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# IBM SOA: Integrating Advanced IT in Networked Enterprise Control. Research and Education Solutions

Theodor Borangiu, Dan Sevcenco and Anamaria Dogar

*IBM Romania*
*{theodor_borangiu, dan.sevcenco, anamaria.dogar}@ro.ibm.com*

**Abstract**. The environment of the manufacturing industry is characterized by radical changes and companies are facing today more than ever great challenges that result from alterations in the global framework. One proposed development project aims at qualifying specialists in SOA for Enterprise Management (the ERP, business level) and Control (the design, engineering and distributed process control level) through the "SOA for Enterprise Management and Control (SOAEMC)" Master program to be implemented in 2009. Students graduating the SOAEMC Master Program will acquire both *deep skills* in control and communication technologies (CCT) and *complementary competencies* in systematic software development (SWD, considering application lifecycle management) and enterprise modelling and integration (EMI). Another academic development project proposal aims at offering technologic transfer and innovation support to SME for reengineering of: agile shop floor manufacturing control, management of changes in customer orders and high availability of networked production resources.

**Keywords**. Service-oriented architecture, education, enterprise control and management.

## 1. Introduction

The environment of the manufacturing industry is characterized by radical changes and companies are facing today more than ever great challenges that result from alterations in the global framework. Not only do technological changes (particularly in ICT) have a big impact on manufacturing companies, but also the market registers dramatic, unpredictable variations in size and types of product batches. To be competitive, manufacturing should adapt to changing conditions imposed by the market. The greater variety of products, the possible large fluctuations in demand (from mass production to short lots), the shorter lifecycle of products expressed by a higher dynamics of new products, and the increased customer expectations in terms of quality and delivery time are challenges that production companies have to deal with to remain competitive. Besides these market-based challenges, manufacturing firms also need constantly to be flexible and adapt to newly developed processes and technologies and to rapidly changing environmental protection regulations.
In this environment of high technological dynamics, changing working environments, increasing globalization and fast changing markets, information exchange has become increasingly important, and knowledge about customer needs has become crucial for the survival and progress of enterprises. Knowledge has therefore become an additional production factor besides work, capital and ground. The dynamics of this knowledge have furthermore led to a new paradigm – the knowledge-driven economy – in which enterprises need continuously to adapt themselves for sustainable competitive advantage.
Innovation is recognized as the driving factor for sustainable economic growth. In a knowledge-driven economy, however, *the nature of innovation has changed* radically. As the markets have become customer driven, production firms need to tailor innovation to dynamically changing customer needs. Due to the increase in technology complexity, and the fact that most products are multi-technological in nature, the complexity of products and processes has increased. Innovation is, therefore, *increasingly complex* in nature; the knowledge content of such kind of innovation has grown with the complexity and *is highly specialized, based on experience*, and therefore mostly of *tacit character*.

Finally, *innovation is not limited to technology*, but *also occurs* more and more *in other fields* like *organization and processes*. Consequently, innovation is seen as a "strategic concept" aiming not only at new products, but also at exploiting the complex innovation potential including solution-oriented product-service combinations up to totally new business models and the transformation of industry structures. Innovation is viewed as a multi-dimensional concept, which goes beyond technological innovation to encompass new means of distribution, supply, planning, marketing or design.

As the character of innovation has changed in the knowledge-driven economy, the focus must be directed as to which general principles enterprises need to act upon and what activities they should pursue to foster the innovation creation process within the organization (in particular, a proposed collaborative innovation space that would assists regional SME not disposing of own R&D skills and resources).

