports cycle time of key processes and at a key manufacturing station, Servo Track Writer (STW). (See Figure 6.)
Material (inventory) dashboard	This dashboard tracks factory inventory, including the receiving warehouse, work in progress, engineering locations, and finished goods inventory. Targets are set for each location based on the daily manufacturing schedule.
Production output dashboard	This dashboard tracks assembly line output, including hard drive and printed circuit board assemblies. These outputs are compared with targets based on the manufacturing schedule. Because the assembly station is the beginning of the drive manufacturing process, any delay or slip in output can affect the entire manufacturing and shipping operation.
SPT monitor dashboard	This dashboard monitors activities and availabilities of one of the longest processing periods and most important stations in the drive manufacturing process, Single Plug Tester (SPT). Individual drives are tested in SPTs for hours, and hundreds of SPTs are on the factory floor, loaded with drives. SPTs can become bottlenecks unless used to their maximum capacity. This dashboard gives real-time visibility of each SPT, including utilization and the products being run.
Quality dashboard	This dashboard measures the quality of drive production in units of Defective Drives Per Million (DPPM). DPPM targets are based on products and customers. Problems with components or tools on the manufacturing line introduce defects. The longer the delay in detecting a problem, the more extensive (and expensive) the effort to repair the affected drives.

objectives are to maintain high quality, uncover root causes of product failures, and improve future versions of products. QIS can pinpoint component-level defects before hard drives are shipped, and can trace back from failures in the field to the root cause. The data captured by QIS can also be used to make future production decisions, when combined with data from the data warehouse and R&D's modeling databases.

While these three capabilities form the foundation for managing operational performance, they did not give executives and managers the visibility into operations that they needed. Specifically:

- A number of legacy systems remained non-integrated. Management struggled with combining real-time and historical data from 30+ systems to make strategic and operational decisions. Queries and report generation were expensive, cumbersome, and required many consultants.

- The data refresh rate was inadequate and uneven across systems. Outdated data led to different re-

sults (there was no "single truth") and did not support real-time decision making. Management was without the real-time information needed in demand management and distribution (that is, forecasts, billings, backlogs, sell-through). The factories in Malaysia and Thailand could not obtain real-time data on production yields, workstation availability, and component inventories.

- Managers needed better analysis capabilities. They wanted a user-friendly system accessible through the Web that would support standard reporting, detailed, ad-hoc, drill-down queries, graphical reporting, and executive summaries.

Revamping WD's Business Processes

WD's senior management team, which includes the CIO, looked at how real-time dashboards could best be used. They agreed that the dashboards alone wouldn't change decision making.

Take, for example, the 5-hour daily production meetings (8:30 a.m. to 1:30 p.m.) where factory management decided what needed to be produced. Not only did these meetings manage production inadequately but corporate management in California did not know of the decisions made in these meetings. Management realized these meetings could be much shorter (less than 2 hours, in fact) if the participants used the dashboard data. Furthermore, the executives in California could work with updated production information.

Top management drafted new business policies and processes to put the VIS to work. Three new policies were deemed critical:

- **Align time-based objectives across the enterprise:** WD had to translate strategic enterprise goals into measurable, time-based operational objectives for each department. The result would be consistent metrics.

- **Capture key performance indicators (KPIs) in real time:** To improve corporate performance, WD needed real-time monitoring—horizontally across organizational groups and vertically within business units. With real-time KPIs, teams could analyze them across groups and business units.

- **Foster cross-team collaborative decision making:** The dashboard environment would need to enable joint decision making and collaborative working across teams, departments, enterprises, and geographic areas. Achieving such collaboration took months because the geographically dispersed teams had to decide what information they needed to hand off to R&D, corporate planning, new production groups, the factories, distribution, and customers—so that they could be "virtually there" via their dashboards. This concept of being "virtually there" was new to some WD executives.

In WD's VIS, the dashboards become managers' eyes and ears into operations. These policies aimed to ensure that decisions and actions were coordinated.

The Management Dashboards

Two real-time dashboard information systems were developed: one for the factory and one for demand planning, distribution, and sales information (the corporate dashboard).

The factory dashboards were custom-developed in-house and rolled out in late 2000. They are used to monitor such quantities as yields, quality, and production output. The corporate dashboards were developed from off-the-shelf software (Business Intelligence Product Suite from Cognos) and rolled out in 2001. They are used to monitor billings, sell-through, weeks of inventory, and more.

The dashboards tap into WD's information flows as shown schematically in Figure 4.[11] The four types of factory dashboards and ten types of corporate dashboards are shown at the top. The VIS and its information flows are in the middle. The three constituencies (at the bottom) are the factories in Asia, corporate offices in California, and customers around the globe. Information flows among these components as follows, going from right to left.

- Forecasts of customer demand from WD distributors and original equipment manufacturers (OEMs), on the right, flow into the central corporate business management information system (in the middle).

- Corporate combines these demand forecasts with feedback on production and inventory levels to create build requirements: how many units of which type are to be produced when.

