Enterprises must respond ever more quickly to unpredictable events and new threats and opportunities in their environment. Event processing has emerged as the key enabler for situation awareness and a set of guiding principles for systems that can adapt quickly to shifts in customer demand and market conditions. Written by experts in the field, this book explains how to use event processing in the design of business processes and the systems that support them.

This special edition is a subset of a longer book of the same title published by The McGraw-Hill Companies (ISBN 978-0-07-163350-5). It describes the relationship of event processing to other IT initiatives, including business process management (BPM) and business intelligence (BI). It also explores the kinds of business problems that event processing can address, and gives examples of real-world applications. Event processing is one of the most interesting aspects of modern technology. It will bring fundamental—and favorable—shifts in the nature of business and the practice of IT.
Event Processing:
Designing IT Systems for Agile Companies
Dear Reader,

*If I were to make a prediction it would be that every big and medium sized company will be using CEP in one way or another within the next few years. Then the search will be on for the next source of competitive advantage.*

Alan Cane, FT.com

Event processing has matured and evolved dramatically since I co-founded Apama with Dr. Giles Nelson back in 1999, based on revolutionary research we led at the University of Cambridge, UK. Yes, it is has revolutionized the capital markets industry through the advent of high-frequency trading systems. But it’s also used to intelligently track and respond to millions of moving objects, like trucks, ships, planes, packages and people. It’s used to uncover revenue leakage and for monitoring and continually optimizing the network and business support systems in telecommunications. It’s used to predict and intelligently manage unexpected events in airlines, rail and logistics. Utilities use it for smart-grid demand-response. Financial services and other companies use it to detect fraud and insider trading. It drives real-time promotions, location-based advertising and improved customer experience. In fact, it enables all types of firms to optimize their businesses and dynamically adapt to changing conditions based on what’s happening now—and what’s about to happen.

In a survey carried out last year by Vanson Bourne, 89% of respondents stated that they cannot get a single view of process performance because information on business processes is held in multiple operational systems. The report also showed 80% use middleware to try to bring data together but not to the satisfaction of those in charge of operations. And 67% admitted they hear about problems in service from customers before they identify the problems themselves.

For the CIO, event processing provides a way of responding to executives’ complaints that they have insufficient real-time informa-
tion to efficiently run the business. By using event processing along with other technologies such as BPM, firms can continuously improve business processes based on opportunities and threats as they occur—and thus drive efficiency and real competitive advantage.

I encourage you to find out more about how event processing can enable your business to do more with less and enhance revenue within your business through continuous intelligence, anticipating and responding to opportunities and threats.

Dr. John Bates
Chief Technology Officer
Progress Software
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Introduction

Event processing makes dramatic improvements in business processes and IT systems possible. It has a direct, tangible impact on the lives of businesspeople. Event processing changes the way they do their jobs by giving them better visibility into what is happening in their company and its external environment. It also improves a company’s reaction time to unforeseeable situations, reduces the end-to-end elapsed time of business processes, and improves the quality and availability of information.

When you can see what is going on in your sales operations, customer contact center, supply chain, or service network in near real time through a dashboard on your web browser, you are using event processing. When an insurance company condenses a 25-day process for paying a claim down to 9 days, it is using event processing. When an application system can be adapted in days rather than weeks to support a new set of requirements, it is likely using event processing as well.

Event processing is an increasingly important part of enterprise service-oriented architecture (SOA) and business process management (BPM) strategies. Event processing is synergistic with SOA and BPM, making them more effective and better able to respond quickly to escalating business requirements.

Defining Event Processing

An event is just what you think it is—anything that happens. We react to events every day, and we’re always learning better ways to handle them. Events are all around us and have always been all around us, like the air we breathe and the winds that we exploit to fill our sails and create windmill power. For many centuries, people used sails and windmills without understanding the Bernoulli principle or much else about the scientific properties of airflow. However, thanks to advances in the fields of aerodynamics, engine design, and material science, we now use the power of air currents to fly airplanes, helicopters, and spaceships. Even our windmills are more powerful and efficient because they use specially shaped impeller blades instead of using simple sails or blades mounted on wheels as in early designs.

In a similar way, companies that deal with millions of events in their daily operations can learn better ways to use events to their benefit. Analysts have an intuitive understanding of how to design business processes that are triggered by events. However, they could accomplish much more if they understood better how events actually work and used modern design patterns and software tools to harness the power of events.

We need to distinguish between the general concept of responding to real-world events, which is practiced more or less continuously by every company and person, and
the design discipline known as *event processing*, which encompasses the principles, reference architectures, design patterns, and best practices that are the subject of this book. Many business analysts, managers, and application architects have only an informal and limited knowledge of this subject. Event processing is not included in many business and computer science courses and textbooks, and when it is, it is treated as a side issue rather than a focus. Most people are more familiar with the characteristics of systems that are not event based, such as time-driven and request-driven systems, because those design styles are more commonly used in business applications (although the terms *time-driven* and *request-driven* aren’t explicitly recognized in many cases).

In some crucial ways, event processing changes the rules of the game. Event-driven design differs from conventional design in a way that can be compared to the difference between left-brain and right-brain thinking.

### Why Event Processing Has Become Critical

If event processing is such a great idea, why hasn’t everyone been doing it all along? Event processing is underutilized partly because relatively little data on current business events has been available in digital form until recently. In the past, many events either were undetected or were detected but not reported in a digital form that could be sent over a network or manipulated by a computer. Now, more events are detected and represented electronically, although, unfortunately, many are still not readily accessible to the people, devices, or IT systems that could benefit from them.

The amount of available event data is rapidly expanding because of the decreasing costs and increasing speed of computers and networks, and the unifying power of the World Wide Web and its communication standards. We are blessed with an explosion of event “streams” flowing over corporate networks—data from websites, enterprise application systems, e-mail systems, cell phones, RFID readers, GPS systems, and a variety of other sensors and devices. This wealth of event data will grow as the cost of the relevant technologies continues to drop and companies create new sources of event data in their operations and the outside environment. Our challenge is to make better use of this data.