Despite all the differences and particularities in the detailed design of innovation management, the following success factors must be promoted for innovating discrete, repetitive manufacturing companies in the knowledge-driven economy:

- *Growth-oriented*: sustainable growth through innovations
- *Strategy-oriented*: long term future-perspectives through innovation strategies
- *Customer-oriented*: to focus a solution of customer specific problems
- *Competence-oriented*: integration of competences from internal and external partners
- *Technology-oriented*: using the potential of applied research (new technologies and processes) successfully

With IBM support, it is aimed the creation of a regional innovation cluster by networking academic and industry partners with the purpose of generating new knowledge and regional competitive advantage:

- Diffusing tacit knowledge (i.e. knowledge based on individual or organizational experience), needing spatial proximity of knowledge and innovation agents
- The lack of perception from manufacturing industries of clear market needs is replaced by a common vision about future technologies and their application demands, posted on the portal
- Creating premises for a culture of innovation and trust within the university-industry cluster of partners with complementary competencies

## 2. New Master program SOA for Enterprise Management and Control

One proposed development project aims at **qualifying specialists in SOA for Enterprise Management** (the ERP, business level) **and Control** (the design, engineering and distributed process control level) through the "SOA for Enterprise Management and Control (SOAEMC)" Master program to be implemented in 2009.

Students graduating the SOAEMC Master Program will acquire both *deep skills* in control and communication technologies (CCT) and *complementary competencies* in systematic software development (SWD, considering application lifecycle management) and enterprise modelling and integration (EMI). Knowledge will be transferred in a 3-semester hands-on training program:

- CCT.1 : SCADA and Distributed Control with PLC Networks
- CCT.2 : Heterogeneous Industrial Communication Networks and Fault Tolerance
- CCT.3 : Systems- and Network Security
- SWD.1: Model Driven Engineering for SOA
- SWD.2: Business process Modelling and Requirements Management
- SWD.3: Analysis and Design of Software Architectures
- R&D.1: Research and Development Activity
- CCT.4 : Data Flow Modelling and Computing Networks
- CCT.5 : Distributed Databases and KB Production Systems
- CCT.6 : Applied AI and Rapid Deployment Automation (RDA) Solutions
- SWD.4: Software Testing and Quality Assurance
- SWD.5: Configurations- and Changes Management
- EMI.1 : Enterprise Modelling and Integration
- R&D.2: Research and Development Activity
- CCT.7 : Multi-Agent Systems and Holonic Manufacturing Control
- EMI.2 : Enterprise Resource Planning
- EMI.3 : Supply Chain Integration, Operations- and Forecast Management
- EMI.4 : Interoperability and WEB Services
- R&D.3: Research and Development Activity
- MPRJ : Master Project

The SOAEMC program qualifies specialists (engineers) for the networked compartments of modern manufacturing companies: (1) *Offer Request- and Customer Order Management* for products and services (requested skills: marketing, requirements analysis, business modelling, WEB services, document management, engineering (CAE), resource planning – CAPP); (2) *Product Design and Batch Planning* (requested skills: CAD, group technology, CAE / CARE (reengineering), information management, applications development, management of changes, ERP, CAPP); (3) *Production Execution, Control and Monitoring* (requested skills: process automation, RDA, Computer Aided / Integrated Manufacturing – CAM / CIM, Computer Aided

Quality Control – CAQC, applied AI, LAN, high availability, maintenance); (4) *Supply Chains, Sales and Delivery* (requested skills: operations management, document management, supply chain integration, interoperability and WEB services, service management, SOA).
Integrating the CCT, SWD and EMI theory and exercises content in a multi-functional e-learning platform will allow sharing, training and development resources in the area of SOA for the management and distributed control of discrete, repetitive production structures. The existing pilot enterprise platform located in the University's "Computer Integrated Production (CIP)" Laboratory will be finally integrated in the multi-functional e-learning system, with real-time laboratory experiment facilities, remote resource control, product traceability and batch production tracking.
This e-learning platform, part of the collaboration portal is presented in Fig. 1.