- Based on the build requirements, each factory (on the left) determines its supply requirements and commits to building the hard drives. This production data is used for component planning by both first-tier and second-tier suppliers (on the far left). The product is then manufactured and ready for distribution

- Products shipped to customers provide data feedback both to the factory and to corporate.

The Factory Dashboards

The manufacturing and engineering staff who run a factory face tight requirements. When working near capacity, a factory can produce as many as 100,000 hard drives a day. Achieving this level of production requires that the production line not be shut down and that disks not require rework. Both cause significant economic loss. Furthermore, to remain competitive, WD continually improves its manufacturing process. An improved process must be monitored to make sure the modifications actually make things better.

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[11] The dashboards shown at the top of Figure 4 are conceptual, not actual.

Figure 6: Yield Dashboard
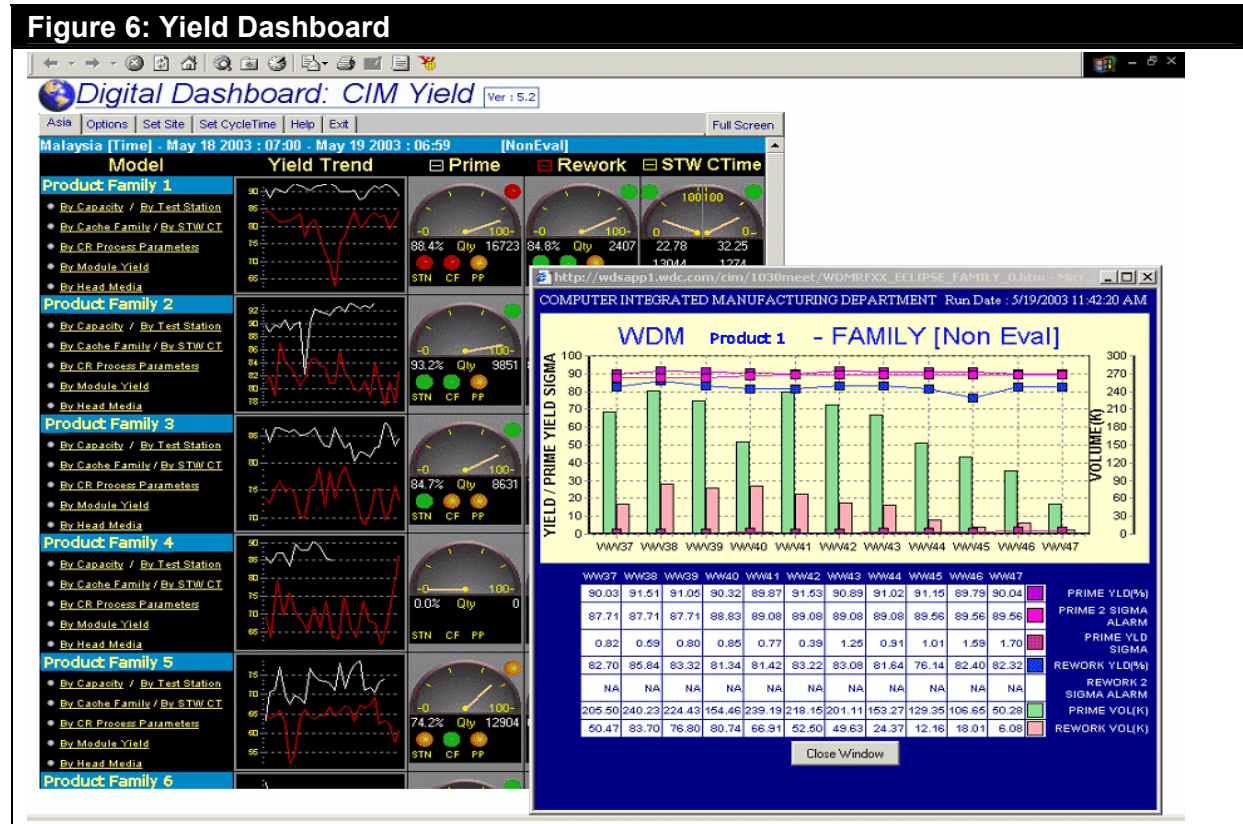
To assist factory staff in meeting these demands, the IT department built five factory dashboards. The four core requirements for the factory dashboards were to:

1) *Show KPIs*: Show the health of the factory by providing near-real-time, graphical views of KPIs.

2) *Display metrics*: Show when a KPI goes below 2 sigma of its allowable value.

3) *Allow drill down*: Give staff ways to drill down on each KPI to find the source of a problem.

4) *Issue alerts*: Automatically issue alerts to the individuals responsible for a KPI so they can initiate damage control.

The final requirement, for automated alerts, distinguishes these dashboards from typical executive information systems. Unanticipated events can cascade quickly, requiring fast response. Hence the need for automated alerts.

The five dashboards are yield, material, production output, station monitoring, and quality.[12] Each is de-

scribed in Figure 5, and the yield dashboard is shown in Figure 6.

