Engineering Service Products: The Case of Mass-Customizing Service Agreements for Heavy Equipment Industry

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ABSTRACT

Service agreements are one-of-a-kind, and commit the service providers to certain configuration, execution, and delivery of their processes and resources over a long time. To improve productivity, the providers need a way to mass-customize the service they produce while the customers need to be able to evaluate and bench-mark the service they obtain. The field lacks sufficient results to allow neither party to construct the agreements with the efficiency and effectiveness they need. We submit that the mass customization model of manufacturing can help solve the problem; however, to achieve this goal, new and comprehensive understanding of service production is required. Therefore, we develop a reference model of service agreement engineering to help mass-customize and evaluate service agreements for, first, manufacturing-based and, then, non-manufacturing-based products. The reference model provides the static knowledge on the structuring of service processes and resources and the dynamic assessment of their costs and risks, useful for both providers and customers. We used the observer-participant method to develop and test the model with the Power Systems Division, Aircraft Engines Division, and Transportation Systems Division of General Electric Corporation. On-going work generalizes it for IT outsourcing and other non-manufacturing based service agreements. The results have promises for generalization into other service products, such as facilitating the Application Service Providers of e-business to host many different, custom processes provided to its clientele on a common base of resources.

I. The Problem of Engineering Service Products for Manufacturers

Manufacturers of heavy industry are increasingly expanding into the service sector, not just offering financial services to customers but also becoming service providers to industrial equipment and machinery. These new service products, in the form of service agreements, are strategically important to them for reasons more than one. To begin with, heavy equipment service has increasingly become a proactive, complex, and perpetuating process that generates much more revenues than the sale of the products themselves. For example, an aircraft or a power generator could last for decades, and hence their service tends to be a dominating cost item on the customers' long-term budget. Then, service also brings them close to their competitors' products and the customers' needs, to reap better marketing intelligence. This trend, as evidenced in General Electric (GE) and similar companies, is part of a general pattern in the heavy industry sector; and the pattern is even more pronounced in the Information Technology (IT) industry and the IT-based non-manufacturing service sector. The recent redefinition of IBM as a solution provider is a visible example, adding to the continued movement of banks and other service businesses towards outsourcing their IT. The application service providers of e-business have also broadened the practice of business processes outsourcing. Service agreements are at the center of all these new products of service.

Unlike selling physical products, service agreements are not one-time transactions. A complex service agreement in the above domains exposes the customer to long-term quality, reliability, and risk ramifications, and commits the provider's processes and resources over a long time. The customer must be able to analyze sufficiently the service agreement they accept; while the provider must be able to plan, design, and commit its enterprise assets to deliver the service they promise. Neither is easy and both are important, since the customer bets its business on the service agreements and the provider its profitability. However, the field does not offer much of a scientific basis for either side to assess and engineer their service agreements, and both sides continue to rely on ad hoc efforts to develop the one-of-a-kind service agreements. This problem clearly adds to the low productivity in the service sector.

We submit, however, that the new breed of service agreements is amenable to the same level of performance of mass customization of manufactured products. While IT is transforming the traditional manufacturing paradigm into one of striving towards customization, traditional service products are also seeking a transformation into relying on re-usable processes and resources, as evidenced in e-business practices. In fact, the concept of ***mass customization*** could be the unifier of both worlds. Therefore, we develop a new, ***reference-model-based approach*** to help mass-customize service products using proven IT methods, and achieve a level of performance comparable to that of products engineering in manufacturing. Although this approach has promises for service agreements in many domains, we stress ***heavy equipment, IT outsourcing,*** and the ***application service provider (ASP)*** model of service in this research. These practices all feature real-time online processes across the clientele and the host enterprise, and can all benefit from mass-customization to configure and re-use the enterprises processes and information resources. Among them, however, service agreements for heavy equipment pose arguably the highest complexity on the execution processes of the service providers, and hence represent the largest challenge to the research on a reference model. Results for this problem will be poised for generalization into domains of lesser complexity.