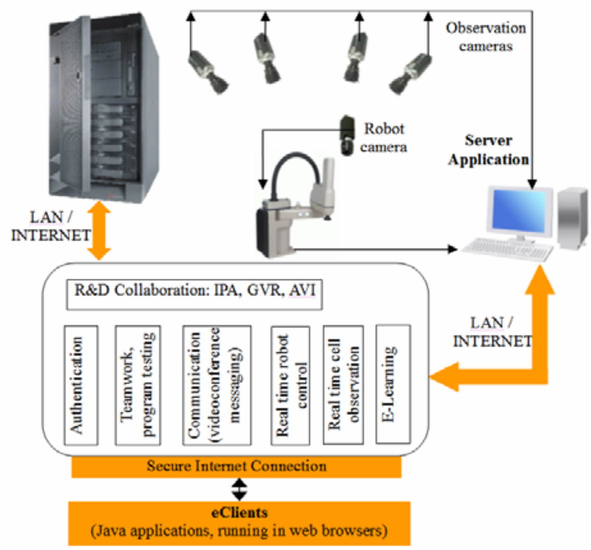


Fig. 1. The structure of the collaboration portal & communication platform

## 3. The *Computer Integrated Production* Pilot Enterprise Platform Formatting the manuscript

Another academic development project proposal aims at offering technologic transfer and innovation support to SME for reengineering of: agile shop floor manufacturing control, management of changes in customer orders and high availability of networked production resources.
The proposed solution to this project is making available to industry partners a distributed enterprise control architecture in which information entities, having manufacturing counterparts in the CIP pilot enterprise platform, cooperate to solve together the assigned tasks. The innovation goal is to share knowledge about shop floor agility – a central problem in manufacturing companies. Agility means more than (production) being flexible or lean: it corresponds to operating efficiently but in a competitive environment dominated by change and uncertainty.
The need of methods and tools to manage the process of change addresses both the level of business process reengineering (including information technology infrastructures) and shop floor (where production processes are executing). A particularly critical element in the shop floor reengineering process is the control system. Current control / supervision systems are not agile because any shop floor change requires programming modifications, which imply the need for qualified programmers, usually not available in manufacturing SMEs. Even small changes (e.g. rush customer orders, resource breakdown or material storage depletion) might affect the global system architecture, which inevitably increases the programming effort and the potential for side-effect errors.

There is a need of new methods and instruments that eliminate or reduce these problems, making the process of changes (reengineering) faster and easier, focusing on configuration instead of codification, must be developed and offered to industry partners.
This **methodology** used for shop-floor reengineering compensates for the deficiencies of both hierarchical and heterarchical enterprise control systems, and is based on several new concepts for the design of manufacturing systems such as Fractal Factory, Bionic Manufacturing, and Holonic Manufacturing Systems. Each concept attempts to model a manufacturing system based on some analogies with other existing theoretical, natural or social organization systems. The *agent-based* and *holonic* paradigms symbolize these new approaches; they deal with the re-configurability in discrete, repetitive manufacturing by introducing an adaptive production control system that evolves dynamically between a more hierarchical (providing global efficiency / optimality) and a more heterarchical (self-adapting, fault-tolerant, agile) control architecture, based in self-organization and learning capabilities embedded in individual holons (information counterparts of resources, processes and products). Workable Holonic Manufacturing Execution System (HMES) design principles are exposed in the core of the innovation roadmapping approach (R&D on SOA for shop floor agility).
The Service-Oriented Architecture of the platform supports the development of more powerful reconfiguring and interoperability tools, using more complex self-organization and learning techniques. Service composition in multi-agent manufacturing systems is the combination of single services and all the interaction patterns between them. The evolution and re-configurability of this class of production

structure is facilitated using multi-agent systems supported by *web services technology* since it is possible to add, remove and modify resources and services without interrupting processes.

