JOURNAL OF EMERGING TECHNOLOGIES IN ACCOUNTING
Vol. 1
2004
pp. 1–21

Principles of Analytic Monitoring for Continuous Assurance

Miklos A. Vasarhelyi
Michael G. Alles
Alexander Kogan
Rutgers, The State University of New Jersey

ABSTRACT: The advent of new enabling technologies and the surge in corporate scandals has combined to increase the supply, the demand, and the development of enabling technologies for a new system of continuous assurance and measurement. This paper positions continuous assurance (CA) as a methodology for the analytic monitoring of corporate business processes, taking advantage of the automation and integration of business processes brought about by information technologies. Continuous analytic monitoring-based assurance will change the objectives, timing, processes, tools, and outcomes of the assurance process.

The objectives of assurance will expand to encompass a wide set of qualitative and quantitative management reports. The nature of this assurance will be closer to supervisory activities and will involve intensive interchange with more of the firm's stakeholders than just its shareholders. The timing of the audit process will be very close to the event, automated, and will conform to the natural life cycle of the underlying business processes. The processes of assurance will change dramatically to being meta-supervisory in nature, intrusive with the potential of process interruption, and focusing on very different forms of evidential matter than the traditional audit. The tools of the audit will expand considerably with the emergence of major forms of new auditing methods relying heavily on an integrated set of automated information technology (IT) and analytical tools. These will include automatic confirmations (confirmatory extranets), control tags (transparent tagging) tools, continuity equations, and time-series cross-sectional analytics. Finally, the outcomes of the continuous assurance process will entail an expanded set of assurances, evergreen opinions, some future assurances, some improvement on control processes (through incorporating CA tests), and some improved data integrity.

A continuous audit is a methodology that enables independent auditors to provide written assurance on a subject matter, for which an entity's management is responsible, using a series of auditors' reports issued virtually simultaneously with, or a short period of time after, the occurrence of events underlying the subject matter.

—CICA/AICPA Research Study on Continuous Auditing (1999)

Companies must disclose certain information on a current basis.

—Corporate and Auditing Accountability, Responsibility, and Transparency (Sarbanes-Oxley) Act (2002)

Please address comments to Miklos Vasarhelyi at miklosv@andromeda.rutgers.edu.

The Guest Editor for this article was Professor Dan O'Leary of the University of Southern California.

Corresponding author: Miklos Vasarhelyi
Email: miklosv@andromeda.rutgers.edu

INTRODUCTION

With the post-Enron support of *continuous assurance* (CA) by the SEC, the AICPA, and Congress, interest in CA has finally reached critical mass. Several years of academic research and conferences culminated in the simultaneous establishment of centers for continuous audit research in the United States and the European Union in September 2002. Three papers in a special issue on CA in the March 2002 volume of *Auditing: a Journal of Practice & Theory* (Alles et al. 2002; Elliott 2001; Rezaee et al. 2002), focused on clarifying the distinction between CA and current audit practices and describing the potential for new assurance products. With CA having been firmly established as the future of auditing, it is now time to shift the focus of the discussion from the potential and promise of CA to a systematic examination of the emerging CA-enabled audit environment.

Vasarhelyi and Halper (1991) predicted that "[Continuous Process Auditing] will change the nature of evidence, timing, procedures, and effort involved in audit work." This paper will first examine the reasons for continuous assurance and then delineate the changes in the nature of assurance encompassing its: (1) objectives, (2) levels and hierarchy, (3) timing, (4) process, (5) tools, and (6) outcomes. The object of this paper is to analyze these changes and the resulting new continuous assurance-enabled audit environment.

This new continuous analytic monitoring-based assurance environment is an outcome of a fundamental transformation in business operations and control: the electronization of the firm through the continued used of legacy systems and the progressive widespread use of Enterprise Resource Planning (ERP) systems. The unique and unprecedented characteristic of ERP is that it seamlessly integrates and automates business processes to achieve real-time information flows. Since CA is progressively being built upon the firm's underlying ERP system, CA inherits these characteristics. However, CA only achieves its full power when it takes full advantage of this ability to automate business processes and integrate information flows. On the other hand, analytic monitoring allows for the increased understanding and monitoring of the integrated and nonintegrated portions of the IT environment. We argue in this paper that the full scope of the capability that automation and integration provides CA has not been fully appreciated and utilized, and show how it provides auditors with an unprecedented toolset that transforms auditing into continuous analytic monitoring of business processes.

While continuous assurance is clearly still an emerging field, the broad forces that will shape its evolution and the nature of the assurance that it will provide are now coming into focus. By identifying the underlying principles of the analytic processes of continuous assurance, and the automation and integration of business processes that give CA its power, our objective in this paper is to provide researchers and practitioners with a clearer roadmap as to how CA is to be implemented, what its capabilities are, and how they are brought about.

We first turn to an examination of the supply and demand for CA services, showing that both have now reached critical mass, driving the recent endorsement of CA by the SEC and the AICPA. Then, in the ensuing sections, we examine the changes in the objectives, timing, processes, tools, and outcomes of the continuous assurance process. The last section provides some concluding remarks.

SUPPLY AND DEMAND FOR CONTINUOUS ASSURANCE

Alles et al. (2002) examined the role of demand in the emergence of CA, and suggested that the major constraint on its adoption was from the demand side, not the supply of the necessary technology. The recent corporate scandals and the passage of the Sarbanes-Oxley Act have only enhanced the demand side effects on CA, removing some of the doubts about its widespread adoption. Elliot (2002), Vasarhelyi (2002), and others have discussed the enabling technologies of CA, such as the use of embedded audit modules (Groomer and Murthy 1989). The new CA-enabled audit environment will emerge from the intersection of these changes in demand, supply, and technology.

The relative speed of expansion or change of each of the three co-determinants affects the feasible set of deployment. Examining these forces in detail, we take the demand-side first. The basic reasons for the need of assurance have only been exacerbated in the new economy, with organizations that are more complex, with more rapid and integrated business processes, and a wider set of legislation and regulations. Many types of management and control information needs exist apart from those served by the traditional financial statement audit, and in the real-time economy these needs can only be satisfied by continuous assurance. In particular, the current series of crises as well as the increasing reliance on technologically enabled business processes suggest new needs for assurance concerning (1) changes in the environment and industry, (2) the existence and effectiveness of controls, (3) increased human resource risks, (4) increased use of outsourced processes, (5) process continuity and integrity, and (6) coherence between endogenous and exogenous factors:

Environment and industry: Over the years, defaults epidemics had plagued particular industries, usually caused by basic economic changes in their environment and by the lack of ability of their management to cope with these changes. This phenomenon has happened in the savings and loans industry and more recently in the telecom industry. After the ensuing wave of defaults and bankruptcies, an intensive set of legal procedures and accusations of improprieties followed. These dramatic changes in the environment are often preceded or occur simultaneously with an increase in the number of mentions in the press and other forms of exogenous indicators. Vasarhelyi and Peng (1999) developed a methodology of semantic parsing and analysis that can serve as an early-warning system for auditors that major environmental changes are occurring with particular clients and more intensive scrutiny is required.

Controls: A key paradigm change in modern business systems concerns the nature of controls. While traditional systems have over the years relied extensively on controls (Vasarhelyi 1980), the intrinsic nature of controls is rapidly changing with automation and the prevalence of IT-based systems often based on ERP systems. Controls in modern systems are typically computer based and entail complex sets of analytics. This requires assurance concerning the existence of controls: that these controls are operational, that their warnings are properly observed and distributed, and that the controls are comprehensive, covering all relevant aspects of operational risk.