The challenge of servicing heavy equipment stems from the complexity of delivering service in the new **proactive** manner. The scope of the proactive service processes and systems extends much beyond the servicing of the equipment per se. Some of these enabling processes or systems would have to inter-operate between the manufacturers and the buyers of the equipment in an extended enterprise manner. They include, for example, the continual monitoring of performance with operational data, identification of anomalies from the data to diagnose the root cause of problems, and prognosis to estimate the life of the equipment. They also lead to pooling of the information drives, the forecasting and control of the inventory, as well as managing fleets of equipment. These processes and systems also feed directly into fleet analyses for the contracted equipment and risk assessment and management for a portfolio to which it belongs. The aggregation of data, knowledge and decision logic gives rise to the costing and pricing of the (long-term) service agreements. This proactive service delivery dictates additional integration of information and the flow of data and knowledge among the service provider, the customers, the suppliers, and the divisions within the enterprise. Thus, engineering service agreements means the planning and design of the service delivery platform as much as the planning and design of the service agreement contents. To define the requirements for service agreements and their platform on a case-by-case basis is a daunting task with numerous obstacles and challenges. Since no two service agreements are identical, the individual designs could all be different in their execution details. Thus, engineering service agreements on an ad hoc basis is not a preferred solution. We also recognize that a service agreement need to encompass multiple viewpoints and has value for top-level managers as well as for operational managers, system developers, customers, supplies and other stakeholders. Thus, we need a reference model abstracting the fundamental requirements into generic processes and resources to guide the engineering while achieving customization. The reference model should serve as a starting point for a corporate to plan and design the overall service platform, as well as serving as a blueprint to steer the development of individual service agreements.

The concept of a reference model is not new for IT-based manufacturing. Previous results include libraries of design functions and manufacturing processes, such as the decade-long international efforts embodied in CIMOSA, STEP and many others - see Hsu and Rattner 1992 [6] and Hsu, et al. 1995 [7], for a discussion. Reference model for information integration is also an established method (Hsu and Pant 2000 [8] and (Pant and Hsu 1999 [13]). For the equipment service sector, manufacturers such as GE, General Motors, Saab, Rockwell Automation, and Otis Elevators have studied opportunities for remote monitoring and diagnostics, two critical processes and technologies for achieving proactive service delivery. The ubiquity of the Internet and the emergence of lower cost and more powerful embedded microprocessors have also facilitated this new practice (Moozakis 2001 [12]). However, there have not been sufficient results in the literature describing what data, knowledge, and processes are required for the new service products in order to achieve the necessary integration and coordination among manufacturing functions, customers and suppliers.

The general literature of service does not provide many results in the way of reference models or mass customization. Researchers define service in numerous ways, such as a package of explicit and implicit benefits performed with a supporting facility and using facilitating goods (Collier, 1987 [1]), and a three facet concept: the prerequisites for service, the customer process, and the customer outcome (Edvardsson and Olsson 1996 [4]). Many works define the characteristics and attributes of service businesses, including the commonly used descriptors of intangibility, perishability, simultaneity, and heterogeneity; which distinguish service businesses from manufacturing businesses in the way they pose problems for service providers that the manufacturers do not encounter (Zeithaml et al, 1985 [16]). In an attempt to gain insights for service businesses, Lovelock (1983) [9] addressed the nature of the service act, the relationship between the service provider and customer, the customizability of the service, the demand and capacity, and the service delivery. Many others focused on strategic planning and service design, such as Proficiency in New Service Development, Project Synergy, Market Characteristics, and the Nature of the New Service Offering (de Brentani 1991 [3]). They are some of the results closest to the research. However, from the perspective of a reference model for service products, they do not describe the requirements of proactive service delivery, which is central to service agreements for, at least, heavy equipment.

This paper, therefore, contributes an analysis of such requirements, a new reference model based on the analysis, and a new method of mass-customization using a reference model to optimize the development of service agreements for heavy equipment industry; all of which are empirically established. We discuss the research approach in the next section, Section 2, and present the reference model in Section 3. Testing results at GE, along with illustrating cases, are analyzed in Section 4 to substantiate the claims of the work. The last section, Section 5, concludes the paper with a summary of the contributions and future work of the research presented.

II. The Approach to Developing a Reference Model

The proposed reference model is based on a study conducted at GE over the past several years (see Dausch 2002 [2] for a complete documentation). We used primarily the *observer-participant* research method (see Yin 1994 [15]), supplemented with studying results from the literature, to investigate significant and representative industrial practices and thereby abstract the common elements into a reference model. Since one of the authors is a senior computer scientist at GE Global Research, we were able to use this approach most effectively and engaged in the process several business units and their client companies, through a number of significant corporate projects. In particular, we studied in depth the case of GE as a service provider for heavy equipment, including the scope of typical GE service agreements, the processes and resources required of their (proactive) delivery, and the implied enterprise systems at GE Industrial and Power Systems, Transportation, and Aircraft Engines. The results give rise to a reference model for heavy equipment. Since this class of service represents a high end of complexity, we are currently applying it to the IT outsourcing domain and other non-manufacturing service, especially ASP, through a research partner, Genesys Consulting Services, Inc., of Albany, New York. The resultant model we developed features an Object-Oriented representation ready for implementation in software code for use by practitioners. We validated the model with users at these and additional GE Divisions and customers.