The other reason that formal event processing has been used sparingly until now is that competition and customer demands were less urgent in the past. Companies had more time to respond to events than they have today. A person driving 30 miles per hour doesn’t need as much advance warning of upcoming curves or obstructions on the road as a person driving 60 miles per hour. Companies today are operating at a faster pace, so early notification of emerging business threats and opportunities is increasingly important. Companies that know how to leverage event processing have an advantage over those that don’t.

### About This Book

The goal of this book is to make the knowledge of the event-processing design discipline more widely available. If you understand how event processing really works,
you can design business processes and IT systems that will offer your company better timeliness, agility, and information availability.

The book is aimed at a broad audience, including business analysts, IT architects, CIOs, application managers, project leaders, process modelers, and technology-aware businesspeople outside of the IT department. It bridges the gap between the business literature, which describes the aspirations of agile companies, and the technical literature, which explains how to write event-driven programs. The book does not expound on the value of situation awareness, rapid response, accelerated business processes, or expanding the event horizon to see further into the future, because it assumes that you either already know about these concepts or can find an explanation elsewhere. This book focuses on how to achieve these, not why you’d want to.

This short book is a subset of a longer book of the same title (*Event Processing: Designing IT Systems for Agile Companies*, McGraw-Hill, 2010, ISBN 978-0-07-163350-5). This subset describes the relationship of event processing to other IT initiatives, including business process management (BPM) and business intelligence (BI). It also explores the kinds of business problems that event processing can address, and gives examples of real-world applications. The full book contains a more-complete explanation of event processing concepts, terminology, architecture, and best practices for designing and implementing event-based systems.

Event processing is one of the most interesting aspects of modern technology. It will bring fundamental—and favorable—shifts in the nature of business and the practice of IT.
Positioning Event Processing in the IT World

In the following pages, we will explain how event processing contributes to business process management (BPM) initiatives. We'll also look at the relationship between traditional business intelligence (BI) and business activity monitoring (BAM) systems.

Events in Business Process Management

BPM projects are more successful when they use event-driven architecture (EDA) and complex event processing (CEP) appropriately. BPM encompasses two related concepts:

- In some contexts, it is a discipline for designing, simulating, monitoring, and optimizing systems in a deliberate and systematic way that is conscious of end-to-end business processes.
- Elsewhere, it refers to the use of BPM software, such as orchestration engines and workflow engines, at run time to direct the sequence of execution of software components and human activity steps in a process.

Both concepts of BPM always involve events, but they don’t always involve event objects or the discipline of event processing. The next two sections explain the role of events in BPM initiatives.

The BPM Discipline

The BPM discipline is a collection of methods, policies, metrics, management practices, and tools used to design, run, and manage systems that support a company’s business processes. Business managers, users, business analysts, and software engineers all have roles to play when using a BPM approach.

The life cycle of a business process begins with process discovery, analysis, and design. Process modelers develop an understanding of how the business should work, not just how it currently works. The goal is to avoid re-creating a suboptimal process in new technology (“paving the cow paths”). Business processes and data are modeled to develop a “to be” business architecture—a conceptual view of how things will be done in the future. A process modeler, usually a business analyst or system analyst,
will take the lead in developing and documenting the logical rules for the sequence of activities and data flows. This is the basis for determining which aspects of the process should be automated in application software and which should be done manually or in a machine of some kind. This leads to subsequent steps in the development cycle, including detailed design, coding, testing, and deployment, and then maintaining applications and databases.

Note: The maxims that system design should begin at a business level and that it should reflect a broad, end-to-end view of the process have been part of good IT practices for many decades.

The origin of systematic approaches to business process design can be traced to Frederick Winslow Taylor, the inventor of scientific management and the time-and-motion study, who did his major work between 1880 to 1915. Scientific management provided an early foundation to the much-later business process reengineering (BPR) movement that was inspired by Hammer and Champy’s seminal 1993 book, *Reengineering the Corporation: A Manifesto for Business Revolution*.

The underlying principles of modern BPM reflect the insights of scientific management and BPR. However, modern BPM puts more emphasis on continuous change and ad hoc variability. The process and the business environment in which the process lives are constantly monitored and measured. Business processes are adjusted frequently, and hence the terms “continuous process improvement” and “business process improvement” have become goals for many advanced development organizations. Processes are becoming better able to support instance agility because they allow certain flow decisions to be made by a person dynamically at run time. Activities may be skipped or executed out of order, or additional activities may be inserted into the process. This is especially important for semistructured business processes that cannot be fully planned in advance.

Software vendors offer a variety of sophisticated tools for business process analysis, modeling, and simulation. However, many BPM initiatives are still carried out with manual analysis and simple drawing tools.

**BPM Software**

BPM software manages the flow of business processes at run time. It keeps track of each instance of a business process, using rules to evaluate events as they occur and programmatically activating the next step for each instance at the appropriate time. Vendors offer several types of run-time BPM software products, including orchestration engines, workflow products, composite application tools, and other BPM tools. Orchestration tools primarily control activities that are executed by software agents. Workflow tools primarily control activities that are executed by people.

BPM software is sold as a separate product or bundled into a business process management suite (BPMS), enterprise service bus (ESB), packaged application suite, or other application infrastructure product. A BPMS is the most complete of the product types that offer run-time BPM software. It includes tools for all of the aspects of the BPM discipline, including process modeling, analysis, simulation, and run-time monitoring and reporting.
The sequence of execution and the rules for controlling the conditional flow of a process are mostly or entirely specified at development time by a software engineer or a business analyst. Most process development tools have a graphical interface, although sometimes a scripting language or traditional programming language can be used. Modern BPM also seeks to make it possible for power users and managers outside the IT department to directly modify a business process in certain, limited ways without the direct involvement of IT staff.

The BPM discipline doesn't require the use of BPM software at run time. A process can be designed with a formal BPM methodology and modeled and simulated with BPM design tools, but still be instantiated as an application system that doesn't use run-time BPM software. When run-time BPM software is not used, the process flow is controlled by scripts, application programs, or direct human control. Conversely, run-time BPM software can be used without a formal BPM design program. However, the trend in application development projects is toward using both.