Each parameter on a dashboard is assigned a "target value," which, when hit, causes an alert to be issued, often to the pager of the manager in charge of the station or product. The manager then uses a specific Decision Support System (DSS) to analyze the problem. As the vice president and managing director for WD Asia noted:

Our factory dashboards provide us with a 'virtual control room,' which, at a few moments' glance, tells us where our trouble spots are so we can respond much more rapidly to issues than before, and we can do it from practically any place in the world.
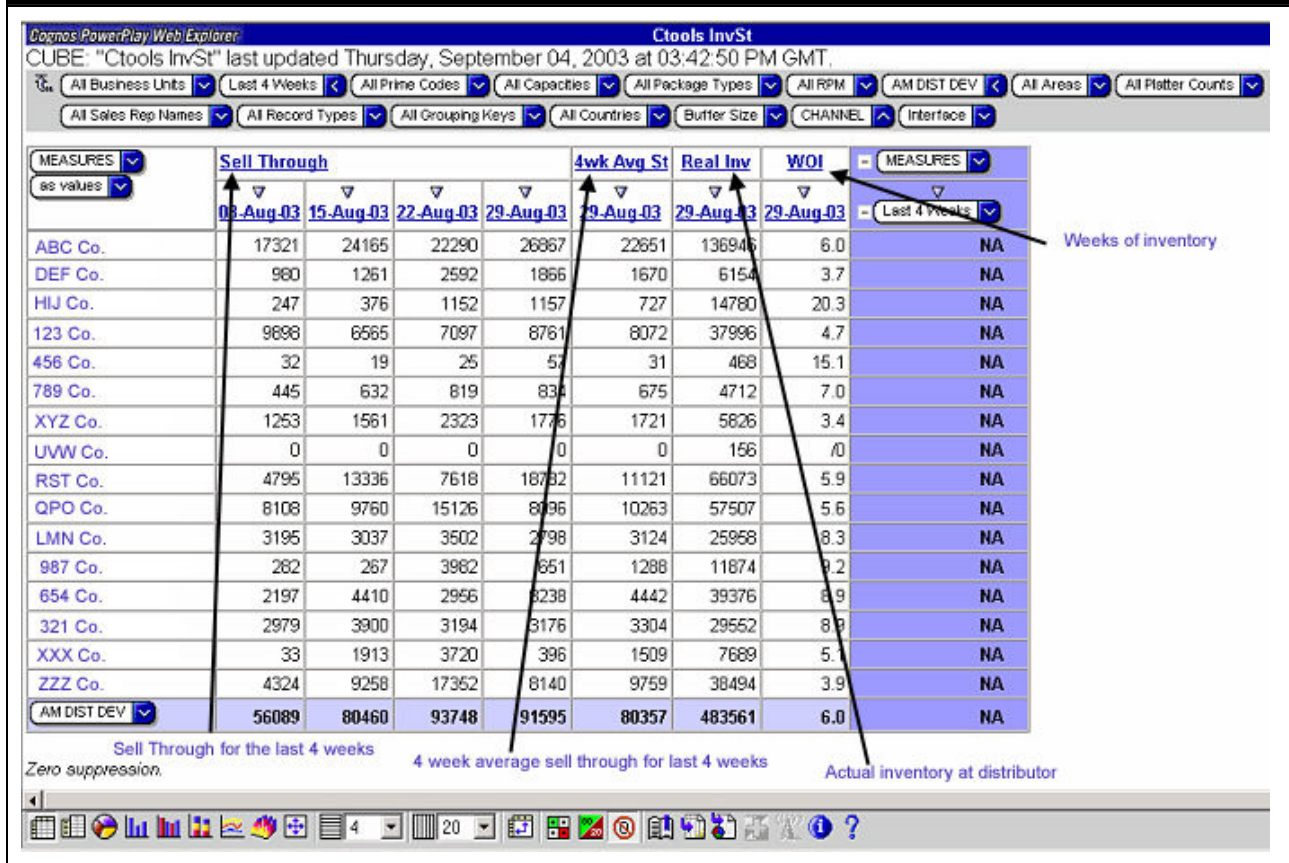
The Corporate Dashboards

Ten corporate dashboards were created:

1) Billings and returns

2) Backlog

3) Outlook

4) Finished goods inventory

5) Distributor inventory and sell-through

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[12] The Quality dashboard is not shown in Figure 3.

Figure 7. Distributor and Sell Through Report

6) Point of sale

7) Planned shipments

8) Finished goods in transit

9) Revenue recognition

10) Customer/channel status

The dashboards are designed to accommodate all levels of management by varying the level of information aggregation. Each dashboard has its own "data cube," which houses the data for its displays. These data cubes are subsets of WD databases.

An example of one dashboard is the Distributor Inventory and Sell-Through Dashboard. "Sell-through" refers to goods sold through distributors. Figure 7 shows this dashboard. Before this dashboard was available, it was difficult and time consuming to find out how much finished goods inventory distributors had, how many finished goods were sold through the previous week, and how many weeks of inventory they had. The dashboard displays all this information on one screen.