Human resources: Major corporate personnel changes serve as a red flag for potential problems and system instability. Templates can be used to look for fraudulent patterns and HR databases can be scrutinized for unorthodox changes. Patterns in personnel changes can indicate problem areas and increased risks.

Outsourcing: The increased outsourcing of business processes is creating virtual parts of businesses that do not naturally flow through the corporation's value chain. New methodologies such as along and across the value-chain analytic monitoring, as well as transaction control tag monitoring, must be used to preserve and evaluate process integrity.

Process integrity: Traditional audit technology has not been able to provide logical links among the pieces of business to define its logical functioning. Intrinsic relationships exist between the parts of business that can be analytically examined, relationally modeled, to give assurance of macro-process integrity.[1]

Internal and external process coherence (integrity): Most organizations operating in a particular industry tend to have a coherent set of operating statistics with operating ratios falling within a predictable range. This allows auditors to define outliers that require examination. The real-time economy now offers a much larger set of dynamic reference points, measurements, and standards. These are obtained through relentless measurement, exponential increase in sensors, intensive collection of statistics, and the progressive adoption of mutually accepted methods of measurements and standards.

---

[1] See the "Continuity Equations" section later in the paper.

Turning now to the supply side, the effects and technologies evolving in the real-time economy give rise to the need of an independently provided monitoring and control (MC) platform that supports management monitoring and control processes.

A major facilitator for CA is the implementation of an MC layer, which unites various IT systems in a firm into one integrated platform that allows for seamless real-time information exchange. ERP systems allow for an unprecedented level of automation and integration and substantially facilitate the existence of the MC layer. For organizations where all systems are encompassed in an ERP system, the monitoring and control layer would be part of this system. A user of the layer, for example, an auditor, is able to drill down all the way to the individual transaction level and then roll up the data for analysis at any level of aggregation. It is this capability that CA systems can draw upon to enable real-time confirmation and matching and to do new data-intensive forms of analytic procedures.

While the electronization of business processes (Vasarhelyi and Greenstein 2003) has been actively pursued for several decades, and the implementation of modern ERP systems for over a decade, auditing has been slow to adapt to these environmental changes. First, the electronization of business processes was simply ignored, and this approach was termed "auditing around the computer." Whatever information was needed was extracted on paper. Subsequently, the auditors started utilizing the new information technology and termed this new approach "auditing through the computer." However, this utilization, at the very best, automates standard audit processes and procedures, by utilizing computer productivity tools (e.g., MS Office), and computer-assisted audit techniques (CAAT) that are basically data analysis software (e.g., ACL or IDEA). This approach is limited because, on the one hand, it does not take advantage of the new technological possibility to automate and integrate various audit processes and procedures and, on the other hand, it does not provide sufficient response to the new challenges of auditing a modern digitized corporation.

Consequently, there is a direct analogy between the automation and integration of business processes and the deployment of ERP systems on the one hand, and the automation and integration of audit processes and the deployment of continuous auditing systems on the other hand. The relationship between ERP and CA extends to lessons on their implementation. ERP has been dogged by the cost and complexity of its implementation, which is a reflection of the fact that it is much more than a technology. Integration of information flows can only proceed when the underlying business processes are also automated and integrated and have achieved a consistency in purpose and operational practices. As Hammer (1990) predicted, the full benefit of technology only comes about when it is used to completely rethink processes, rather than simply being used to do mechanically what was previously done manually. But ERP goes one step further by forcing businesses to adapt their processes to the needs of the ERP system, rather than following a "clean sheet" approach where business processes are first reengineered and then the enabling technology is obtained. It turned out to be simply too costly to develop fully customized ERP systems for different firms and so ERP essentially became "one size fits most."

It is likely that similar issues will arise with CA systems, both with regard to the need for customization, and more importantly, about how it will force auditors to analyze and reengineer their audit processes. This has profound implications for the way in which auditing is carried out and the scope of the impact that CA will have on audit practice. CA will first be used to reduce the cost of current audit procedures or to assure processes that cannot easily be assured by traditional methods. But the ERP analogy suggests that it will take time before the investment in the implementation of CA will start paying off. Moreover, once CA reaches a critical mass, the technology will itself begin to drive audit methodologies, leading to a true reengineering of audit processes. This will have a transformational effect, especially given that much audit practice remains rather idiosyncratic, and has not been subject to formalization and process analysis, let alone reengineering, thus far.

OBJECTIVES OF CONTINUOUS ASSURANCE AND ANALYTIC MONITORING

The basic objective of the traditional audit focuses on providing assurance on the accuracy of the financial statement. Trade-offs between the benefits of this assurance, and the then current information technology led to the development of a materiality threshold of acceptable error. The modern audit, with great improvements in information technology, has changed these trade-offs in the direction of a much finer and timely assurance effort. Eventually, with the increased granularity of data distribution, through the distribution of tagged XML elements, data-level assurance will become necessary. The continuous audit will aim at providing prompter, and more accurate assurance on more granular data for a much wider set of financial and nonfinancial variables.

Levels of Assurance and Audit Objectives

The *audit objectives*—the specific assertions whose verification is the intent of the audit tasks—vary in a continuum, from well-defined issues such as transaction verification, to tasks that are of much higher order of complexity, relying extensively on human judgment, such as the estimation of contingent liabilities. Tasks that are routine and mechanical in nature can be readily transferred from a manual to a CA system and done more comprehensively and cost effectively, taking advantage of the automation and integration of the firm's ERP systems. The question is whether the effectiveness of CA declines monotonically from one end of the audit objective continuum to the other. If that is indeed the case, then the impact of CA on auditing and its ability to create a new audit environment is lessened, as it essentially does not do much more than automate existing audit methods. CA still adds a great deal of value by freeing auditors from mechanical tasks that are better handled by automated systems, thereby giving them more time to focus on matters that require pure human judgment. However, that is still a second- rather than first-order effect on the audit process.

To examine this matter, we propose to distinguish between four levels on the audit objective continuum and examine the role of CA on each one. These four levels of continuous auditing are hard to define in mutually exclusive or exhaustive ways, but they do serve to illustrate the necessary functional dependence of CA on the audit objective. Our four levels of analysis are:

Level 1: Verifying atomic elements of transactions (e.g., movement of money, information, at the data level).

Level 2: Assuring the appropriateness of the measurement rules used in transaction processing (i.e., GAAP).

Level 3: Verifying the adequacy of estimates and their assumptions, as well as the consistency of high-level measurements.

Level 4: Auditing and questioning high-level judgments and facts about the organization.

Exhibit 1 displays in a summary form the four levels of continuous audit, their objectives, procedures, level of automation, and changing paradigms.

While the automation of the first level seems sufficiently straightforward, the really surprising effect of the CA methodology is in its applicability to the other (higher levels). While the extent of application of CA decreases with the increase in the complexity of the audit objective, we argue that certain audit procedures can still be applied, sometimes formalized, and automated even at the high end of the continuum of audit objectives. The key is to undertake formal process mapping, analysis, and reengineering of audit processes. Analogous to the reengineering preceding ERP, it is likely to be the case that a good proportion of audit tasks currently thought to be matters of pure human judgment can, in fact, be systematized to a far greater extent than is currently imagined. The move toward CA

EXHIBIT 1
Levels and Characteristics of Analytic Monitoring

	Level 1 Transactional Verification	Level 2 Compliance Verification	Level 3 Estimate Verification	Level 4 Judgment Verification
Procedures	Rule/waterfall review of data	Formalization of standard relationship with XML derivative	Upstream/down-stream verification	
	Process interruption	Continuity equations	Continuity equations	Continuity equations
	Value chain transaction tracking	Structural knowledge	Value chain relationships	Expert systems
Degree of automation	High	Mixed	Mixed	Low
New paradigms procs., techns.	Continuous reconciliations	Continuity equations	Continuity equations	Continuity equations
	Invisible tracking/ transparent markers		Extensive use of exogenous data	Use of exogenous data
	Automatic confirmations			
	Rule-based trans. evaluation			
		Time-series/cross-sectional analysis	Time-series/cross-sectional analysis	Time-series/cross-sectional analysis

will require auditors to explicitly state the assumptions underlying their estimates and judgments, which is the first step toward bringing these tasks to within the capability of automated CA systems.