BPM is naturally complementary to service-oriented architecture (SOA). SOA's modular nature and well-documented interfaces can reduce the effort required to modify or add activities in a business process. SOA applications are more likely to use BPM engines at run time than traditional (non-SOA) applications are.

Note: SOA can be successful without using either development-time BPM design tools or run-time BPM orchestration or workflow software. However, you should never develop an SOA application without considering the architecture of the business process and considering the end-to-end business process model prior to development.

BPM and EDA

Business processes always involve business events in a general sense. However, they aren't event-driven in every aspect, nor do they use EDA for every interaction. As you know, most processes are a mix of event-, request-, and time-driven interactions. We'll describe the relationship between BPM and EDA in this section. The next section describes the role of CEP in BPM.

The disciplines of event processing and BPM sometimes use different terms to describe the same phenomena. Consider an order-to-cash business process consisting of the five steps shown in the visible process at the bottom of Figure 1:

A. Capturing a customer’s order
B. Performing a manual approval if the order has some unusual characteristics
C. Filling the order
D. Shipping the goods
E. Issuing a bill (concurrently with shipping)

In event processing terminology, running through this whole process once to implement a specific action such as “Fred Smith buys a laptop” would be a coarse-grained
business event. In BPM terminology, this would be a “process instance” or “business transaction.”

In both BPM and event processing terms, the process instance is initiated by a business event—capturing Fred’s laptop order in the order entry system (A). The order-capture event is fine-grained. It is only one of many business events that take place within the larger “Fred Smith buys a laptop” event or process instance. In event-processing terms, manual approval (B), order fulfillment (C), shipping the goods (D), and issuing a bill (E) would also be business events. Within each, additional layers of more-detailed events might be identified, studied, and implemented. In BPM terms, each of these steps is an “activity.” The event processing perspective describes the change that occurs, whereas the BPM perspective describes the actions that carry out the change, but they’re referring to the same part of the same process.

The relationships among agents that implement this business process can be structured in an event- or request-driven manner, or a combination of the two. Assume that BPM software is being used to orchestrate the flow of this process. The order-entry application (A) can inform the run-time BPM software that a new order has arrived by sending a notification containing an event object that says “Fred Smith just submitted an order for a laptop” (see “1. Use simple event to trigger new process instance” in Figure 1). Each event in an event stream from application A would trigger a new process instance (a separate order). Alternatively, application A could have triggered the start of a new process instance in a non-event-driven way by invoking a request/reply web service that instructed the BPM engine to “enter new laptop order for Fred Smith and send a reply back to acknowledge that the order had been received.” Either way, the BPM software would create a new process instance and assume con-
control of the process, triggering steps B, C, D, and E in succession until the process instance for Fred’s purchase had completed.

The choice between an EDA or a request-driven style of interaction between application A and the run-time BPM engine has implications on the looseness of the coupling and the agility of the application. But either technique accomplishes the goal of signaling the occurrence of a business event that initiates a new business process instance. Similarly, the BPM software can trigger each subsequent activity step by issuing a request (steps B and E) or by sending event notifications (steps C and D). The notification that triggers step D is labeled “2. Event” in Figure 1. In some cases, an activity or the whole process can be time-driven rather than request- or event-driven (not shown in Figure 1).

The run-time BPM software (workflow engine or orchestration engine) must be aware of certain events to know when to start or stop activities. For example, it must learn that a previous step has concluded before it starts the next step. Again, an EDA-style notification can be used to convey this information within the run-time BPM software, or a request-driven mechanism may be used.

**BPM and CEP**

Conventional BPM engines control the process flow by applying rules that refer to things that have happened to the application software that is implementing the business process (in this case, it would be steps A through E). A recent advance in BPM technology involves the use of CEP software to augment the intelligence of run-time BPM software (see “1. CEP assists BPM engines” in Figure 2). The CEP engine gets information about events that occur outside this business process from sources such as sensors, the Web, or other application systems. It also gets information about events that are occurring within the business process from the BPM software. From these base events, it can synthesize complex events. These are forwarded to the BPM software to enable sophisticated, context-dependent, situation-aware flow decisions. Only a few BPM engines have this capability today, but we expect this to become more common in the future.

Most commercial run-time BPM software products have a BAM dashboard feature for process monitoring (this is sometimes called “process intelligence”). Run-time BPM software emits notifications to report events that occur in the life of each process instance. The monitoring software captures these events, tracks the history of each instance, calculates average process duration and other statistics, and reports on the health of the operation through the dashboard and other notification mechanisms. The monitor can give early warnings of anomalies for individual process instances and for aggregates (groups of instances, such as all orders for computers submitted in the past week). Process-monitoring dashboards generally enable the user to drill down into the detailed history of an individual process instance when necessary.

All process monitors implement a basic form of CEP in the sense that they apply rules and perform computations on multiple event objects to calculate what is happening in a business process. However, process monitors are not general-purpose CEP engines, and most process monitors don’t listen to events from outside the managed
business process (that is, all of their input is derived from internal process events happening within applications A through E). However, a few leading-edge projects have linked CEP engines with process-monitoring tools (see “2. CEP assists process monitoring” in Figure 2) to provide a broad, robust, situation-awareness capability that encompasses both internal process events and external business events. We expect that this will become more common in the future.

Process monitoring can also be implemented in scenarios where there is no run-time BPM software (not shown in Figure 2). Business processes that are not controlled by run-time BPM software are more common than those that are. Businesspeople still want visibility into what is happening in those processes so that they may deploy a process monitor and BAM dashboard. Supply chain management is a type of process monitoring that usually is implemented without run-time BPM software, or with only small parts of the supply chain under the control of run-time BPM software.

Figure 2: Using CEP with BPM.
**Summary of Event Processing in BPM**

The BPM and event processing disciplines evolved independently, but they are beginning to influence each other more heavily as CEP moves beyond technical domains to support business applications, and as BPM becomes more sophisticated and dynamic. The relevant technologies are a good fit with each other, and the resulting synergy produces better process management and business decisions (see Figure 3). A combined discipline is forming under the label “Event-Driven Business Process Management” (EDBPM) encompassing a body of work on technology and best practices.