The reference model consists of two basic components: the knowledge on the common processes and resources of service delivery (*the static model*) and the assessment on risks and costs of alternative configurations of these processes and resources (*the dynamic model*). The static model provides the basic elements and the derived requirements that are typically found in the strategic statements of a business and in the tactical or operational aspects of a business. The next section presents a detailed discussion of such a reference model for heavy equipment service agreements.

III. A Reference Model for Heavy Equipment Service Agreements

A. An Overview of the Model

The general practice of service agreements involves several different classes of users (e.g., customers, engineers and managers), uses, and perspectives (Dausch 2002 [2]). The model starts with the basic goals and objectives of the provider and the customer, then builds bi-directional linkages or associations between the goals (strategic perspective) and the basic information, processes, and offerings of service delivery (tactical perspective), in an ontological manner (see [Hsu and Pant 2000] for the method). By applying these multiple views, the reference model provides a starting point and an anchor point for executives, senior level management, business planners, system designers, users and others, involved in the development and execution of the service agreement, as shown in Figure 1 below.

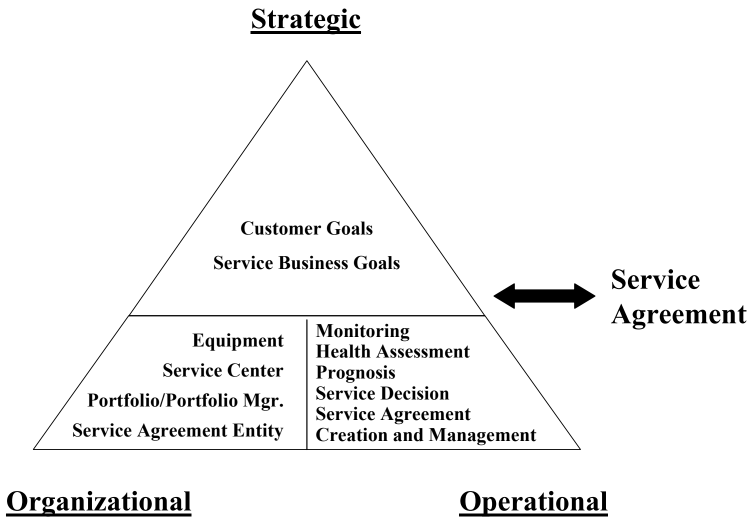

Figure 1. Overview of the Reference Model.

The model has two tiers. The top tier, Strategic, contains goals and goal hierarchies. The bottom tier, Organizational and Operational, contains views of business entities and processes. Service Agreement appears twice in the above figure. On the right, it represents the service product, a definition of who is the service provider, who is the customer, what equipment is covered by the agreement, how long the agreement is in effect, what type of service is provided by the agreement, and what conditions or actions are necessary to keep the agreement in effect. However the content of service agreements varies widely across industries and sometimes even within an industry; thus, providing us with the motivation to model the service agreement as a collection of elemental parts with associations to other elements in the model. This feature allows for the customization of the service agreement. Thus, the model also represents a service agreement as a business entity in the lower tier so as to associate it with other entities. In this structuring, it is represented as a complex object consisting of numerous elements allowing for customization of the service agreement.

The model provides for multiple entry points depending on the user’s area of interest or focus. Top-level managers and strategic planners may begin with a particular goal in mind so would enter the model from the top tier. A customer or a sales person may also begin with a goal or may start with the service agreement. Operational managers and systems designers typically would focus on some particular aspect of the business such as a process or organizational need; so they would begin with an entity or process from the bottom tier. Next we discuss each tier in more detail beginning with the strategic views.