We shall now examine in more detail the characteristics of each of the four prescribed levels.

Level 1: Transaction Evaluation

As transactions flow through corporate systems they will be examined, classified, and aggregated, and records of these tasks will be stored by the system at varying points, locations, and degrees of detail. Different types of analysis can be used for different kinds of transactions depending on the type of data they contain. The traditional differentiation between master and transaction data is being progressively refined into a hierarchy of data and storage types depending on factors such as the nature and frequency of the data usage, the geography of the data flow, the location of the activity, the nature of their security and privacy, and existing best practices captured in ERP systems.

Detecting transaction irregularities will range in methods from traditional transaction edits to rule-based evaluations. Basic entry edits include validation of account numbers, checks against lists of clients, regions, products and departments, plausible validity ranges, time validity ranges, and so forth. The validity of these tests depends on the accuracy of various thresholds and other parameters used. The setting of such parameters will typically be done as configuration of a CA system, which has to be reexamined and updated on a regular basis.

Additional verification procedures have to validate the flow of a transaction to make sure that the sequence of processing corresponds to the process specifications defined in the system. Examples of process-flow verifications include checking if the sale corresponds to an inventory movement, to a bill issued, or to purchase queries received through the website. Real-time process-flow verification becomes possible in CA due to the automation and integration of audit procedures. These verification procedures cannot be done in real time during conventional audits, and very often are not done at all since there is no tight integration of audit processes such as with the audits of accounts receivable and of finished goods inventory.

The continuity and completeness of transactions can be verified in CA using the formal specification of workflow of business processes stored in corporate ERP systems. Automated CA procedures can verify that the transaction has been processed at all the previous steps as required by the process specification. Moreover, structural knowledge of workflow, captured in continuity equations, allows the prediction, to some degree, of transaction flow and whether transactions are missing or have been tampered with. For example, Hume et al. (2000) tapped a very large AT&T biller at many points and succeeded in tracking hundreds of millions of transactions and reconciling their transaction flow. Structural workflow knowledge adds to this reconciliation by allowing flow prediction and loss diagnostics. Note that manual verification of continuity and completeness of a significant number of individual transaction flows presents an insurmountable challenge.

Transaction flow verification within the boundaries of the enterprise, as described above, can be extended beyond these boundaries across the supply chain links if CA is implemented at both ends of a value chain link. This is implemented as a real-time automated confirmation process that creates a certain level of integration between CA systems that are implemented and operated by different assurance providers. Both CA systems will benefit since they can confirm in real time that a receivable booked by Company A matches a payable booked by Company B.

Modern security technology such as encryption and digital signatures can be incorporated in the CA system to prevent or detect transaction tampering. Furthermore, certain types of fraudulent activities have distinct formal patterns and can be detected by matching transactions against fraudulent pattern templates or by using other artificial intelligence techniques such as neural networks (which are currently successfully used for identifying fraudulent credit card transactions).

Level 2: Measurement Rule Assurance (Compliance)

A major task in any audit is to verify that the measurement rules (such as GAAP) are properly applied to the business transactions verified at the first level. Examples of verifying proper rule application include establishing that a certain transaction is properly recorded as revenues, that another transaction is indeed a loan and not a forward contract, or that an expense is properly classified as a capital expense—all examples that have arisen in the current crop of corporate scandals. The problem with automating the verification of such rules in a CA system stems from the fact that while automated rules are strictly formal, the existing rules have a significant amount of imprecision in their formulations. On one hand, if the measurement rules are fuzzy, then they give too much manipulation leeway to the management and cannot be verified. On the other hand, the complexity and variety of modern business transactions make the creation of an exhaustive set of specific measurement rules impractical. The difficulty of finding an appropriate trade-off currently manifests itself in the ongoing extensive debate about principle- versus rule-based accounting standards. Depending on the outcome of this debate, the degree of automation of Level 2 CA procedures will differ.

The automation of CA procedures at this level will utilize a formalization of many measurement rules using knowledge representation methods and the use of automated reasoning techniques. The appropriate technology has been developed in the domain of artificial intelligence and expert systems. Fisher (2003) has demonstrated the feasibility of increased formalization of accounting standards and the benefits of this process. Without going into details of knowledge representation schemes, we can say that a measurement rule is formalized as a special template (whether this template is a sentence in a first-order language, a Horn clause, or a frame is a matter for another discussion). The hierarchical structure of the accounting standards will be reflected in the formalization so that the templates representing more specific rules override the templates representing more general rules.

The Level 2 procedures will use pattern matching and other techniques to verify an application of rules and either will automatically conclude that this application is justified or will identify this case as unresolved and submit it for the consideration by the human auditors. While the latter cases cannot be guaranteed to be assured in real time, the selectivity of the process will make sure that the scarce resource of human judgment is utilized in the most efficient way. Thus, the participation of human auditors in this type of CA processes is effectively an application of "audit by exception."

Level 3: Estimate Assurance and Consistency of Aggregate Measures

Many estimates are utilized in business measurement and reporting for various reasons. Certain accounting numbers have to be estimated because the underlying information technology made their direct measurement either impossible or too expensive. For example, percentage of work completion used to be difficult to measure, and therefore had to be estimated. However, modern ERP systems and cost accounting techniques allow sufficiently precise measurement of the percentage of work completion in many cases. Note that the fuzziness of accounting standards discussed above may have a direct implication on the difficulty of direct measurement of the percentage of work completion.

A more substantial reason for using accounting estimates is due to the impossibility of knowing the future. Clearly not every account receivable will be collected and not every loan will be paid off. It is usually implicitly assumed that only a human expert can estimate, say, a bad debt allowance. However, many such estimates do not have to be based on intuition. Very often, the intuition of human experts can be captured and formalized in a model that utilizes both internal parameters (like past experience with collecting accounts receivable) as well as external parameters (such as market interest rates, unemployment levels, various economic growth indicators, etc.). The ubiquity of Internet connections to external sources of relevant data and the high level of automation and integration of the firm's own ERP systems make such automatic estimates feasible. Formal models providing such estimates can be incorporated into both ERP and CA systems. Even if a company does not generate an estimate automatically, the CA system can still utilize its own formal model of an estimate to assure in real time that the estimate used by the company is acceptable. Of course, creating a formal model of an accounting estimate is not a simple proposition and may add significant costs to the development of a CA system. A cheaper alternative will be if a company utilizes a formal model for automatically deriving an estimate.[2] Then auditor's task will be reduced to verifying the acceptability of this model, which has to be done only once, and can be done offline, on the basis of whether the parameter values used in the model are reasonable. This is a much simpler task and one that can be automated more readily. While not every estimate can be derived in a formal way, even partial implementation of estimate assurance in the CA system will greatly expand the scope of real-time assurance and reduce the workload on human auditors.