<table>
<thead>
<tr>
<th>Relevance of EDA to BPM</th>
<th>Relevance of CEP to BPM</th>
</tr>
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<tbody>
<tr>
<td>Single event can trigger new process instance</td>
<td>Business process monitor can use complex events to track and report the health of a process and its individual instances</td>
</tr>
<tr>
<td>Single event can trigger new activity step within a process</td>
<td>Run-time orchestration or workflow engine can make decisions on process flow based on complex events</td>
</tr>
<tr>
<td>Activity can emit a new event notification to trigger another process or activity</td>
<td>CEP software can identify a threat or opportunity situation that triggers a new business process instance</td>
</tr>
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Figure 3: Summary of event processing in BPM.

**Event Processing in Business Intelligence**

Enterprises use business intelligence (BI) systems to make better decisions. BI applications can be categorized as analyst-driven, process-driven, or strategy-driven. Analyst-driven systems, the most common type of BI applications, rarely use event-driven CEP. Some process-driven BI systems deal with near-real-time information—these are known as business activity monitoring (BAM) systems. BAM systems leverage event-driven CEP extensively. Strategy-driven BI systems, including performance management systems, occasionally use event-driven CEP. This section explains these three kinds of BI in more detail and then describes the relationship between BI and event processing.

**Analyst-Driven BI**

Analyst-driven BI applications primarily serve analysts and knowledge workers. They provide in-depth, domain-specific analysis and information delivery using ad hoc queries, periodic reports, data mining, and statistical techniques. This style of BI answers questions such as:
Do we have enough account executives on the street to meet our sales quota?

Which customer segments are buying the most?

Should we retire a product line because it is underperforming?

**BAM**

BAM provides situation awareness and access to current business performance indicators to improve the speed and effectiveness of operations. It’s a type of continuous intelligence application and it uses CEP in most usage scenarios.

BAM differs from analyst-driven BI in fundamental ways:

- BAM systems are typically used by line managers or other businesspeople charged with making immediate operational decisions. In contrast, analyst-driven BI systems are used mostly by staff people preparing recommendations for strategic or tactical decisions.

- Much of the input for BAM is event data that has arrived within the past few seconds or minutes. Historical data is used to put the new data in context and to enrich the information before it is distributed. The event data is often in a fairly raw form—it’s observational notifications, sometimes with missing, out-of-order, or unverified messages. BAM data is often held in memory for immediate processing, and in some cases, it isn’t saved on disk. However, some BAM applications need access to vast amounts of historical data. They may use in-memory databases with specialized data models such as vector database management systems (DBMSs) or real-time, in-memory variants of online analytical processing (OLAP) technology. In contrast, analyst-driven BI relies mostly on historical data from previous days, weeks, months, or years. Analyst-driven BI data is a mix of event, state, and reference data. Most data used in analyst-driven BI has been validated, reformatted into a database schema that is optimized for queries (such as conventional OLAP), and stored in a data warehouse or data mart on disk.

- Most BAM systems run continuously, listening to incoming events and communicating with businesspeople through dashboards, e-mail, or other channels. BAM systems typically use a mix of event-driven (push) and request-driven (pull) communication to interact with users. The event-driven communication alerts people when something significant happens. Users then make requests to drill down into root causes or look up information needed to formulate a response. In contrast, most analyst-driven BI is request-driven, where the end user submits ad hoc queries or asks “what if” questions through a spreadsheet that sits in front of a database. Alternatively, analyst-oriented BI is sometimes time-driven, using periodic batch reports.

- Some BAM systems execute a response through a computer system, actuator, or other fully automated mechanism. In contrast, analyst-driven BI always involves a human decision maker.
Strategy-Driven BI

Strategy-driven BI, the third category of BI, is used to measure and manage overall business performance against strategic and tactical plans and objectives. These applications typically serve corporate performance management (CPM) and other performance management purposes. They provide visibility into such issues as

► Are we on track to meet our monthly sales targets?
► Will any of our operating divisions overspend their capital budgets this quarter?

Formal performance management applications are less common than analyst-driven BI or BAM systems. Most managers still use less-systematic approaches to performance management, such as spreadsheets or manual analysis of traditional reports. However, performance management systems for sales, marketing, supply chain, HR, and others areas are becoming more common for the same reason that operational decision-making BAM is becoming more common—the growing amount of data available in electronic form.

Performance management systems differ from BAM systems in several ways:

► Performance management system users are typically at a higher level in the organization than BAM system users. Executives, senior managers, and department heads use performance management systems, whereas lower-level line managers or functional decision makers are more likely to use BAM systems.

► Performance management dashboards differ drastically from BAM dashboards, although most of the input data for both kinds of dashboards are event data. Performance management dashboards generally show summary-level data from one or more business units collected over many days or weeks. Totals and averages are compared against targets, often using scorecard-style displays. In contrast, most data used in BAM systems is a only few seconds or minutes old and the data is summarized at a lower level.

► Decisions made on the basis of performance management systems typically have a medium-term time horizon. If nothing is done for a few hours or days, it often doesn’t matter. In contrast, BAM systems are generally targeted at more urgent, although often narrower and less consequential, decisions. Decisions made on the basis of BAM may only affect a small part of the company’s work, such as one or two customers or one day’s results.

► Performance management systems are used by people. The issues tend to be complex and require human judgment. In contrast, some BAM decisions are simple enough to fully automate. The majority of BAM systems still involve human users too, but automated decisions and responses are becoming more common over time.
Positioning BI and Event Processing

In the language of event processing, all three kinds of BI systems perform CEP because they compute complex business events from simpler base events. However, BI users and developers rarely think of events or CEP in a formal or explicit manner. They are aware that they are dealing with things that happen, such as business transactions, but they don’t think of them as “event notifications,” “business events,” or “complex events.”