B. The Strategic Tier: Service Agreement Planning

The strategic views include the customer goals, the service provider goals, the goal hierarchies, and the associations between the goals and the elements of a service agreement in the bottom tier (as a business entity). The customer goal hierarchy identifies the goals and the associated sub-goals that are important to the customer and may be influenced or contributed by the service provider. These goals represent the subset of the customer's business goals that are incumbent on the complex equipment they own. These goals are included in the model for the following reasons: to align the business' goals with the customer's goals through associations and to identify the information, processes, and offerings associated with achieving or supporting the customer's goals. The customer goal hierarchy uses the goal decomposition pattern [Eriksson et al 2000] to identify and associate the goals and the sub-goals. The break down of higher-level goals into lower-level goals makes the goals more concrete and better addresses how the higher-level goals will be achieved by providing more specific lower-level goals. The customer goal hierarchy consists of the following goals: satisfied customer, increase profitability, increase market share, reduce loss opportunity, increase market differentiation, increase reliability, guarantee availability, increase availability, guarantee reliability, comply with regulatory agency, comply with insurer, guarantee by-product, guarantee efficiency, reduce operating cost, and reduce maintenance cost. For brevity, we depict the five sub-goals that contribute to achieving the satisfied customer goal in Figure 2, and the satisfied share owner goal in Figure 3.

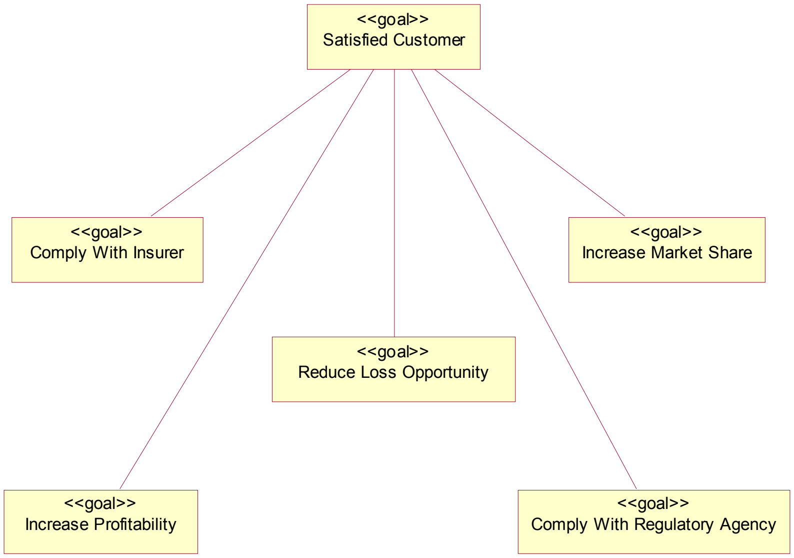

Figure 2. A Subset of Service Business Goal Hierarchy.

The service business goal hierarchy identifies the goals and their sub-goals that are important to the service provider and to the manufacturer. This portion of the model most likely needs to be customized for individual companies. The hierarchy consists of the following goals: satisfied share owner, increase profitability, service leader, positive public perception, satisfied customer, reduce service cost, increase revenue, improve service quality, increase market share, increase service density, growth through acquisition, increase market differentiation, expand to 3rd party equipment, increase service depth, increase service level guarantee reliability, guarantee availability, guarantee performance, optimize operation, and develop proprietary technology.

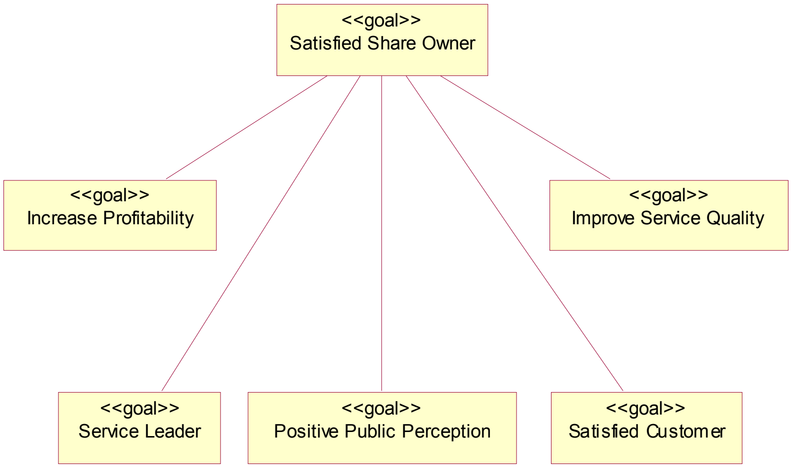

Figure 3. A Subset of Service Business Goal Hierarchy.