The spectrum of procedures applied at this level of CA includes automatic versions of various analytical review procedures, which will be based not only on internal but also external parameters, which the CA system can receive as an online feed. For example, the distribution representing the aging of accounts receivable can be automatically compared with the distribution derived from the experience of other companies in the industry. If there is a significant discrepancy between the two distributions, or the company has significantly changed the parameters of its estimates, then the CA system can generate an alarm to draw the attention of human auditors. The wide use of automatic

[2] An extreme view of this suggestion may entail that GAAP contain a series of "approved" estimate models, placed in a web library, and corporations use these models disclosing the parameters applied.

analytical review procedures in CA will significantly increase not only the efficiency, but also the effectiveness of auditing.

Level 4: Judgment Assurance

Since industrial-age companies used fairly simple information systems and unsophisticated financial instruments, their audit could primarily consist of verifying assertions through simple procedures such as counting cash and inventory, confirming invoices, etc. The audit of post-industrial-age companies run by sophisticated ERP systems and utilizing advanced financial instruments has to incorporate complex, high-level judgments, which are specially important for making the currently required going concern decisions. Such judgments may have to deal, for example, with the relevance of contingencies, the extent of related-party transactions, the boundaries of corporate systems, and the nature of the relationships across the value chain. The CA methodology and modern analytic technology allow for extensive gathering of exogenous evidence that provides crucial input into these judgments. Among the tools that a CA system can utilize for the purpose of automating or semi-automating some of these judgments are automatic searches in litigation databases and searches in the major news sources. The degree of automation of such sophisticated high-level judgments is clearly limited—but not nonexistent—and the likely role of the CA system will be that of a facilitator. Modern data warehousing and data mining tools can be built on top of a transaction-monitoring CA system to visualize critical parameters of the auditee and help the auditors to make their critical judgments. It is reasonable to expect that the analytical monitoring technology described above will be the essential contributor toward significantly improving the quality of high-level judgments, which in turn will result in a significant reduction of the audit risk.

An Example of the Four Levels in the Pension Area

The problems around measurement, reporting, and auditing of pensions are well known and have troubled standard setters, pension managers, and pensioners for decades. For example, auditors can use continuous assurance methodology to provide the following assurance services:

Level 1: Flag and extract all transactions that pass resources between the company and its pension fund, extract all transactions that affect pension-related ledger accounts, and vouch for these transactions.

Level 2: GAAP specifies maximum and minimum contributions to pension plans as well as ways to account for pension obligations, and other pension-related items. This level would create a logical template evaluating compliance with the rules of ERISA and GAAP.

Level 3: On a more analytical level, the continuous assuror can examine the formally disclosed rules relative to pensions that allow for the organization's actuarial estimates. Accounting standards require the disclosure and usage of an interest rate in the assumptions about pension estimates such as interest rate, employee related obligations vis-à-vis age and years of employment, asset returns, but the standards do not require a relationship between the historical returns of the fund and the future return assumptions. The future will bring corporate measurement rules that link endogenous and exogenous data in the measurement of business and its assessment.

Level 4: At the judgment assurance level, the auditor could make assertions about the appropriateness of pension plan funding and the quality of the management of the fund, the quality of the assets held by the fund, or the cost incurred in managing the pension portfolio. Some of these judgments may be relevant for a wider set of assurance and management services that may eventually arise.

TIMING OF CONTINUOUS ASSURANCE

Online/real-time systems provide the opportunity of immediate assurance processes either simultaneously or just after a particular economic event. This form of verification is different from the pure *ex post facto* nature of the traditional audit process. It provides the opportunity of controlling a process simultaneously or just after the event and in certain cases the ability to interfere with the conclusion of the event correcting its nature. These factors are very different from the traditional audit and should be stated objectively and eventually carefully researched.

A continuous audit procedure, that in CA for example implies day-to-day repetition of an audit step (say reconciliation) becomes a type of meta-control and will eventually become part of a corporation's internal controls. The continuous auditor will then assume the role of secondary verifier by checking if the procedure is really being performed.

A continuous audit procedure that points out an erroneous transaction, and an auditor who acts to correct this error, becomes a proactive actor in corporate information processing. New methods must be developed to maintain his/her independence.

The continuous audit is distributed across the year, performed mainly automatically, and will be a form of "audit-by-exception" where the system is considered materially correct (has an evergreen opinion) until an alarm states it otherwise. The conceptualization of the time frame of a "clean opinion," the meaning of an alarm in the impairment of an opinion, and its usage as audit evidence are further issues for research and the development of standards and principles of practice.

Furthermore, corporate processes have a time cycle of their own. There are instantaneous, hourly, daily, and monthly processes. Each will have a different frame of time for the calculation of their analytics and for the determination of the meaning of an audit alarm.

THE NEW PROCESSES OF CONTINUOUS ASSURANCE

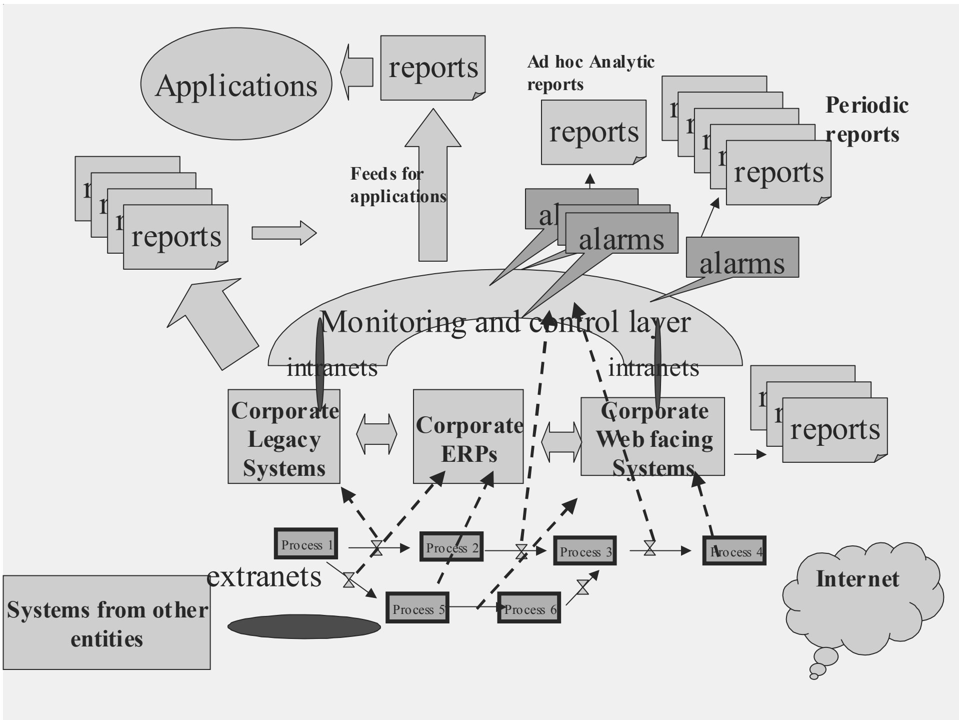
CA will fundamentally change the process of assurance and will consist of an overlay of analytic control processes on top of a monitoring architecture. This section discusses the process, hierarchies, the MC layer, and the steps to be followed confronted with traditional methods.

The Process of Analytic Monitoring

Continuous assurance requires two key components: an IT structure for data gathering and an analytic monitoring methodology to support monitoring, control, and assurance. Since a CA system is an overlay on top of a set of existing systems, the CA IT architecture has to utilize a middleware layer to provide integration between loosely coupled applications such as the firm's ERP system, their legacy systems, and the new web-facing systems. Exhibit 2 shows the proposed architecture of the corporate enterprise systems, where the CA system is shown as an instantiation of the monitoring and control (MC) system.