The dashboard required changing data collection. Formerly, distributors reported sell-through and inventory at the end of each week. That data was entered into regional databases and then consolidated at corporate, where it was imported into an Excel spreadsheet. About one hour later, paper reports were created and distributed, unless errors and new categories caused delays.

Now, inventory and sell-through data is collected automatically into one repository. The data cube, which is used to tabulate the KPIs and present the data, is refreshed every 20 minutes during primary collection times, and once an hour for the remainder of the week. These frequent refreshes help detect new trends. New categories are automatically included, quarterly comparisons are also automatic, and a single e-mail notifies employees of the availability of the report.

Implementation of the dashboards encountered all the usual problems encountered in decision support and executive support systems: poor data, inadequate se-

curity safeguards, and user uncertainties about what they really wanted.

How the VIS Accelerates WD's OODA Loops

Each dashboard contains its own set of real-time metrics and KPIs for tracking and analyzing critical operations. Each KPI and metric has a target performance level and a variance setting (some set in advance and some set by the system). Exceeding a setting triggers an alert to the appropriate supervisor or manager.

A well-designed dashboard can help people accelerate the OODA loops of the processes monitored. It can also accelerate OODA loops that span multiple processes and departments. So, to manage the fast cycle environment of its supply chain, WD coupled its dashboards with both performance management and learning, using a nested structure of OODA loops.

The factory and corporate dashboards are used in a three-level nesting of OODA loops, as shown in Figure 8.

Shop floor OODA loop. The shop floor supervisors in the factory operate in the innermost OODA loop using factory dashboards. When a product or station target is violated, they are immediately alerted via pager or flashing light. Sometimes the problem can be resolved within minutes by diagnosing it through the dashboard.

Factory OODA loop. Production managers operate at the next higher level because they need a broader view of the factory—such as seeing multiple product lines. They also receive alerts when their targets are out of range. But a more important aspect of their job is using the factory dashboards, with a different set of KPIs, to perform "health checks" on the operational performance of the factory (that is, determining that things are working as they should). The health check is analogous to a medical health check, which measures vital signs that indicates whether or not critical body functions are within normal limits.

The production managers use the factory dashboards in more of a learning mode. In their daily production meeting, they use the factory dashboards to analyze the previous day's performance and discuss ways to improve processes or avoid problems encountered the day before.

Because of the real-time nature of the data, problems already handled by the factory's shop floor supervisors are filtered out, minimizing the information overload on the production managers. The managers can more easily see the unresolved critical problems, which quickens their OODA loop.

Corporate OODA loop. Like the factory loop, the corporate OODA loop is about learning. It also involves a "health check"—but of the entire enterprise. This loop involves senior executives, and the resulting actions typically have broad implications, for the corporation and the factories.

Although not electronically connected, the factory and corporate dashboard systems are connected through the data they share and the communications and interactions of the managers who use them. The dashboards reduce the physical distances between the factories in Thailand and Malaysia and corporate management in California. As a result, people can meet virtually and resolve problems quickly. Often, employees or teams send references to a specific screen to another team so that both can discuss the problem and make a decision. To make this possible, managers can give permission for others to see a screen.

By making these connections and conversations easy, WD has sped up the OODA loops across the company. People who need either a factory or corporate dashboard can access it from anywhere. This capability very effectively couples senior executive decisions with operations, and does so by drawing on consistent, real-time, high-quality data.
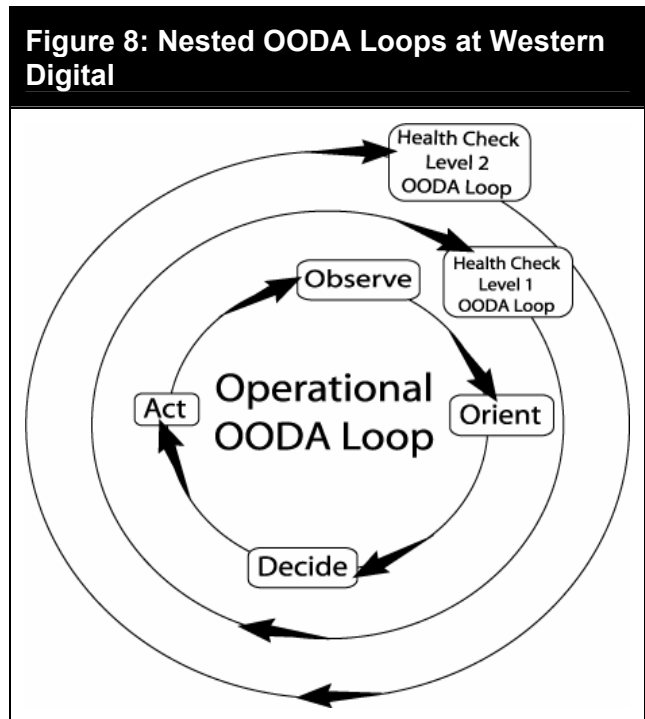

Figure 8: Nested OODA Loops at Western Digital

Dashboard use has not lead to micromanagement by top management, though. In fact, micromanagement was more prevalent before the dashboards. Previously, the shop floor supervisors, production managers and supply planners defined their own data in their "silo." The data came from redundant sources and often did not agree, if requested at different times. The dashboards give everyone the same data. Micro-intervention isn't needed because the data is more reliable.