Note: Typical Interaction Patterns Used in Business Intelligence Systems

- Analyst-driven BI is usually request-driven, but occasionally time-driven.
- BAM, the near-real-time aspect of process-driven BI, relies heavily on event-driven CEP for data collection and the initial notification, and then supports request-driven inquiries for subsequent drilldown.
- Performance management and other strategy-driven BI uses time-driven, periodic reports as its primary mode of interaction.

BAM is the only type of BI that makes heavy use of message-oriented middleware (MOM), low-latency event-stream processing (ESP) engines, real-time, in-memory DBMSs, and other trappings of event-driven CEP. Other kinds of BI are more likely to leverage traditional BI analytical tools and DBMS technology that can support very large databases and OLAP data models. Those technologies provide rich analytical capabilities for ad hoc inquiries into historical event data and other data.

Companies that invest in formal, systematic BI programs generally try to standardize BI data models, metrics, and tools across a broad swath of their business units and management levels. However, BAM initiatives are generally outside the scope of such programs. Most BAM implementations are “stovepiped”—they are associated with a single functional area, process, or application system. The most common way of acquiring BAM capabilities is to buy a packaged application that includes a dashboard as an accessory. The second most common way of acquiring BAM is to implement a dashboard or other monitoring capability as part of a custom application development project.

Piecemeal, stovepiped BAM can be quite valuable because it provides timely visibility into the key metrics that matter to a particular task. However, it falls short of providing the comprehensive situation awareness that is helpful for certain decisions. Even today, some business people use two or three different BAM systems as part of their job. As the number of stovepiped BAM systems grows within a company, the company naturally acquires MOM, CEP suites, visualization tools, analytical tools, and, most importantly, experience in implementing BAM. This provides the foundation for more-improved, holistic BAM systems. Over time, we expect that BAM stovepipes will become somewhat more integrated. It will be more common to see a single BAM dashboard (or “cockpit”) provide monitoring that spans multiple application systems and business units.
This doesn’t mean that one dashboard will satisfy the needs of everyone in a company. BAM dashboards must implement very different views of the situation for each business role. The view of a supply chain will look different on a BAM dashboard on the loading dock than it does on the sales manager’s BAM dashboard or the fleet manager’s BAM dashboard. And the performance management dashboards for mid- and upper-level managers will inherently differ from the BAM dashboards used by lower-level managers and individual contributors.

BI professionals and BAM developers will need to collaborate more often in the future. Businesspeople are pressing BI teams to provide more-current data, and they’re also pressuring BAM developers to use more historical data to put real-time event data into context. Most of the underlying business-event objects and other data are the same for conventional BI and BAM systems. Both kinds of systems ultimately draw from the notifications that are generated in transactional applications. Architects and data administrators will be able to improve both types of applications by developing their understanding of the flow of transactional and observational notification data between applications. Conventional BI and BAM won’t merge, because the kinds of decisions and the end-user interaction patterns are inherently different. However, they will need to exchange data more often and cooperate more closely on defining data semantics.

Continuous Intelligence
Compared to Periodic Intelligence

Much of the growing interest in event processing derives from its ability to support near-real time continuous intelligence. As the pace of business accelerates, continuous intelligence becomes ever more important to a company’s success. Companies that continue to rely exclusively on traditional, less-timely, periodic intelligence systems are at an increasing disadvantage. In this section, we’ll summarize the structure of periodic intelligence systems and then contrast the structure of event-driven, continuous intelligence systems.

Periodic Intelligence

Transactional applications carry out the fundamental business functions in a company (see lower level of Figure 4). Some transactional applications run the customer contact center, while others conduct order-entry, manufacturing, shipping, billing, and other functions.

Virtually all application systems produce operational-level management reports (see middle layer in Figure 5) to summarize what’s happened at the transaction layer. These reports provide slow-motion, periodic situation awareness, based on past events. Data on events that occur in transactional application systems are put into databases to be used later to generate batch reports or to provide the base material for ad hoc queries and analysis. Managers and analysts get scheduled reports on sales, accounting, inventory, financial controls, manufacturing, transaction volumes, service levels, and other metrics. The reports lag the actual business work by a few hours or days.
because they are typically produced at the end of the day or once per week. Conventional operational performance management reports give a fairly narrow view of business operations because they reflect the activity only within one application system or a set of related systems in a functional domain. In many cases, they fail to draw attention to exception conditions that may require management attention.

A broader and deeper view is available through tactical and strategic performance management and other business intelligence (BI) programs (see upper layer in Figure 4). BI systems pull together data from many applications and multiple business units. BI data is typically stored in data warehouses and data marts, and made available to analysts and managers for a wide range of performance management activities. However, since the reports are time-driven or request-driven, the decisions are aimed at medium- or long-term issues rather than immediate decisions.

**Continuous Intelligence Systems**

CEP-based systems play approximately the same role as conventional management and analytics applications, with one big difference. CEP-based systems provide continuous intelligence because they’re event-driven rather than time- or request-driven. A continuous intelligence system is an event-driven system that supports automated or partially automated decision making and runs in an uninterrupted manner (see Fig-
An event-driven system sends alerts when things occur, not according to a predetermined schedule or upon receiving an ad hoc inquiry from a person.

Continuous intelligence systems report various kinds of complex events, including exception events and key performance indicators (KPIs). Situations of interest are reported in seconds or minutes instead of hours or days. Continuous intelligence systems implement a management-by-exception approach to avoid overloading managers with superfluous details of routine transactions. These systems operate fast enough to allow an operations manager to intervene in a transaction while it is still in flight, rather than waiting until after it has completed. In some cases, a continuous intelligence system is used to trigger an automated response rather than merely alerting a person. As with conventional, periodic intelligence systems, continuous intelligence systems often support interactive analytics. For example, a manager or analyst can experiment with “what if” kinds of analytical operations on the data.

Event-driven, continuous intelligence systems complement and usually do not replace traditional periodic intelligence systems. Companies should continue to rely on periodic management and analytical BI systems for many process management and corporate performance management purposes. Continuous intelligence is still in the early stages of adoption. Most companies practice it in a few areas, but its fast growth is just beginning.