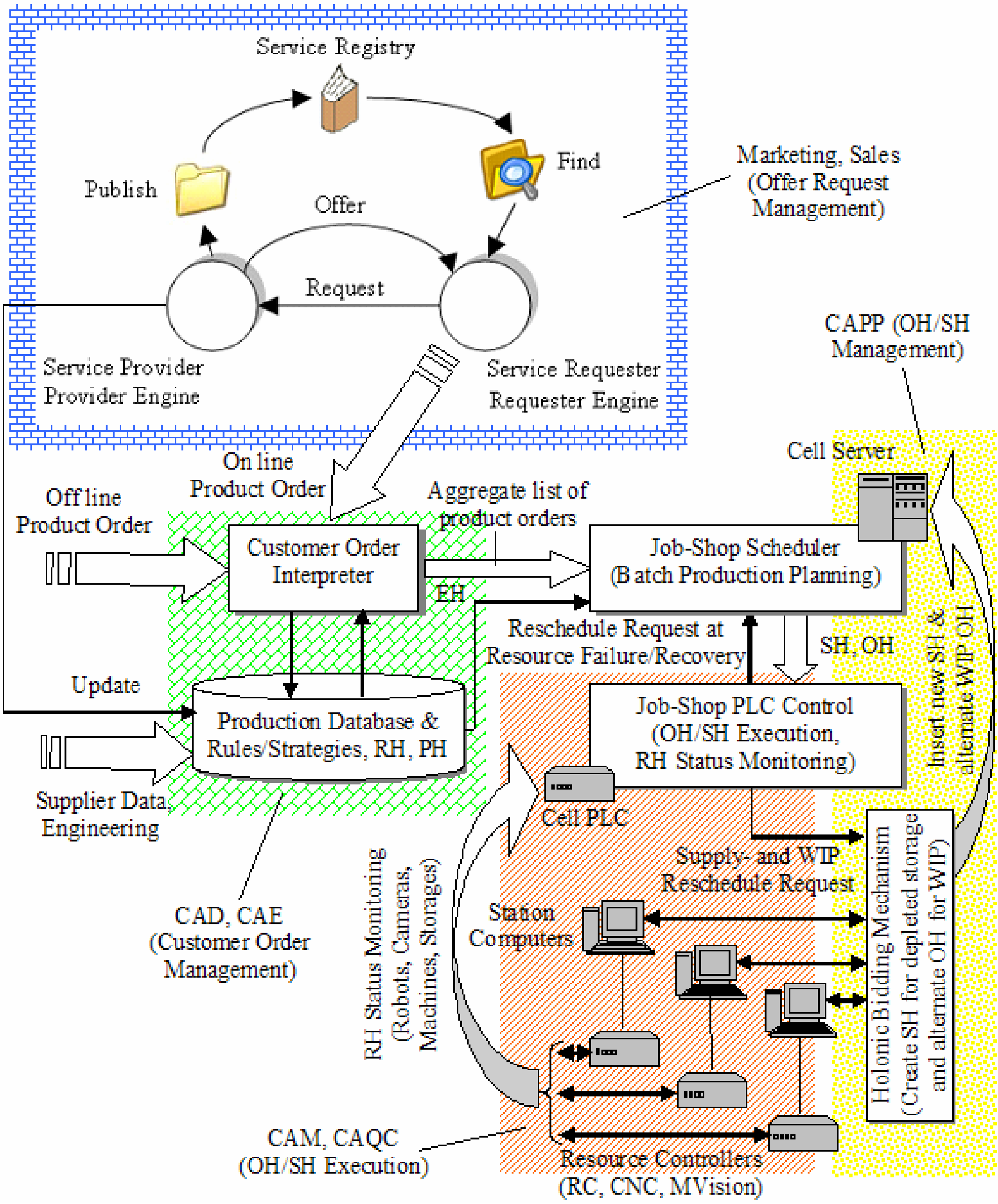


Fig. 2. SOA integrates job-shop, team-based manufacturing with multi-agent resource control

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A generic architecture must be proposed to improve shop floor reengineering; components of this architecture and their capability / behaviour will be possibly reconfigured by industry projects (roadmaps proposing, testing and validating various production scenarios). This generic distributed enterprise control architecture aims at accommodating the following requirements:

- *Modularity*: production systems should be created as compositions of modularized manufacturing components, which become basic building blocks. The building blocks should be developed on the basis of the processes they are to cater for.

- *Configuring rather than programming*: the addition or removal of any manufacturing component (basic building block) should be done smoothly, without or with minimal programming effort. The system composition and its behaviour are established by configuring the relationships among modules, using contractual mechanisms.
- *High reusability*: the building blocks should be reused for as long as possible, and easily updated for further reuse.
- *Legacy systems migration*: legacy and heterogeneous controllers should be considered in the global architectures and a process should be found out to integrate them in the new agile architecture.