The third set of views associates certain service provider goals and customer goals with the appropriate subset of service standards. The intent is to define the service standards elements that are to be included in a particular service agreement to address the goals as deemed important or necessary by the service provider and/or customer. The service standards dictate how the services are to be performed. For example, to achieve the “comply with insurer” goal, the service agreement may have the following service standards: availability of equipment, equipment performance, equipment reliability, response time, problem resolution time, availability of service personnel, and availability of equipment for servicing. The specific set of standard elements depends on many factors including the types of risks covered by the insurance policy and requirements by the insurer for operating and maintaining the equipment.

C. The Organizational Section: Service Agreement Design

In the lower tier on the organizational section of the model, the model provides entity views describing important concepts of the service delivery business as high-level abstractions of key entities and the relationships between the entities. These views also establish a common vocabulary that is essential for the understanding of the service paradigm and for the development of other views and sections of the model. Some of the entities include service center, customer, service provider, portfolio manager, operator, equipment, service agreement, portfolio, service engineer, service manager, service agreement details, and service event. Using standard UML (Unified Modeling Language) notation, the entities are modeled as classes and relationships as associations, aggregations, and generalizations. The model provides entity views that center around a specific entity, which we define as the focus of the view. Within this section of the model, there are four such foci: the service agreement, the equipment, the service center, and the portfolio. Figure 4 illustrates the service agreement as an example, in UML.

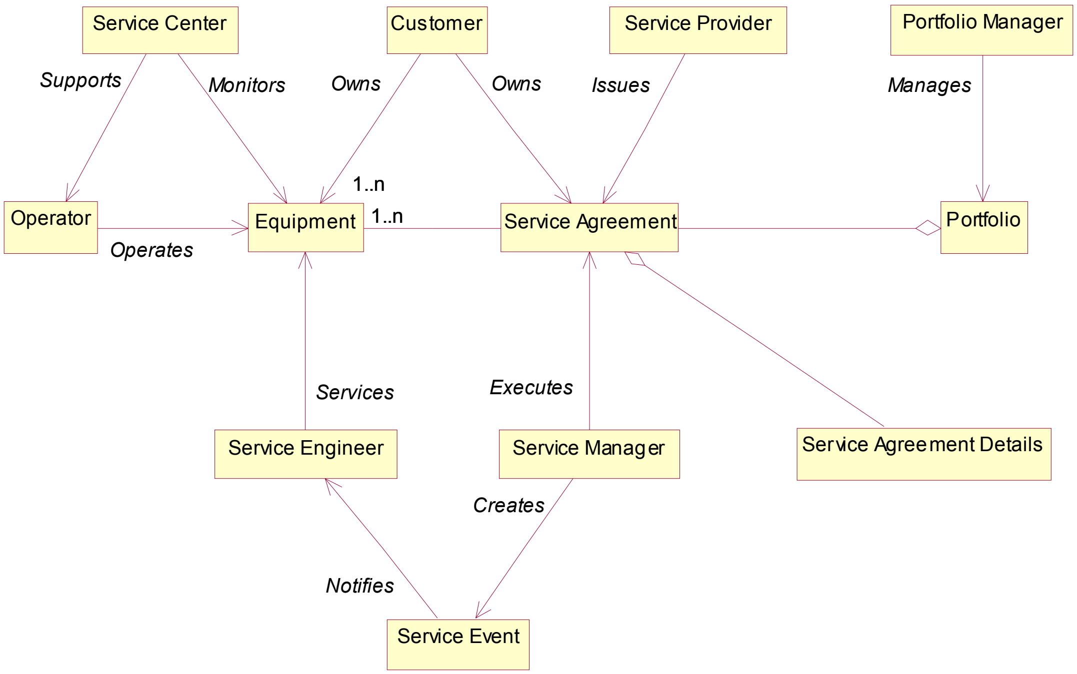

Figure 4. An Entity View: the Service Agreement.

As shown in the diagram, a service center of a provider supports the operator of the equipment, monitors the equipment on site, and issues the service agreement to the customer. A portfolio represents a collection of service agreements managed collectively by the portfolio manager. Typically, the service agreements belonging to a portfolio are either for a particular customer or for specific models of equipment. The service engineer services the equipment and is notified by the service manager of a service event. Views like this one provides guidelines to management on how to organize the service organization and what roles and behaviors are needed by the various entities.