THE BUSINESS IMPACTS OF WESTERN DIGITAL'S VIS

More than 225 managers and professionals at all levels of the company now use the dashboards. Their use changed how the OODA loops are managed, resulting in both measurable gains and continuing savings. On a pure cost-savings basis, these systems have paid for themselves many times over. However, the real payoff has come from quickening the OODA loops and decision cycles in ways that have changed WD's strategic capabilities.

Cost Savings

Cost savings have come in three forms: better visibility, more efficient querying, and less information overload and faster decision making.

Better visibility. Over the last several quarters, the increased visibility of finished goods inventory has allowed WD to increase inventory turns from 22 to 29, decreasing inventory by $25M in 2002, for annual savings of almost $3M in inventory carrying costs. Those savings alone paid for the entire dashboard IT infrastructure (the dashboards and the related reporting (business intelligence layer)). When this solution was proposed in FY2000 under the name "Business Management Information Systems," estimated cost of capital and expense was approximately $1.2M—with an ROI of one year. By saving almost $3M in inventory carrying costs in 2002, that ROI was realized in less than one year.

Western Digital's margins have more than doubled over the three-plus years since the dashboards were introduced. Management attributes these margin gains in large part to improvements in supply chain management, data visibility, and demand planning made possible with the dashboards. In improving demand management, WD has, on occasion, even been able to recapture missing revenue.

More efficient querying. Before the dashboards, it cost $1500, on average, for highly paid database administrators to create one of the hundreds of cross-application or cross-database reports requested each year. Now, users create multiple views "on the fly." Report requests have dropped from 200 to 50 per quarter, saving about $900K a year. Furthermore, the dashboards have eliminated about 50% of the printed paper volume, with an estimated savings of $800K a year. Custom reports now take an average of 10 minutes for managers to create, and they can easily combine real-time and historical data.

Less information overload and faster decision making. Executives, managers, and professionals now detect and analyze critical operational problems differently. Production supervisors and engineers no longer need to crunch data from several systems to measure KPIs. The dashboards feed this information to them. They can focus on performing the detailed analysis of trigger violations. Much of the noise and "unreal" problems are filtered out by the system. As a result, daily production meetings at the factories now take 1.5 hours, on average, rather than 5 hours. These meetings involve some 15 supervisors and managers, so time savings alone translates to $350K a year—time better spent on other work

Strategic Advantages

Strategic advantages come from faster analysis and decision making, immediately available information, quicker reflexes, and faster OODA loops, enterprise-wide.

Faster analysis and decision making. Executives using the corporate dashboards to identify KPI problems experience much less information overload. Formerly, they received information in different formats at different times from different managers, making quick, robust analysis difficult. Now, they can make strategic decisions quickly because they no longer need to spend hours trying to interpret the data correctly.

The better business intelligence capabilities has helped focus management attention. For example, one WD executive described how one product line can be used to benchmark others:

> With the dashboard we get one up-to-the-minute snapshot showing a comparison of yields for 16 product lines in the last month on one screen shot or graph, rather than 16 spreadsheets that are difficult to compare. The difficulty is in showing relationships. Dashboards easily show us where the relationships intersect and help us to diagnose problems. Dashboards help provide knowledge rather than just information.

Immediately available information. With the dashboards, everyone sees the same information, anytime, anywhere and updated at the appropriate time intervals. Before the dashboards, a salesperson on the east coast visiting a customer at 8 a.m. could not obtain the most current information because the account manager on the west coast was not at work yet. As expressed by the Senior Director of Sales for Latin America,

> *The comfort zone that management can get to the data almost real-time, anywhere in the world, is practically priceless. We have had events where the dashboards were accessed from a customer site, and we were able to quickly explain an issue by confirming product shipments, quarter-to-date billings, and sell-through volumes on the spot. This type of service and information availability improved our quality image and market share.*

Quicker reflexes. The reaction time between receiving data and acting on it has shortened from hours, sometimes days, to minutes. Timely alerts to manufacturing supervisors for "out of control" situations has reduced waste on the production lines. Analysts can catch demand-supply imbalance problems as they occur (rather than the day after), and react quickly to resolve them and limit damage. As one account manager put it,

> *"Instead of sending cumbersome spreadsheets back and forth, we can look at the same data at the same time and make real-time decisions even when we are at different locations. We also eliminated the need to create the spreadsheets."*

Faster OODA loops enterprise-wide. While many of the business impacts discussed above resulted in measurable gains and millions of dollars in savings, the longer-term benefits are harder to assess quantitatively. Yet, they exist and are clearly strategic.