The system of analytic monitoring uses the MC layer with Key Performance Indicators (KPIs) and formal inter-process relationship models for measurements of flows and levels and to detect variances through metrics and to generate alarms when the standard for discrepancy is reached. This level of analytic monitoring lays on top of a level of actual direct measurement of systems that can be tapped and monitored, as well as processes that still do not have automation and have to rely on pure, high-level analytic monitoring. Clearly, if there are too many discontinuities without direct process monitoring the job of high-level monitoring becomes close to untenable.

EXHIBIT 2
The Monitoring and Control (MC) Layer in Corporate System Architecture



Hierarchy of Auditing: Primary, Secondary, and Tertiary Monitoring

The role and functions of continuous monitoring and continuous assurance in the evolution toward the real-time economy have to be understood within the hierarchy of control and monitoring processes comprising the organization of an enterprise. The underlying structure is the operational process where basic corporate activities are performed.

The *primary monitoring and control process* is the managerial internal control process where enterprise activities are recorded and measured through various metrics and compared against standards (which may be formal, empirically derived, intuitive, or inter-related). Furthermore, discrepancies are compared against the standard of discrepancy (which also may be formal, empirically derived, intuitive, or inter-related) and a decision made whether a management action, a signal to the audit process, or a stronger alarm may be warranted.

The *secondary monitoring process* is the external audit (or assurance) process entailing various forms of monitoring of both the underlying corporate activities and internal managerial controls. Some of this secondary monitoring can be similar to some primary monitoring processes (like monitoring the integrity of execution of business transactions), but the important distinction is in that the monitoring entity is independent and some of its algorithms are opaque to operating management.

The *tertiary monitoring process is the monitoring of the audit process*, performed partly by the audit firm and partly by a trusted independent party, which used to be done as peer review of public accounting firms under the auspices of the AICPA SEC Practice Section. The higher-order monitoring processes are not in place yet in any form, but they may include some degree of reporting directly to statutory authorities.

An Architecture of Continuous Assurance: The MC Layer

Alles et al. (2002) argue for the independent provisioning of the MC layer through the usage of a non-auditor-entity in conformance with the Sarbanes-Oxley Act. The main elements of the MC architecture are: (1) data-capture layer, (2) data-filtering layer, (3) relational storage, (4) measurement-standards layer, (5) inference engine, (6) analytic layer, (7) alarms and alerting layer, and (8) reporting platform. The proposed architecture can support all of the four levels of analytic monitoring from transaction verification to subjective judgment. While other approaches to CA may utilize a slightly different architecture, most of the functions represented in the MC architecture have to be performed.

Similarly to the implementation of ERP systems, the implementation stage will include process mapping and design as well as the development of interlinked analytic tools that describe the structure of the applications and their interlinking. The planning, implementation, and installation of the MC infrastructure will require very significant investment of efforts up front, changing considerably the cost balance of the work and possibly requiring new business models for the assurance functions.

The primary mode of operation of the MC layer will be discrepancy-based audit monitoring (or "audit by exception"). The MC layer will be continuously capturing the enterprise data feed and analyzing it to detect any deviations from normalcy. As discussed earlier, such deviations or exceptions can be detected at all four layers of audit objects. The key assurance capability of the MC layer is its exception-detection capability, which is provided by the inference layer on the basis of knowledge represented in the measurement standards layer, and libraries of exceptions, symptoms of systems pathologies, and patterns for fraud detection contained in the analytic layer.

Whenever a significant exception is detected, an alarm will be activated and delivered to the defined parties through a set of media including emails, telephone calls, paging, and faxes. When an alarm is delivered, auditors will review the evidence, including the automatic diagnostics performed by the MC layer, and try to identify the underlying problem. The auditors will also have to decide on their course of action, possibly considering operational issues and even the interruption of enterprise processes.

Since neither the enterprise nor the external environment remain static, the CA system will have to include continuous updating and improvement capability. The tests and models implemented in the MC layer and their parameters have to be continuously re-evaluated and modified to achieve the superior level of performance. Certain model and parameter updating can be automated, while deeper changes in the structure and nature of tests and models will require the involvement of highly qualified human experts.

Steps in the Process

CA will entail a different set of steps and processes than the traditional audit. Overall the continuous audit will entail much front-end architectural work, some low level of monitoring work, some levels of constant process modeling work, and active diagnostic work when alarms occur.

Front-end MC architecture: Work with corporate IT and users in the definition of metrics[3] to be tracked, points and methods of data extraction, evaluation of management's MC structures, determination of standards of measurement and exception, definition of alarms, and alerts.

Front-end analytic monitoring structuring: Identification of processes and key metrics. Creation of relationships between the levels and flows, as well as stochastic relationships. Identification of processes of direct-measurement (where there are for example ERPs) and processes that are being monitored just at the high analytic level through KPIs. Identification of KPI's and points of measurement.

Continuous discrepancy-based audit monitoring, alarming, and alerting: An MC structure will be constantly issuing different levels of alarms to activate management action or just to warn of some data or measurement condition. Alarms are objects with a set of attributes including addresses, condition, and form of alerting. Some alarms will be of audit interest either for business monitoring or for exception recording or for condition diagnostic. This step also includes diagnostic work identifying root causes and audit consequence of the alarms. These alarms, in terms of nature, frequency, and diagnostic are captured also as a new form of audit evidence.

Long continuous data gathering and model building: Most processes are dynamic and their standards change over the year based on new business models, management actions, and market conditions. Consequently, models must also change and adapt to dynamic conditions. Substantial research is needed in the development of analytic adaptive models that improve the accuracy of successful alarms but do not adapt to pathologic conditions (see Hoitash 2003).

Discrepancy analysis: Diagnostic conditions will require auditors to understand the nature and magnitude of the discrepancies observed and make decisions on courses of action in the range of: (1) observe and ignore, (2) observe and record, (3) observe and try to understand the effect, (4) observe and warn interested parties about the diagnostic, and (5) intervene in a process.

Multilevel opinions: Different audiences will depend on the CA process, e.g., banks for covenant monitoring, insurance companies for certain specific events, or stockholders for certain unusual events.

Tertiary "Black Box" Monitoring

Demand for tertiary monitoring will increase as the reputation of audit firms declines, so reducing that form of guarantee of audit integrity. Alles et al. (2003a) discuss the use of CA methodology to enable tertiary monitoring through the creation of a "Black Box log file"—a special logging procedure that will record major audit events, essentially providing an "audit trail of an audit," facilitating peer review or tertiary monitoring process in general. The widespread adoption of CA will make it harder to draw a clear distinction between the different levels of the monitoring hierarchy, because they will all be based on the common underlying ERP system. Moreover, the sophisticated real-time analytics that CA will make possible will become increasingly attractive to both internal auditors and even operational managers. This will make it particularly difficult to tell where internal auditing ends and external auditing begins, especially as external auditors face the need to increase the scope of their audits to deter the kind of sophisticated financial manipulations revealed by Tyco, Enron, and Global Crossing.

Alles et al. (2003b) argued that the distinction between the scopes of auditing and consulting is a gray area for fundamental reasons. A similar argument applies to the distinction between the scopes of internal and external auditing, especially when both are CA-enabled.

[3] Vasarhelyi and Halper (1991) define the five elements of continuous audit to be: metrics, analytics, standards, alarms, and method of measurement.