Figure 5: Continuous-intelligence systems are event driven.
Incorporate Event Processing into IT Architecture

Some leading-edge corporate IT architecture programs are beginning to pay attention to event processing, although IT architecture historically did little or nothing to explicitly address EDA or CEP.

Companies that have formal enterprise architecture guidelines that prescribe design patterns should document their guidance on when to use event-driven, request-driven, and time-driven patterns. Some companies separate enterprise architecture from application architecture. Enterprise architecture is strategic and general in scope—it answers questions such as, “How should all of our systems work?” Application architecture (sometimes called solution architecture) is more tactical and specific—it answers questions such as “How should this system or set of systems work?” Both types of architecture should allow all three design patterns and provide advice on where to use each.

Companies that have a review process that verifies application system design as part of the development cycle should examine the conceptual design of every new system to confirm that EDA and CEP have been utilized where appropriate. The architecture review committee should expect that almost every large application system has some EDA components. Most large systems should also have some continuous monitoring capabilities. These will leverage observational notifications and do some type of CEP, although commercial CEP platforms will appear in a minority of projects during the next several years.

The Role of Event Processing in Business Applications

The material presented up to this point emphasizes the role of event processing, EDA, and CEP in business process management and business intelligence with a specific emphasis on the role of continuous intelligence as opposed to periodic intelligence. Next, we describe the central role of event processing in business applications. Event processing software will become increasingly critical in dealing with issues that impact all aspects of life: quality of food and water, safety of pharmaceutical drugs, healthcare, homeland security and national defense, energy, natural resources, finance, entertainment, and mitigating natural disasters. We discuss only a few of these applications here because of limited space. The key point is that there is no single business vertical that is the exclusive sweet spot for event processing. Finance and defense were early adopters of event processing technologies, and leading companies in other verticals exploited event processing for competitive advantage.

The best way to incorporate event processing into business applications is to ensure that IT architecture is informed by event processing. An architectural framework helps ensure that multiple applications in the enterprise have the same structure. Next, we discuss how to incorporate event processing into architecture.

We outline the role of event processing in a few applications. Countries around the world are deploying smart grids as they reduce their carbon emissions by using renewable resources such as wind and solar energy. Managing events is an essential aspect of the smart grid. We describe the role of event processing in track-and-trace applications; these applications are central to systems that ensure the quality of food
and drugs, and that ensure that worldwide logistics works efficiently. The 21st Century workforce is undergoing massive shifts; for example, almost 50% of electric utility engineers will be eligible for retirement benefits in the next decade. At the same time the skill sets required for utilities are changing rapidly as utilities demand integration of IT with more traditional electricity, gas, and water management. We discuss the key opportunities that event processing offers in restructuring the 21st Century workforce. Next we discuss Finance: the vertical that drove the development of event processing in general and CEP in particular. The important role of CEP in the telecommunications and airline industry is discussed in the final paragraphs.

The Smart Grid

Let’s look at the smart grid in more detail to understand the tradeoffs in the cost of developing and configuring systems to meet each user’s specific needs. An important aspect of the smart electric grid is demand-response—a mechanism by which businesses and residents adapt demand to the availability of power in general and renewable power in particular. Let’s look at two (of the many) options that utilities can offer consumers:

1. The Simple Option consumers select from a small number of options each year offered by the utility. For instance, consumers get rebates if they allow the utility to turn off some their appliances, such as air conditioners, for a few hours a year. Consumers who sign up for rebates may override control by utilities—for example, they may override the utility’s signal to turn off an air conditioner on a hot day; but, in this case, consumers are charged penalties and rebates no longer apply. Alternatively, consumers may elect to pay a higher price and not give the utility any control over the consumer’s consumption of power.

2. The Sophisticated Option home owners and businesses buy and sell power to utilities, from instant to instant, depending on the price of power, the rate-payer’s needs for power, and the rate-payer’s ability to supply power. Home owners and businesses may generate power using distributed energy resources such as solar and wind or by drawing power from batteries in plug-in hybrid electric vehicles or other devices. With this option utilities or Independent Systems Operators (ISOs) will manage real-time markets for millions of small customers many of whom will be both producers and consumers of power.

The effort required to enable users to customize the system to meet their requirements in the first option is minimal: customers merely check off a box on a form received by surface mail. Even for this simple situation customers need to be educated about the penalties incurred by overriding control commands from the utility after customers sign up for rebates. The second option exploits smart technology more fully: it uses prices to obtain dynamic adjustment of supply and demand. The investment required in configuration technology, user interfaces, economics, psychology, and training of consumers is, however, much greater in the second option than in the first.
Track and Trace: Transport and Logistics

Most shipping, trucking, railroad, and other logistics companies use track-and-trace applications that allow the company and its customers to track the location of an item and trace its path from shipment to destination. Concerns about mad cow disease and bioterror attacks are leading toward a national farm identification system that tracks every farm animal with an identifier and possibly a tag or microchip from birth to death.

Contaminations of milk products with melamine, peanut butter with salmonella, and spinach with E. coli have highlighted the importance of ensuring safety in food supply. Tracking food sources, both animal and vegetable, helps identify problems early and minimize risk.

Electronic pedigree systems record major events—location of manufacture, shipment, prior sales, and trades—that occurred over the lifetime of items such as pharmaceutical products. All these applications track events in the items’ histories—whether they are packages, cows, tomatoes, medicines, or data. Some applications send alerts when histories deviate from norms: for example, when a food shipment that should have been kept at temperatures below a specified threshold is exposed to higher temperatures for an extended period, or when a package that should have arrived at a trans-shipment station by a specified time doesn’t arrive.

Expectations of track-and-trace applications and components are closer to expectations of EDA systems than to those of systems based on request-driven or time-driven interactions. We want to initiate the process of detecting a salmonella outbreak or tracing a lost package as soon as possible—not on a once-a-month or even a once-a-day basis. And we expect these components to be continuously active carrying out tasks; we don’t expect them to remain passive, waiting for requests.