One benefit is that WD is continuously becoming a more agile competitor, as the OODA loops accelerate at all levels of the enterprise. Tactical OODA loops provide feedback and learning to operational management, which, in turn, feed the executive decision-making OODA loops. WD now ties together executive decision making, supply chain movements, and internal operations into a virtuous circle that can function effectively as various situations unfold. As a result, as an enterprise, WD can learn faster and act with more vigilance, even as the supply chain continues to speed up.

WD's supply chain recognizes the company's contributions. In May 2003, for example, WD was one of eight suppliers that won a WorldWide Procurement Supplier Award from Dell Corporation.

Matt Massengill, CEO of WD, said it this way:

> *"The alerts in the management dashboards allow us to drive quicker to root cause. Planning meetings are now about the performance in production or sell-through rather than about whether the data on spreadsheet A is consistent with B, C, and so on. We now spend more time making decisions based on the data."*

LESSONS LEARNED

The real-time dashboards and their underlying infrastructure have changed how WD manages operations, from the boardroom to the shop floor in the factory. The bottom-line effects of improved visibility, real-time information, and quicker OODA loops occur at all levels of the enterprise. WD is a faster-learning and more vigilant enterprise, so it can operate more leanly. Its ability to link executive decision making with operations in real-time through dashboards has given it a strategic edge as a responsive supply chain partner. Western Digital's experiences provide seven lessons.

Lesson #1: Design The Real-Time Management Dashboards To Be The Nerve Center For Managing The Enterprise.

WD's experience shows that management dashboards can become the central point for managing an extended enterprise vigilantly. By providing the means for human-computer interaction, they are a critical component of a VIS architecture. These dashboards may be glitzy, or not. Some may display mainly tables of text. They should provide instant access to information (i.e., observe). But they also should combine event-based alerts (i.e., orient) with company history. And the information should be sharable, to give people ways to track and manage (i.e., decide-and-act) activities and processes across functions.

Lesson #2: Plan and Schedule the Coordination Among Teams to Use the Dashboards to Manage Enterprise-Wide.

Dashboards can show real-time metrics, workflow executions, alerts, and various slices from information cubes from other dashboards, providing a holistic picture that allows teams to collaborate more quickly and

make decisions. Often these teams are in different functional areas, different geographic locations, and responsible for different business processes. One purpose of providing the information via dashboards should be to eliminate the separation of people in space and time, thereby allowing managers to be "virtually" in the room. Another purpose is to identify problems and opportunities that could otherwise be missed.

This coordination is being accomplished at Western Digital by using the corporate dashboards as the focal point of meetings among managers from sales and marketing, distribution, and the factory. These meetings are not ad hoc, though. They are scheduled daily, weekly, monthly for specific purposes—quality review, production planning. The meetings provide the human coordination and intervention needed to deal with enterprise-wide problems. The goal is to act quickly in a coordinated fashion.

To manage enterprise-wide, Western Digital makes sure that people with multiple perspectives are always involved in an OODA loop.

Lesson #3: Build A Learning Loop Around Each OODA Loop To Foster Group Learning Because The Faster The Loop, The More Important The Learning Reviews And The More Frequent They Need To Be.

As cycle times become shorter, errors and exceptions occur more quickly as well. To keep up, enterprises need information systems and management processes that record incidents and retain their history, so that groups can review and learn from them.

Western Digital embeds group learning into its OODA loops through its organized "health checks" and review meetings, both of which take place around the dashboards. WD learned that the shorter the cycle times, the more frequent and important the "health checks." Each OODA loop needs its own learning loop, designed specifically for it. Dashboards and VIS need to be designed and managed to support this use, and the learning loops need to be part of the management culture.

Lesson #4: Match the Time Latency of Each OODA Loop to the Organization's Needs and Capabilities to Become Truly Vigilant. Do Not Indiscriminately Chase Zero Latency.

"Just because information is available in real-time does not mean that an enterprise can act instantaneously on it."[13]

At first sight, it would appear that achieving zero latency in any portion of an OODA loop is the Holy Grail. But Western Digital has learned that "real time" in practice actually should mean "being sufficiently vigilant for the OODA loop you are in"—not zero latency. On the sensing side, the incoming information must be validated; otherwise, there is a lot of "noise." Also, the various information feeds need to be synchronized. Both add time to the sensing portion of the loop, but improve the enterprise's ability to be vigilant.

At WD, the OODA loops around the manufacturing process are much faster and closer to real time than the OODA loops around demand management in the supply chain, because validating the information about sales and demand takes longer. Furthermore, some parts of the organization cannot or do not need to act in real time.

The most effective OODA loops provide fresh information when the organization needs to respond. The computer-based sensing portions support the human-based responding portions. There is no point in getting fast sensing (the observe and orient portions of the OODA loop) if no actions can be taken. Likewise, there is not point in being able to respond quickly (the decide-and-act portions) if there is no fresh information. Investing in sensing capabilities that provide information more frequently than an OODA loop requires may not be the best use of IT funds or management attention. When in concert, the two provide the building blocks for a sense-and-respond enterprise.