TOOLS FOR ANALYTIC MONITORING IN CONTINUOUS ASSURANCE

Each CA level has its own requirements to achieve assurance and, hence, uses different tools and methodologies. As discussed in the first part of this paper, demand is likely to drive CA away from *ex post* evaluation to a closer-to-the-event review. Further, software, people, and analytic thresholds may, at a certain point, intervene into processes and cause their interruption prior to completion. This is a paradigm shift in the nature of auditing that will cause major behavioral resistance and potentially require changes both in the view of independence as well as in many regulations of the professional conduct of accountants. In this more active role, the auditor is part of a meta-control and this intervention process will have to be understood and regulated. To distinguish from the traditional auditor role we call this *analytic monitoring* whereby the functions of performance evaluation, review, assurance, and intervention are rebalanced between auditors, managers, and operational staff.

Understanding both the new demands for assurance and, on the supply side, the automation and integration that underlies CA systems, enables the construction of new audit tools and processes that provide the unique analytic monitoring capability of CA. These new assurance technologies, which are discussed in greater detail by Vasarhelyi et al. (2003), will create an entirely new audit environment. These new technologies facilitate new objectives, processes, and tests, with modern IT systems facilitating a series of intrusive and increasingly transparent activities by analytic monitors:

- Observing events when they happen
- Alarming when exceptions occur
- Drilling down to finer degree of aggregation
- Integrating data across multiple and distinct processes
- Performing repeated tests with low variable cost

We next examine some of the tools that will underlie analytic monitoring in CA and the forces that will shape those tools.

Continuity Equations

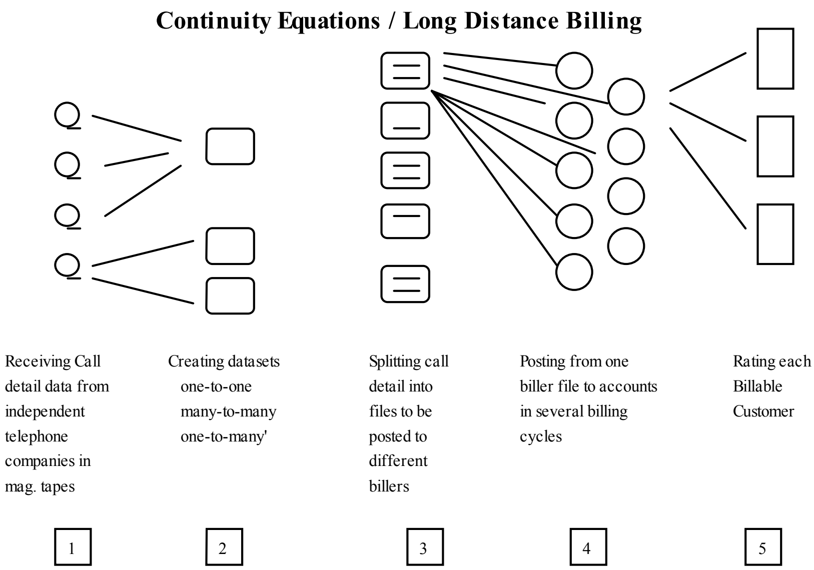
The CA environment facilitates bringing an entirely new set of data into assurance processes, with consequently expanded new analytic methods and insights. One category of such analytic methods is what we call *Continuity Equations*, which incorporates structural knowledge into business assurance processes. The objective is to add context to financial data by relating business processes and their ensuing measurements. Structural information about business processes is used to model how data varies with management decisions and how it migrates from process to process throughout the value chain.

The first application of continuity equations was in a tool that was prototyped at Bell Labs in the early 1990s. Exhibit 3 displays a set of sequential processes that entailed bill preparation in the former Bell system (now AT&T).

Transactional data were received from the operating telephone companies in the form of magnetic tapes, which were then extracted into datasets and segmented into other types of datasets that separated types of transactions, which were then rated (priced) and accumulated into 20 different billing cycles. At the end of the cycle at bill pull time, these were rated again now with the optional calling plans that depended on monthly usage for establishing the rates. Finally the bill was prepared, printed, distributed (mailed), and consequently payments started coming in, followed by accounts receivable management, collection actions, customer support, secondary sales, etc. These processes are structurally and logically linked and structural equations provide the model and methodology to use this knowledge in assurance (and management). For example, the effect of a new advertising campaign can be traced through to its impact on usage, billing, and cash receipts. In examining transactions, understanding of knowledge structures serves to identify major breaks in control and

EXHIBIT 3
Continuity Equations

Linking financial and nonfinancial processes analytically



logic and to determine population discontinuities and other problem. More specifically, a detected violation (in a deterministic or stochastic sense) of a continuity equation will trigger an audit alarm to be investigated and acted upon.

Implementing continuity equations is even more feasible today because of the automation and integration of business processes brought about by ERP systems. The bigger constraint is to understand the dependencies behind the business processes, thus allowing the chain of links between management actions and metrics to be delineated and mapped into continuity equations. When they are, CA will truly evolve from an *ex post* verification system to a real-time control tool. The regulations and institutional arrangements necessary to support such a shift must be created.

Tagging Data Accuracy

The advent of technology also will change the basic unit being assured. While in a traditional audit, the fact that the auditor attests that statements are not materially incorrect does not mean that account balances, footnotes, or specific transactions are fairly represented. Consequently, when a number out of a corporate report or financial statement is used, one cannot state that it is fairly represented, as it may be that while the financial statement is fairly presented in aggregate, this particular number is grossly wrong.

A solution to this problem is the emerging technology of tagging—for example, XML for semantic information—which will be the basic building block of interoperability. Tagging enables transactions to flow from application to application with attached contextual information that allows the application to understand its content, process it, and pass it along to the next application. In this universal transaction channel (internal or external or shared as an extranet) one important variable will be data accuracy, and tagging will potentially enable an assessment of data accuracy to be attached to each dataset to be carried throughout the process. For example, a telephone call measured at the switch and properly encrypted including origination and integrity identifiers will have reliability close to 1. On the other hand, a number drawn from an unaudited monthly report, a quarterly statement, or from a company annual report will have very different levels of reliability. This potential transaction or data accuracy measure will need not only contextual source information, but also some assessment of reliability modeling and measurement.

A modern continuous assurance environment could have tags that will identify source, nature, assuror, and transformation of data. For example a piece of data that describes the level of cash for Morgan Stanley would have tags saying (source = Morgan Stanley financial statement, auditor = PWC, reliability level = 0.992 under the 50m materiality threshold, etc.).

These issues are rather nonintuitive and to make them feasible will require bringing in some formulation, standardization, and resolution to these issues. However, data-level assurance is one of the most intricate and difficult problems that will face the real-time economy and it is a problem that has not been addressed by tagging organizations (e.g., xbrl.org) that simply focus on setting standards for their labels and their exchange.

Time-Series Analysis

The concept of using time-series analysis in analytical review has been in the accounting literature for a long time (Stringer 1975). Over two decades ago the firm of Deloitte, Haskins and Sells issued its regression-based STAR package in an effort to better model the time-series behavior of the firm and to aid in detecting variations. But this package has not had wholesale adoption and, in general, there is less use of time-series analysis in auditing than one might imagine. One reason is that data is very aggregate at the financial statement account level and does not provide sufficient depth for rigorous statistical analysis. On the other hand, CA architecture provides great atomicity of data in a continuous flow of information, rather than being restricted to monthly data sets, as is common today. The new set of analytics implies slicing time periods/aggregating data and creating points of comparison and this should greatly increase the accuracy of data analysis under CA.