One proposed architecture is a multi-agent based one (MAS) that supports the reengineering process of shop floor control / supervision architectures. In an innovative way, this generic MAS architecture uses contracts to govern the relationships between coalition members (manufacturing agents) and postulates a new methodological approach in which the reengineering process is included within the life cycle. This concept considers modularity and plugability as one of its most important foundation principles. The control system architecture being proposed in the innovation platform for industry considers that each basic component are modules of manufacturing components that can be reused and plugged or unplugged with reduced programming effort, supporting in this way the *plug & produce* metaphor.

The generic MAS proposed as reference architecture assumes that there is a similarity between the proposed reengineering process and the formation of consortia regulated by contracts in networked enterprise organizations. The problems a company faces in order to join a consortium are analogous to the shop floor adaptation problem, i.e. the formation of a coalition of enterprises to respond to a business opportunity is analogous to the organization of a set of manufacturing resources in order to perform a given job.

Thus, a manufacturing component or module is seen as a physical piece of equipment that can perform a set of specific functions or basic production actions on the shop floor such as moving, transforming, fixing or handling. An agentified manufacturing component is composed of a manufacturing component and the agent that represents it. The agent's skills are those offered by the manufacturing component, which is connected to the agent through middleware. A coalition / consortium is an aggregated group of agentified manufacturing components, whose cooperation is regulated by a coalition contract, interacting in order to generate aggregated functionalities that, in some cases, are more complex than the simple addition of their individual capabilities. A shop floor cluster is a group of agentified manufacturing components which can participate in coalitions and share some relationships, like belonging to the same manufacturing structure and possessing some form of technological compatibility. The different coalitions that can be created out of a cluster represent the different ways of exploiting / operating a manufacturing system. A broker will be used to help the formation of coalitions to reduce the complexity of the individual agents in terms of coalition formation.

Multi-agent systems for enterprise reengineering can be approached with the new emergent Service Oriented Architecture (SOA) technology which supports the development of more powerful re-configuration and interoperability mechanisms, using more complex self-organization and learning techniques. Service composition in multi-agent manufacturing control systems (MAS) is the combination of single services and all the interaction patterns between them. The re-configurability and evolution of the production structure is facilitated using multi-agent systems supported by web services technology since it is possible to add, remove and modify dynamically resources and services without interrupting the processes. The development of orchestration and choreography mechanisms and tools, including orchestration engines for composition, coordination and collaboration, must be considered to support intelligent, re-configurable and modular manufacturing control systems

SOA concepts can be used to face the problems of interoperability in the autonomous, intelligent re-configurable MAS architecture implemented as a HMES. Each smart device controller encapsulates functions and services that its associated physical device can perform (e.g. jogging the conveyor, moving the robot along a particular path, etc).These services, that can be modified, combined, added or removed (e.g. a new product can be handled by a robot after the aggregation of a new gripper), are then exposed to be invoked by other smart device controllers. *Self-organization* (i.e. the capability to dynamically re-organize itself in the presence of disturbances) and *learning* (i.e. the capability to acquire new knowledge supporting the dynamic behaviour evolution) mechanisms should be considered to provide each MAS component with capability to dynamically evolve during its life-cycle. SOA middleware can be used to face the problems of interoperability in the form of service requester and service provider mechanisms.

A provider hides its internal structure and shows only the necessary functionalities to the outside world, in the form of services. The list of provided services must be published, so they can be found by the service requester. A service discovery facility will act like a director in which services can be added, removed and located. It is estimated that the integration of web services with manufacturing software agents brings benefits for the developed MAS technology. The adoption of web services in the multi-agent, HMES holarchy satisfy the requirements:

- Resources can be encapsulated with a service provider that acts like a bridge between the internal structure and the exposed interface.
- Some services can be composed by other services, creating a levelled structure of services (e.g. task-and product-oriented learning of virtual cameras).
- Interoperability in the MAS can be addressed by using common communication semantics based on the use of open protocols, namely web technologies (services).
- Fault-tolerant attribute is provided (anomalies that may occur during the production processes, and identification in advance of possible future disturbances are handled).