Most track-and-trace problems have features common to all EDA applications. The consequences of poor track-and-trace systems are severe; in the food industry the consequences include deaths and loss of confidence in basic staples such as milk and bread. An analysis of cost-benefit measures shows that CEP is an appropriate technology for many applications dealing with track and trace. The detection of a salmonella or E. coli outbreak, for instance, requires analysis of time-varying data from multiple sources in different organizations. Pinpointing the outbreak to a specific peanut factory or spinach plant requires a great deal of analysis. A study of the cost/benefit measures suggests that public health agencies, fast-food chains, agribusinesses, package-handling companies, and indeed all enterprises that need to track and trace items benefit from EDA. The trends tell us that event processing will be even more widely applied in the future for track-and-trace applications. A look at e-pedigree systems for tracking pharmaceutical products shows that event processing will be adopted more widely in the future.

The U.S. Food and Drug Administration (FDA), in its compliance guide (Vol. 71, Number 220, November 15, 2006), says: “A drug pedigree is a statement of origin that identifies each prior sale, purchase, or trade of a drug, including the dates of those transactions and the names and addresses of all parties to them. Under the pedigree requirement, each person who is engaged in the wholesale distribution of a prescrip-
tion drug in interstate commerce, who is not the manufacturer or an authorized distributor of record for that drug, must provide a pedigree for that drug to the person who receives the drug.” Electronic pedigrees (e-pedigrees) help combat counterfeit drugs and diversion. Wholesalers will require e-pedigrees to acquire or sell prescription drugs. California and other states have passed legislation requiring electronic records of pharmaceutical drugs for their entire life cycle; these laws are planned to take effect at different times in different states. Let’s analyze where track-and-trace is headed in the pharmaceutical industry from the vantage point of the EDA trends.

Trends in prices of radio frequency ID (RFID) and bar-code technology, when compared to costs and errors of manual tracking, favor automation and event processing. The performance of business intelligence systems at ever-decreasing costs will allow many points along the supply chain to track the provenance of drugs. Increasing complexity of regulations in different countries, the global supply chain for pharmaceutical drugs, and the need for rapid detection of counterfeits, point to increasing use of event processing. All the trends—price, performance, pervasiveness, celerity, connectedness, complexity—in the context of greater enterprise agility and situational awareness tell us that information technology in general, and event processing in particular, will play a greater role in the pharmaceutical supply chain.

Workforce of the 21st Century

The trends of price, performance, pervasiveness, celerity, complexity, and connectedness tell us that the workforce of this century will be supported by increasing amounts of information technology in general and event processing technologies in particular. The devices that the workforce manages and maintains are getting increasingly complex. The smart electric grid, healthcare instrumentation, airplanes, cars, water treatment and distribution, and finance will become more complex in the decades ahead. Workers in the field are increasingly connected by communication devices, such as mobile phones, with experts elsewhere; for example, an electric utility worker dealing with an overheated transformer in the field can get advice from experts at headquarters. Celerity is vitally important in managing critical infrastructure such as power and water distribution. Likewise, trends in price, pervasiveness, and power of information technology drive greater use of EDA for the workforce.

The workforce manages tasks on a time-driven schedule as well as an event-driven basis. A tree falling on a high-tension line is an event; this event is detected by the utility, which responds by assigning work crews to the problem. GPS and communication connectivity with workers in the field enable enterprises to have situation awareness about its workforce—it knows which crews are where and how long they’ve been in operation. The enterprise can determine the tools and workforce crews needed to handle a situation at a given location based on crew experience, resources available nearby, and work regulations. Scheduling and managing crews for airlines and railroads requires global situation awareness and dynamic management of the workforce to deal with unscheduled events.

An electric utility worker dealing with an overheated transformer on a pole several meters off the ground needs both hands and total concentration to deal with the
problem. The framework tells us that EDA will support the worker doing the task; for instance, the worker will get just-in-time information about the transformer from RFID tags, detailed information about the device—its type, the time that it was installed, its repair history—will be flashed to goggles worn by the crew, and if necessary expert advice will be transmitted from the utility home office or from the transformer manufacturer. The detection and diagnosis of the specific problem, and the delivery of just-in-time information, are implemented by EDA systems.

**Finance**

Finance is one of the “sweet spots” for applications of event processing technologies. More has been written about applications of EDA in finance and defense than in most of the other business domains. There are many areas of finance where the use of event processing technologies provides a competitive advantage; some of them require millisecond responses and some require complex analyses in seconds or minutes. Many applications in finance have the features that favor event processing. Financial applications must be agile to deal with rapidly changing global conditions:

- they must detect and respond to exceptional conditions,
- they are required to respond instantly,
- they instrument, monitor, and record a great deal of data to build accurate models,
- they monitor activities outside the enterprise, and
- they must respond to unanticipated situations.

Our expectations of many financial applications match our expectations of EDA applications: for instance, users expect financial applications to monitor markets and respond when conditions indicate significant opportunities or threats. Analyses of cost/benefit measures show significant benefits from using event processing applications in finance, particularly in trading capital markets, but also in credit card processing, retail banking, and customer-relationship management applications such as cross-selling and up-selling. Many interactions in finance are not required to be transactional; in these applications businesses make more profit by keeping up with current conditions even if they drop a few events. EDA and CEP are used in many aspects of trading, including cross-trading, reducing errors such as fat-finger trades, algorithmic trading, order routing, market surveillance, and fraud detection.

**Telecommunications**

The telecommunication industry is exploiting event processing in multiple sectors including network operations, provisioning, security management, billing, and location-based services.
Communication service providers (CSPs) have always used events to help manage their networks. What’s changing is the growing size and complexity of networks, and the exploitation of systematic frameworks for the application of EDA and CEP for additional purposes. Modern CSPs offer an expanding set of features spanning voice, data, SMS, music, and video communication. CEP applications detect network-wide problems by rapidly analyzing streams of multiple local measurements. Networks have enormous rates of traffic and large numbers of components; therefore brute-force approaches, in which all events are logged at a central point, are intractable. Event-driven architectures for operations management are organized so as to aggregate simple events into more complex events on a distributed basis. Customer contracts are increasingly detailed, requiring CSPs to monitor uptime, minimum bandwidth availability, burst bandwidth availability, prioritization of content, and other parameters in real time. Events are used to track service levels and assist in deploying new network elements.