Similarly, CA will make greater use of cross-sectional analysis, which will be expanded with substantively increased information being provided at the moment of publication to expand the view of business. Semantic agents, a la FRAANK (Bovee et al. 2002) would identify the arrival of a filing at a public reservoir/data repository (e.g., SEC's EDGAR) and parse their content for particular pieces of information, this information then being placed in a relational database against which cross-sectional analysis model (much richer than the current ratio studies) would be frequently run. These model using time sequencing and comparative ratios would alarm if the most recent data extraction demonstrated significant changes out of the balance.

Dynamic Reconciliation of Accounts

There are transaction aberrations that are not detectable at the aggregate level as balances hide addition and subtractions to an account. Consequently while analytic monitoring adds substantively to the assurance process, it cannot be the only procedure applied. For example, a firm's own internal control processes may monitor the balances on its bank disbursal accounts. But daily balances provide less than full information if the account is cleared every day, with entries and exits washing out in the transfer. Consequently, some dynamic, ongoing system of analysis must be used to fully trace the flow of cash into and out of the account, and to identify any unseemly patterns or behaviors.

Traditional auditor review has entailed typically static reconciliation, cross-sectional, and time-series review of ratios. These measures, although valuable, are too coarse and static for a real-time economy and will evolve to account reconciliations impounded into software and performed every day (or the natural rhythm of the application that can be instant, minute by minute, hourly, weekly, etc.). But note that this could also add substantive conceptual confusion, as the reconciliation becomes an alarmed control, and not an exclusive audit tool. This type of conceptual confusion is prevalent in many CA issues as the traditional audit is an *ex post facto* process and CA is a simultaneous/prior-to/just after process. Consequently many CA procedures are also control procedures.

Data Taps in CA

Continuous data collection in CA can be divided into two generic categories: (1) direct data collection (taps, queries to databases, and embedded audit modules) and (2) indirect data collection (document scanning, tertiary feeds, etc.). Of particular interest is the work performed at AT&T (Hume et al. 2000) where a very large billing system was tapped at many points to verify transaction integrity. The volume of data was overwhelming but enabled confirmation that over 99.97 percent of transactions where accounted for, contrary to prevailing belief that suspected much larger evasion. Hume's work used temporary files being passed process-to-process at the tapping mechanism, avoiding the introduction of intrusive code into the application. CA will have the potential for much higher intensity data taps, but it will require fundamental rethinking of existing audit tools and procedures to take advantage of this enhanced information flow. (Hume et al. 2000), albeit somewhat different, is one of the few instances of the implementation of the concept of "embedded audit modules" often advocated in the literature (Groomer and Murthy 1989; Debreceny et al. 2002).

A distinct characteristic of evolving CA systems will be their reliance on web-based data, which unlike traditional data, is from the beginning electronic and collected at the source. Unlike other forms of data it has, if collected, substantive path information and allows for the partial understanding of client behavior and desires. Corporations are starting to use the web to create an effective two-way communication with their stockholders as well as a way to evaluate, through click path analysis, information usage, and product information search by consumers. Customer usage of web information is highly correlated with actual purchases and the ensuing patterns. Continuity equations can profitably use this information for predicting levels and flows later in the value chain. Furthermore, the emerging area of m-commerce (mobile commerce), will add to click paths information about client locations that will bring even closer to the customer the buying experience. This will be the next variable to enrich the prediction value of continuity equations and structural analysis.

Automatic Confirmations

Vasarhelyi and Srivastava (2002) have discussed the role of extranets in the automatic confirmation of transactions. Corporate transactions that deal with an external organization will typically have mirror systems that initiate and receive the transaction. For example, a purchase order mirrors in a sales/logistic systems, a cash system that issues and ships checks will mirror into a payment system, etc. Progressively, corporations are electronizing their systems and allowing customers to do a substantive amount of self-service. Often extranets are created for:

- customers to examine their checking accounts (can be used for bank balance confirmation as well as to understand the patters of flow and replace cutoff analysis);
- customers and suppliers to review the status of their accounts (payables and receivables);
- customers and suppliers to track the delivery of product; and
- suppliers to keep track of corporate inventories (in supplier-managed inventory situations).

The utilization of confirmations, as a form of audit evidence, while traditional and prevalent in auditing, is an expensive and inexact process. Positive confirmations are fraught with missing observations and negative confirmations are a weaker form of evidence. The advent of web-based banking systems has brought a new degree of transparency to the other side of the transaction and the ability to substantially extend the evidence brought in by extranet confirmations.

Organizations, when opening bank accounts, signing supplier contracts, or adding vendors to their list of approved vendors, will enclose a mutual confirmation clause and potentially some standard confirmation protocol that will be used by both parties in their mutual transactions. This protocol will present some form of security and code for the type of confirmation obtained (e.g., data-level confirmation, account aggregate confirmation) and this information will be added as a label in the data's XML derivative representation. Automatic procedures in the data flow will review the existence (or lack thereof) of the automatic confirmation and provide summaries and exceptions for the assurance process summaries.

The usage of automatic confirmations will substantially change the nature, procedures, scope, and weight attributed to audit evidence. Confirmations, obtained automatically and highly complemented by self-correcting procedures, will eventually be the most important form of audit evidence. Automatic confirmations, provisioned by extranet agreements, will substantively resolve the audit objectives of existence, completeness, and, to a certain degree, accuracy at the transaction level and account aggregation levels.

Control Tags

Tagging also allows for the inclusion of *control* tags, of which users may or may not be aware, and that can contain sequential numbers, confirmatory information, structural information, data-level assurance measures, and path markings. These tags, aimed at providing auditor information, will also substantially change the weighting of audit evidence, allowing for physical validation of audit objectives. For example, a transaction may have tags with the time of its inception, the time of its passage through key control points, an intelligent sequence number, a prevision of a processing path, and conditions for transaction acceptance and rejection. A control tag may link an order to its payment or other transaction it generated along the value chain. Furthermore, the transaction may leave behind *trailing tags* at the process structural points for transaction validation, alternate path routing, or bot-based verification.

These tools of analytic monitoring, all of which are built upon and take advantage of the automation and integration of the underling IT-enabled business processes, will fundamentally change the way in which auditing will be carried out. The audit environment within which the tools will be used will depend on the changes that CA will also drive on the levels, hierarchy, and process of auditing.

OUTCOMES OF THE CONTINUOUS ASSURANCE PROCESS

Finally, the outcomes of the continuous assurance process will entail an expanded set of assurances, evergreen opinions, some future assurances, some improvement on control processes (though incorporating CA tests), and some improved data integrity.

An Expanded Set of Assurances

The CA module in the MC layer can be programmed to issue both periodic audit opinions as well as current audit opinions, which are updated in real time whenever a change in the situation requires an update. Moreover, opinions of different nature, and alarms of different type, can be issued to different stakeholders such as banks, insurers, federal authorities, state authorities, employee unions, and environmental protection organizations. Such reports (with financial and nonfinancial information) can be tailored to the needs of the stakeholder in question (e.g., asset reports for insurers, environmental reports for OSHA, traditional reports for individual shareholders, etc.). Assurance reports with estimated levels of data reliability can be issued to the stakeholders upon the payment of a fully disclosed fee, set in advance, and open to all entities of that category.

The most important innovation of an audit opinion generated by CA is its explicit futurity, i.e., the promise to continue monitoring and evaluating the operations of the firm, informing the (registered/paying) users/stakeholders if any substantive exceptions occur. The general nature of the evaluative analytics and the magnitude of the limiting variances can be disclosed online, while the auditor could reserve the right to utilize undisclosed models and analytical procedures. The new types of audit opinions provided by CA will result in substantive changes in the timing and role played by assurance in society.