The development platform for agent-based systems for enterprise reengineering can use the JADE (Java Agent DEvelopment Framework) software framework developed in Java language by TILAB, which provides some basic and necessary modules such as communication, interface design, agent kernel template, etc. JADE is composed of two parts: (i) the libraries (Java classes) required to develop the agent applications and functions; (ii) a run-time environment providing some necessary services for the agent's execution. The platform will be executed in a distributed, multi-party application with peer-to-peer communication, which include both wired and wireless environment. JADE was chosen as MAS development platform because it implements the FIPA-ACL standard agent communication language which describes every communication act with both a narrative form and formal semantics based on modal logic, and it also includes a normative description of a set of high-level interaction protocols like requesting an action, contract-net, etc.

The development of agent-based control and supervision applications in the cooperative innovation space for manufacturing SMEs raises some important implementing aspects: cooperation between agents, communication, decision-making and scheduling, self-organization, learning and disturbance handling, interaction with legacy systems and *interaction with physical devices*. In order to facilitate the development of agent-based control applications for distributed manufacturing systems, standard mechanisms and protocols should be used to implement the interaction layer between the logical component and the physical device.

The solution to implement this standard interaction process is the development of reusable libraries of objects that represent the functionality of the physical devices and implement the following basic services: *variables* (read and write), *program manipulation* ((download, upload, start, stop, pause, resume), and *events* (notifications). Using these libraries of objects, the agents can easily access the physical device.

One important point when agentifying manufacturing components is the process of connecting the physical controller to the agent. To integrate legacy and / or heterogeneous components in the agents' framework it will be necessary to develop a software wrapper to hide the details of each component. The wrapper acts as an abstract machine to the agent supplying primitives that represent the functionality of the physical component and its local controller. The agents access the wrapper using a local software interface (proxy), where all the services of the wrapper are defined.

## 4. Interrelationship between manufacturing industries and services industries

Today, "manufacturing" industries are including more and more services as part of the "products" they offer to customers. Service packages covering installation, maintenance, updating, training and so on have become an integrated part of the value chain. As a result, in many cases, services became the primary product, or services link products into wider systems.

On the other hand, manufacturing industries have largely transformed their value chains by replacing elements previously organized "in-house" partially or even entirely by external or externalized services. This flexibility is now used in the recession to adapt quickly to changing market conditions by shrinking or dropping services – an effect that can be monitored in flexible staffing services. Finally, services have become a means of enabling knowledge, specialized expertise and even competitive practices to flow faster between organizations – as e.g. can be observed in the consulting industry. This has even affected core industrial functions – such as corporate research and development.

A cooperation space should facilitate understanding the ways in which both service firms and manufacturing firms are increasingly interlinked, both in terms of products offered and in processes for bringing about these products. One is witnessing many hybrid products. An increasing number of manufacturing firms offer services surrounding the actual manufactured product (a process described as *service encapsulation*) e.g. through offering solutions instead of offering merely physical products (*tertiarisation*) and service firms make services better tradable for example by adding a physical element to it as is the case for packaged software (*productisation*). New business models emerge where service and manufacturing firms make joint offerings where demarcations between the two are fuzzy. Both can inspire and learn from each other in terms of user orientation, providing offerings to clients, operational excellence and in organizing innovation processes.

## 5. IBM: The right choice for your SOA. The SOA life cycle

Success with SOA starts with a flexible, robust infrastructure that can be used in conjunction with the existing infrastructure and IT assets to create more business value. It is also needed industry-specific knowledge and best practices to implement a SOA solution— as well as an IT partner that can provide leading-edge skills, assistance and best practices in SOA.

IBM is uniquely positioned to deliver these important assets to industry, because IBM understands service orientation — and business specific. The company's unmatched breadth and depth of investment in SOA totals more than US$1 billion per year. As part of this investment, IBM plays a leadership role in more than 50 standards bodies and holds more than 300 SOA-related patents. IBM also has extensive industry experience in SOA with over a 1000 SOA clients all over the world in industries like yours. IBM also has a thriving ecosystem of IBM Business Partners who can help implement unique SOA solutions.