Lesson #5: Provide the building blocks for the "sense-and-respond" real-time enterprise through a vigilant information system and real-time management dashboards

IT vendors are currently pursuing positioning strategies for the "sense-and-respond" real-time enterprise as their hallmark: IBM touts "e-business on demand," HP embraces the "adaptive enterprise," and TIBCO

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[13] Sawhney, M. "Real-Time Reality Check," *CIO Magazine*, March 2003, pp. 37-38.

sells "real-time publish and subscribe" architectures. However, as we understand it from the public information available and corporate white papers and advertisements, they are positioned mostly as solutions to technology platform problems, rather than management problems.

Understanding the principles of real-time dashboards, VIS, and the structure of OODA loops provide a more informed and richer path to providing the building blocks for the "sense-and-respond" enterprise. The WD experience shows that alerting capabilities can trigger very different real-time performance management in an enterprise. Such IT capabilities help to shape the quickness of the OODA loops for effective "sense-and-respond" working in dynamic supply chains, as well as the management processes around them.

Lesson #6: Justify vigilant information systems on a basis other than return on investment.

The real payoff of VIS comes from accelerating OODA loops in ways that change the capabilities of the enterprise. Oftentimes, though, such grand initiatives are difficult to cost-justify. Financial returns are hard to quantify and risks are high. The Internet bubble increased skepticism about IT-based transformation initiatives.

Sometimes the strategic opportunities of VIS can be quantified—such as the value of increasing the enterprise's ability to respond more quickly to changing customer needs or the value of limiting the enterprise's exposure to suppliers that cannot meet their commitments. CFOs accept estimates that translate these risks into money.

At WD, the CIO justified the IT investment in yet another way. To sway the CFO, he illustrated the "impact of not doing it" by pointing out that not investing would hamper WD's ability to meet its supply chain performance commitments.

With the increasing need to build security and privacy capabilities into information systems, CFOs are likely to accept such justifications because these two capabilities also cannot be justified by ROI.

Lesson #7: Make implementation of an enterprise-wide VIS a management initiative (not a technology initiative) because it requires "active,

collaborative engagement" from all top management to instill the needed organizational transformation.

Taking advantage of real-time dashboards and VIS requires transforming an enterprise's management processes. Such a transformation requires more than the usual "getting top management support." It requires the entire top management team to be actively collaborative because they are the ones who must model the process of using the new information and knowledge differently to manage and steer the enterprise. Use must start at the top.

At WD, CEO Matt Massengill was one of the first to use the corporate dashboard. He demonstrated his use by taking fresh data from the dashboard to his top management and staff meetings. He used the data to emphasize a point, generate lively conversation, and review numerous KPIs. He set an example for how to use the new goldmine of data to manage differently—thereby sending the message that all top management needed to change their way of managing as well.

In fact, Massengill adopted the dashboard so completely that he asked that some views be ported to his PDA. The IT team extracted key Billings to Date, Sales by Region, and Orders by Unit—the extracts most important to Massengill and other executives when they are on the road. Generally, the indicators are "all is well." But they are excellent for alerting the executives when production is below expectations. Such information can make all the difference between "go ahead and board the plane" or "get to a phone."

THE FUTURE OF VIGILANT INFORMATION SYSTEMS

Western Digital's CIO, dashboard teams, and line managers continue to develop the VIS vision, enhance system functionality, and integrate the systems with management practices at WD.

Internally, output to wireless devices is planned, as are dashboards for other business processes.

Externally, WD plans to build dashboards for collaborating with supply chain partners. Such links will deepen visibility into the supply chain and thereby widen and accelerate the information inputs into the OODA loops, permitting even better synchronization along the chain. These dashboards will also give suppliers and customers visibility into WD's manufacturing process. Ultimately, the goal is to speed up the entire supply chain's OODA loops.

Figure 9 shows four types of real-time management dashboards, based on the amount of "business horse-power" required of their underlying VIS and their roots (their DNA). Business horsepower means the ability of the systems to link management decisions to operations and span multiple processes and multiple enterprises. The four are:

- *EIS Business Performance Dashboard*: Monitors business metrics and key performance indicators. Its roots are in Executive Support Systems.14 The corporate dashboard at WD is of this type.

- *Operations Control Dashboard*: Is tightly coupled to operational processes, whether in manufacturing or in service operations. Its roots are in industrial engineering and total quality management. The factory dashboard at WD is of this type.

- *Business Process Dashboard*: Is most commonly used for transactional processes. It monitors business processes across an enterprise while they are executing and can proactively reroute processes and reallocate resources. Its roots are in workflow automation. WD is moving in this direction.

- *Collaborative Dashboard*: Is shared by multiple partners in a business-to-business (B2B) supply chain and provides OODA loop synchronization across enterprises. WD is moving in this direction.

Ultimately, it's the combination of these dashboards at various enterprise levels, and their integration into management processes, that will yield the quickest and most effective OODA loops.