Improvement on Control Processes

The Sarbanes-Oxley Act through its Section 404 requires an auditor's opinion on the quality of corporate internal controls. While the profession is interpreting the law as the requirement to document controls, and their consideration under COSO, the issue of measurement, monitoring, and evaluation of controls in a heterogeneous integrated computer environment is far from being resolved. CA and analytic monitoring can: (1) provide data evidence that controls are functioning without their direct measurement through the understanding of the data consequences of ineffective/nonoperational controls, (2) can repeat computer operation tests (e.g., the test for duplicate payments) activated by auditors to assure that those controls are working, and (3) can "ping" (query) specially designed controls about their operating or pick data from this control on the nature of its functioning.

Improved Data Integrity

The third outcome of analytic monitoring is bringing increased assurance to a lower level of aggregation, in particular the transaction level, providing evidence/inputs for the aforementioned data-level assurance focusing on the tools of Level 1 of analytic monitoring. Automatic confirmations and control tags will provide direct evidence of data-level reliability on particular transactions while high-level monitoring will assure that these are not systematically wrong.

CONCLUSIONS

The progressive electronization of all but the smallest firms has revolutionized the management of business processes and the flow of information within firms. The implementation of ERP results in processes that are automated and integrated to an unprecedented degree, especially since it necessitates that business processes be first reengineered, so bringing them up-to-date and eliminating redundancies and inefficiencies. Continuous assurance systems are built upon a firm's underlying IT systems and so they inherit the ability to rapidly access information from anywhere in the firm's automated and integrated value chain. This will result in fundamental changes in auditing across all its dimensions: objectives, levels and hierarchy, timing, process, tools, and outcomes.

The experience with the evolution of new technologies and business processes suggests that CA will initially be used to do no more than automate existing audit procedures and thereby take full advantage of the capabilities that it has in the new ERP-based environment. This paper describes the tools that will come forward once CA moves to the second stage of its evolution when audit processes are reengineered to exploit the underlying technological capabilities to the fullest. This will lead to the creation of a new system of continuous analytic monitoring that will completely transform the audit environment, in much the same way that ERP systems themselves revolutionized firms' internal monitoring and control systems.

However, to reach that stage will require more than technology implementation. For one thing, it will necessitate auditors actually examining their processes to see if they are susceptible to process mapping and reengineering. This is particularly important if CA is to achieve its full potential, by being progressively extended to higher levels of audit objects, rather than being restricted to the most mechanical of audit task at the transaction level. However, systematizing processes, once thought to be exclusively in the pure human judgment domain, will take a paradigm shift by auditors. At the same time, continuous analytic monitoring will intrude into the internal control arena, especially since it is built on the firm's own ERP systems. This will create concerns with independence and the relationship between internal and external auditing, analogous to the current debate on the boundary between auditing and consulting.

These implementation issues, the specification of the analytic monitoring toolset and the nature of continuous auditing at each level of audit object all require an intensive research effort, extending from establishing solid theoretical foundations to rigorous laboratory testing. The research agenda put forward by Kogan et al. (1999) needs to be expanded from CA alone to the nature of the entire CA-enabled analytic monitoring environment. While the theoretical work in CA has made progress, the field has been hindered by the lack of a proper set of experimental and empirical research. Consequently, establishing viable data laboratories with large quantity of real (not necessarily but preferably current) data emulating corporate ERP systems, legacy systems, web-facing systems, and real economic circumstances including accounting malfeasance is a priority for the continued development of CA.

REFERENCES

Alles, M. A., A. Kogan, A., and M. A. Vasarhelyi. 2002. Feasibility and economics of continuous assurance. *Auditing: A Journal of Practice & Theory* (Spring).

———, ———, and ———. 2003a. Black box logging and tertiary monitoring of continuous assurance systems. *Information Systems Control Journal* 1: 37–39.

———, ———, and ———. 2003b. Should auditing be completely separated from consulting in the post-Enron era? Working paper, Rutgers, The State University of New Jersey, Rutgers Business School.

American Institute of Certified Public Accountants (AICPA). 1997. *Report of the Special Committee on Assurance Services*. New York, NY: AICPA.

Bovee, M., M. Kogan, K. Nelson, R. P. Srivastava, and M. A. Vasarhelyi. 2002. Financial reporting and auditing agent with net knowledge (FRAANK) and eXtensible business reporting language (XBRL). Working paper, University of Kansas.

Canadian Institute of Chartered Accountants and American Institute of Certified Public Accountants (CICA/AICPA). 1999. *Continuous Auditing*. Research Report. Toronto, Canada: CICA.

Debreceny, R., G. Gray, W. L. Tham, Y. Goh, and P. L. Tang. 2002. The development of embedded audit modules to support continuous monitoring of the control environment. Working paper, Nanyang Technological University, Singapore.

Elliott, R. K. 2001. 21st century assurance. Presentation to the American Accounting Association Auditing Section Midyear Meeting, January 12.

———. 2002. 21st century assurance. *Auditing: A Journal of Practice & Theory* (Spring).

Fisher, I. E. 2003. On the structure of financial accounting standards to support digital representation, storage and retrieval. *Journal of Emerging Technologies in Accounting* 1 (1).

Groomer, S. M., and U. S. Murthy. 1989. Continuous auditing of database applications: An embedded audit module approach. *Journal of Information Systems* 3 (2): 53–69.

Hammer, M. 1990. Reengineering work: Don't automate, obliterate! *Harvard Business Review* (May–June).

Hoitash, R. 2003. Information transfer in analytical procedures: A simulated industry knowledge-management approach. Dissertation draft, Rutgers, The State University of New Jersey, Rutgers Business School, Newark, NJ.

Hume, A., S. Daniels, and A. MacLellan. 2000. GECKO: Tracking a very large billing system. Proceedings of 2000 USENIX Annual Technical Conference, San Diego, California, June 18–23.

Kogan, A., E. F. Sudit, and M. A. Vasarhelyi. 1999. Continuous online auditing: A program of research. *Journal of Information Systems* 13 (2): 87–103.

Rezaee, A., R. Elam, and A. Sharbatoghlie. 2002. Continuous auditing: Building automated auditing capability. *Auditing: A Journal of Practice & Theory* (March).

Stringer, K. W. 1975. A statistical technique for analytical review. *Journal of Accounting Research* (Supplement).

Vasarhelyi, M. A. 1980. A taxonomization of internal controls and errors for audit research. Proceedings of the Touche Ross University of Kansas Symposium on Auditing Problems.

———, and F. B. Halper. 1991. The continuous audit of online systems. *Auditing: A Journal of Practice & Theory* 10 (1): 110–125.

———, and J. Peng. 1999. Qualitative corporate dashboards for corporate monitoring. *IS Audit and Control Journal* 5: 45–48.

———. 2002. Concepts in continuous assurance. In *Researching Accounting as an Information Systems Discipline*, edited by S. Sutton, and V. Arnold. Sarasota, FL: American Accounting Association.

———, and R. Srivastava. 2002. Confirmatory extranets: Rebalancing the entire structure of audit evidence. Working paper, Rutgers, The State University of New Jersey, Rutgers Business School.

———, M. G. Alles, and A. Kogan. 2003. New technologies and procedures for the continuous audit. Working paper, Rutgers, The State University of New Jersey, Rutgers Business School.

———, and M. L. Greenstein. 2003. Underlying principles of the electronization of business: A research agenda. *International Journal of Accounting Information Systems* 49: 1–25.