IBM clients have indicated that they think about SOA in terms of a life cycle. They start in the model phase by gathering business requirements and designing their business processes. After processes are optimized, they implement them by assembling new and existing services to form these business processes. They then deploy these assets into a highly secure and integrated services environment. After the business processes are deployed, IBM clients manage and monitor these business processes from both an IT and a business perspective. Information gathered during the manage phase is fed back into the life cycle to enable continuous process improvement. Underpinning all of these life-cycle stages are governance and processes that provide guidance and oversight for the SOA project.

1. *Model* – The model phase start by gathering and analyzing business requirements that will be used to model, simulate and optimize business processes. The resulting business processes are used to design associated software services and service levels to support these processes. During this phase, it is used a model to establish a common understanding between business and IT of business processes, objectives and outcomes, as well as to help ensure that the resulting application meets the defined business requirements. This model also provides a base line from which to measure business performance.

IBM SOA Foundation provides the following products to support the model phase of the SOA life cycle:
• IBM WebSphere® Business Modeler
• IBM Rational® Software Architect

2. *Assemble* – During the assemble phase, there are created services out of existing assets, such as enterprise resource planning (ERP) and financial systems, IBM CICS® applications and other solutions that run the existing business. In many cases, a library of existing services can be used to find services that already exist in the organization. If no functionality exists, there can be created and tested a service to deliver the functionality required for a particular business process. After the required services are available, the services are orchestrated to implement a business process.

IBM SOA Foundation provides the following products to support the assemble phase of the SOA life cycle include:
• IBM WebSphere Integration Developer
• IBM Rational Application Developer

3. *Deploy* – During the deploy phase, there are configured and scaled the run-time environment to meet the service levels required by the business processes. After a business process is configured, there can deployed it into a robust, scalable, highly secure services environment. This services environment is optimized to reliably run mission-critical business processes while providing the flexibility to make updates dynamically in response to changing business requirements. This service-oriented approach also reduces the cost and complexity associated with maintaining numerous point-to-point integrations.

IBM SOA Foundation provides the following products to support the deploy phase of the SOA life cycle:
• IBM WebSphere Process Server
• IBM WebSphere ESB and IBM WebSphere Message Broker
• IBM WebSphere Partner Gateway and IBM WebSphere Adapters
• IBM WebSphere Portal
• IBM WebSphere Everyplace® Deployment
• IBM® Workplace® Collaboration Services
• IBM WebSphere Information Integrator
• IBM WebSphere Application Server
• IBM WebSphere Extended Deployment

4. *Manage* – The manage phase involves establishing and maintaining service availability and response times, as well as managing underlying services assets. It can be monitored the key performance indicators (KPIs) in real time to get the information needed to prevent, isolate, diagnose and fix problems. Understanding the real-time performance of the business processes enables providing vital

feedback to the business-process model to enable continuous improvement. This phase also involves managing and maintaining version control over the services that make up your business processes. The management phase ultimately enables making better business decisions sooner than previously possible.

IBM SOA Foundation provides the following products to support the manage phase of the SOA life cycle:

- IBM WebSphere Business Monitor
- IBM Tivoli® Composite Application Manager
- IBM Tivoli Identity Manager and IBM Tivoli Access Manager

Governance and processes are critical to the success of any SOA project. To help ensure success, there might be chosen the creation of a center of excellence within the business to implement governance policies and to follow proven international governance standards of control objectives for information and related technology. Implementing strong governance policies can result in successful SOA projects — and also has the potential to result in higher profits and increased shareholder value.

IBM SOA Foundation is more than just software. It helps create governance and processes to provide structure to the SOA solution through offerings such as IBM SOA Center of Excellence Workshops, IBM Rational Unified Process® and an IT infrastructure library. IBM SOA Foundation also offers SOA enablement through SOA-related guides, white papers and best practices based on extensive client experiences. And a variety of role-based education, including both in-person and Web-based distance learning are available to develop skills that help build SOA solutions.