The task of provisioning telecommunication services is increasingly time-sensitive and dynamic. Retail customers expect to have new services activated almost immediately after ordering them, but the complexity of managing the provisioning process has expanded as the choice of services and applications has grown. CSPs use event processing to monitor the timeliness and accuracy of provisioning. Delays or patterns of mistakes in provisioning can be detected quickly, allowing the CSP to correct the problem before customer satisfaction is significantly disrupted. Customer relationship management (CRM) programs in telecommunications must be event-driven to ensure that customers receive the service and applications that are personalized for each of them. Better service helps reduce customer churn.

Event processing plays a critical role in maintaining network security. CEP is used to detect patterns that indicate denial-of-service attacks or various forms of fraud such as poaching and spoofing userID s, and theft of service from the CSP. CSPs must respond to security problems immediately, driving the need for continuous event processing.

The emergence of new services has also led to increasingly complicated billing procedures and the need for closer tracking of network content. CSPs must identify the content of messages to be able to correctly apportion charges to each subscriber. Understanding the content is also required to compensate content providers (CSP-provided mediation). For prepaid services, billing must be done immediately so that customers do not over-run their limits. Real-time charging is also emerging as a requirement for other kinds of new services.

In summary, applications in telecommunications have all the features that drive event processing in general and CEP in particular. Telecommunication events occur at very high rates, and the costs of slow responses to events, such as faults, are huge. Celerity—rapid response—is essential. As we look to the future, we see that the trends—lower price, greater pervasiveness, increasing device performance, demand for greater celerity, more complex applications, and greater interconnectedness of devices—will make event processing even more important in many aspects of the telecommunication industry.
**Location-Based Services**

Event processing is essential for implementing context-aware location-based services. For example, E-911 emergency services are becoming available to cell phone users. These are made possible by CEP systems that execute geo-coded triangulation algorithms that quickly determine where the user is located. Companies are also developing advertising services that make real-time offers that are custom-tailored to each user’s location.

**Airlines**

Some business applications are triggered by complex events or use complex events to alter their behavior. The work to acquire notifications and implement the CEP software is a relatively small, although vital, part of the project. These applications are the opposite of pure-play monitoring systems, where most of the effort goes into detecting the situations and the response is a minor aspect of the project.

Some CEP-enabled applications are all-new, but many are developed as extensions or modifications to existing business applications. For example, the sophisticated “enterprise nervous systems” used in modern airline operations are event-enabled systems of systems that encompass many CEP-enabled applications. The essential business operations of major air carriers have been largely automated for 40 years. Transaction workloads that incorporate the central seat reservation systems can exceed 30,000 transactions per second. Other airline applications manage flight schedules, food catering services, flight crew schedules, fueling, aircraft maintenance, gate assignments, and report arrival and departure times (see the right side of Figure 6). These are separate applications, developed largely independently at different times and owned by different business units.

The ability of an airline to respond to change has always depended on the speed and effectiveness of the information transfer between the sources of data and the many business units and applications that depend on it. Airlines continuously track hundreds of flights, each at a different stage in its life cycle. Information about the location of each plane and status of each flight becomes outdated in seconds or minutes.

The observational notifications that drive an airline nervous system originate in hundreds of locations (see the left side of Figure 6). Event sources include telemetry devices on the planes, reports from the Federal Aviation Administration, application systems on the ground, and gate agents and other people. Notifications are sent through a variety of communication technologies to a virtual clearinghouse which maintains flight status information in operational databases. The clearinghouse publishes notifications and accepts inquiries from application systems and people to keep them informed of changing conditions for every flight worldwide.

An airline enterprise nervous system is all about situation awareness. Each business unit dynamically alters its plans when informed of schedule changes, weather, equipment failure, or other events. Planes and gates are reassigned as conditions change. If flights have become bunched together, there may not be enough available gates to serve all planes immediately. By having current information and predictions about
likely future conditions, gate scheduling systems can make better decisions. Airlines pay penalties for flights that arrive after a night-time curfew, so flights that need an early departure are given priority over those that can afford to wait. The enterprise nervous system improves plane turnaround time because fuel, mechanics, food, crews, and baggage handlers are ready at the right moment. Fewer planes, gates, and employees can support the same number of flights. Passengers also have better access to information about the status of flights, and earlier warning of changes.

Airline networks are among the largest and most-complicated event-enabled systems. They combine the challenges of application integration with the challenges of high event volumes in the context of a highly competitive, cost-conscious industry. The underlying applications use a diverse set of operating systems, application servers, transaction-processing monitors, DBMSs, and network protocols. Many of the applications have been in place for years and are constantly being updated. Some applications were modified to accept notifications directly from the virtual clearinghouse. In other places, alerts are sent to people who intervene manually but use the underlying application systems to carry out the business functions. Most aspects of the airline nervous system don’t use CEP software yet. They use simple events or minor sections of CEP logic coded directly into business applications. However, commercial CEP software is used for some parts of the system, and its use is growing as architects identify additional areas where it is helpful.

**Figure 6:** Events and complex events inform business applications.
Enterprises must respond ever more quickly to unpredictable events and new threats and opportunities in their environment. Event processing has emerged as the key enabler for situation awareness and a set of guiding principles for systems that can adapt quickly to shifts in customer demand and market conditions. Written by experts in the field, this book explains how to use event processing in the design of business processes and the systems that support them.

This special edition is a subset of a longer book of the same title published by The McGraw-Hill Companies (ISBN 978-0-07-163350-5). It describes the relationship of event processing to other IT initiatives, including business process management (BPM) and business intelligence (BI). It also explores the kinds of business problems that event processing can address, and gives examples of real-world applications. Event processing is one of the most interesting aspects of modern technology. It will bring fundamental—and favorable—shifts in the nature of business and the practice of IT.