As the concept of the real-time enterprise develops, there will be much activity around development of supporting IT architectures and new types of dashboards. WD stitched together its own sense-and-respond IT architecture using generic IT infrastructure components. However, a new class of specialized IT architectures is evolving, specifically geared to real-time response. Examples include event-based computing architectures,[15] "publish and subscribe" architectures,[16] and B2B integration architectures. All enable seamless integration of business processes, permitting faster response.

Figure 9: Four Types of Real-time Management Dashboards
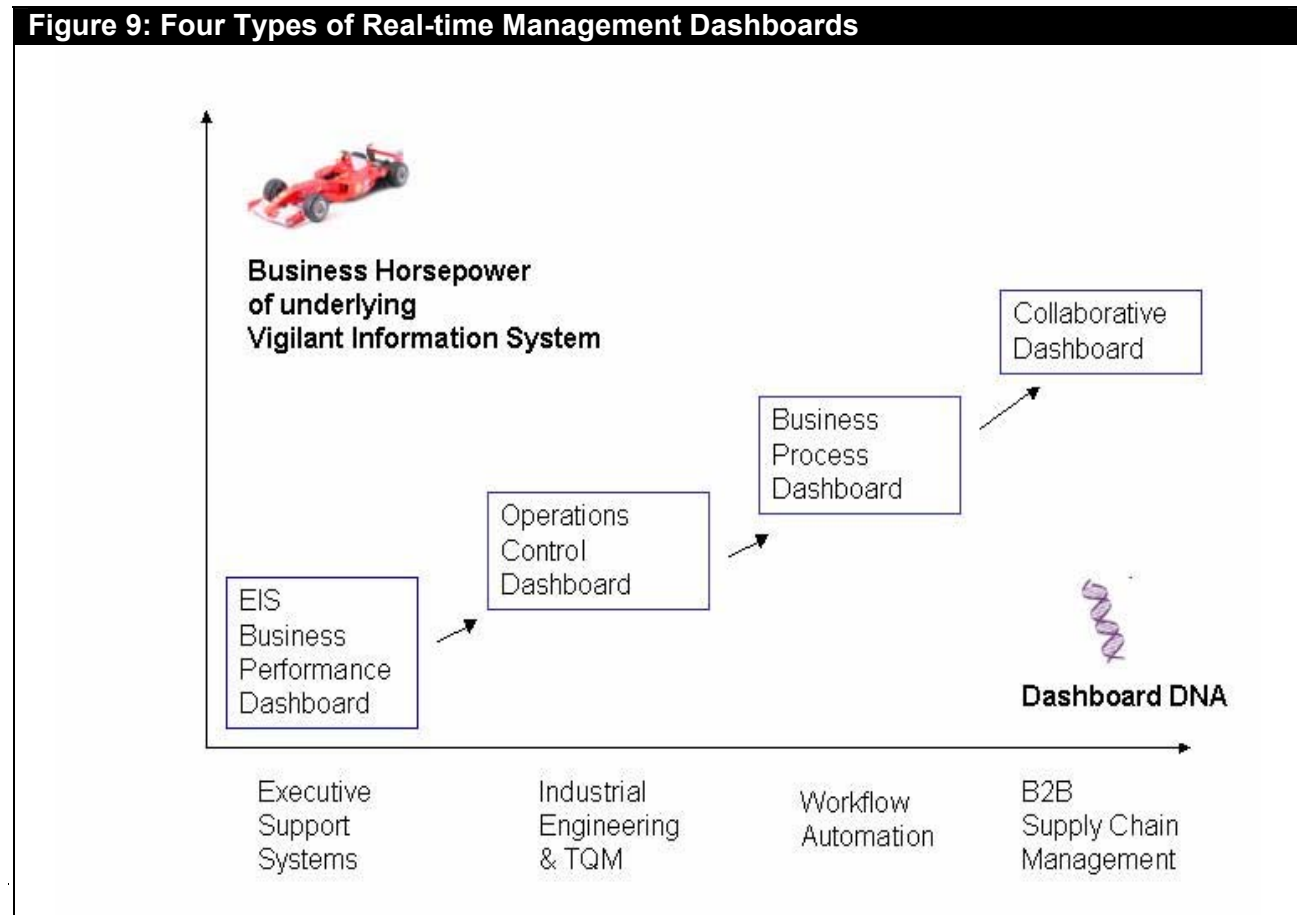
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Houghton contributes to Western Digital extensive experience in operations, materials, and information systems management. Previously, he was CIO and vice president of MIS and network operation centers at Zland.com, where he was responsible for worldwide and co-location hosting data centers. He also served such companies as Adaptec, Jennings Corp., RWD Technologies and Litton Systems in IT management functions.

Houghton earned his bachelor's degree in Criminal Justice and Sociology from the University of Maryland, and information systems management certifications from the University of Maryland and University of California at Davis, as well as under the American Management Association program. He currently is a member of many professional groups, including the Southern California Chapter of SIM (Society of Information Managers); the Southern California Chapter of CIO's, Orange County; WINPOPRO.NET (World Information Professional Network, CIO's); Advisory Board for Proof Point Ventures; and Oracle Leaders Circle.

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