From the modeling perspective, the service agreement is the anchor point because the other model elements are either directly or indirectly related to the service agreement entity or some element that is part of the service agreement. We discuss the fundamental elements here. The service agreement should help manage expectations, clarify responsibilities and facilitate communication between the service provider and its customers, as well as assess risks and costs. For heavy equipment industry, an agreement can be very complex with numerous terms and conditions for performance, availability, and reliability; as well as provisions and penalties for when the equipment does not perform accordingly. The parties to an agreement refer to the service provider and the customer. The service provider can be a service division within the manufacturers or an independent third party that services equipment manufactured by another company. In the second case, the third party service provider may be contracted by the original equipment manufacturer (OEM) to provide service on their equipment. The next component of the service agreement is the contents of the agreement. Since the contents of an agreement varies widely across different industries and sometimes even within an industry, we need to identify and describe the different pieces that make up a service agreement in a more structured approach. We leverage the work of Karten [98] and begin describing an agreement in terms of its key elements: context-setting information, description of services, service standards, service tracking and reporting, periodic review, and change process. Karten organizes the key elements into two categories with the first three elements belonging to the service element category and the last three the managerial element category. We extended this work by adding terms of delivery and termination to the service element category, creating an additional category for financial elements including pricing, pricing schedule, deductible, incremental costs, and incentives, bonus and rebate and creating an administrative element category. These extensions are especially important for the more complicated service agreements. The reference model depicts the service agreement class as an aggregation of service elements, managerial element, financial element, and administrative element classes. The model provides a number of detailed diagrams for the service agreement entity, which further decomposes the element classes. As an example of such diagrams, Figure 5 shows the classes that provide additional specificity to the more general service element class.

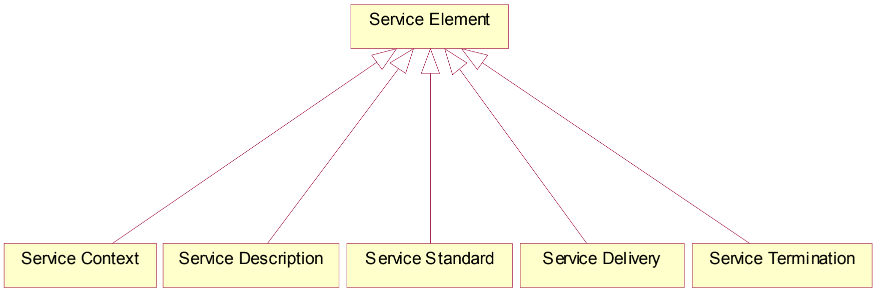

Figure 5. Partial Classes in Service Agreement.

D. The Operational Section: Service Agreement Engineering

In the lower tier on the operational section of the model, the model provides process views, which describe the core processes of the service delivery business. The model consists of *processes, tasks, inputs, outputs, mechanisms, constraints*, and associated *goals* to substantiate the *service engineering* required. The processes and tasks define the business processes and the decomposition of the processes into tasks. The tasks represent the business processes decomposed into varying levels of granularity and detail. They are organized in a hierarchical structure to depict the relationships between processes and tasks. The model represents these processes and tasks as *objects* or *entities*. In addition, the inputs of business processes are defined as those *data classes* that are transformed by the processes into outputs. The model also represents the data classes as objects or entities. The sources for these objects include external sources such as the data provided by customers or suppliers and internal sources such as the outputs from other business processes and human generated data from an expert or one sufficiently skilled. The outputs are also defined as data classes and represented as objects or entities. The sources for these objects include external sources such as the outputs from the customer's processes and internal sources such as the data generated business process. The process consumes input objects from one or more input data classes. The process produces objects from one or more output data classes. Since the objects from data classes are either consumed or produced by the business process, the model provides for the *association* of the data objects to the process at the task level. The mechanisms define the resources or agents required to carryout the process of transforming appropriate inputs into outputs. A process may be constrained by rules, regulations, finances, and such. Both the mechanisms and constraints are represented by classes in the model.

The model provides process views for the following six core processes: monitoring, health assessment, prognosis, service decision, service agreement creation and service agreement management. Each view defines the associations to the inputs, outputs, mechanisms, conditions and goals; and identifies each associated entity and the decomposition of the process into tasks, including the inputs, outputs, mechanisms and conditions for each task. As an example, Figure 6 presents the details on the monitoring process, which is a critical element in providing proactive service delivery since it supplies data and information to many other business processes including health assessment, prognostics, condition-based maintenance, equipment performance, asset management, asset utilization, and contract compliance.

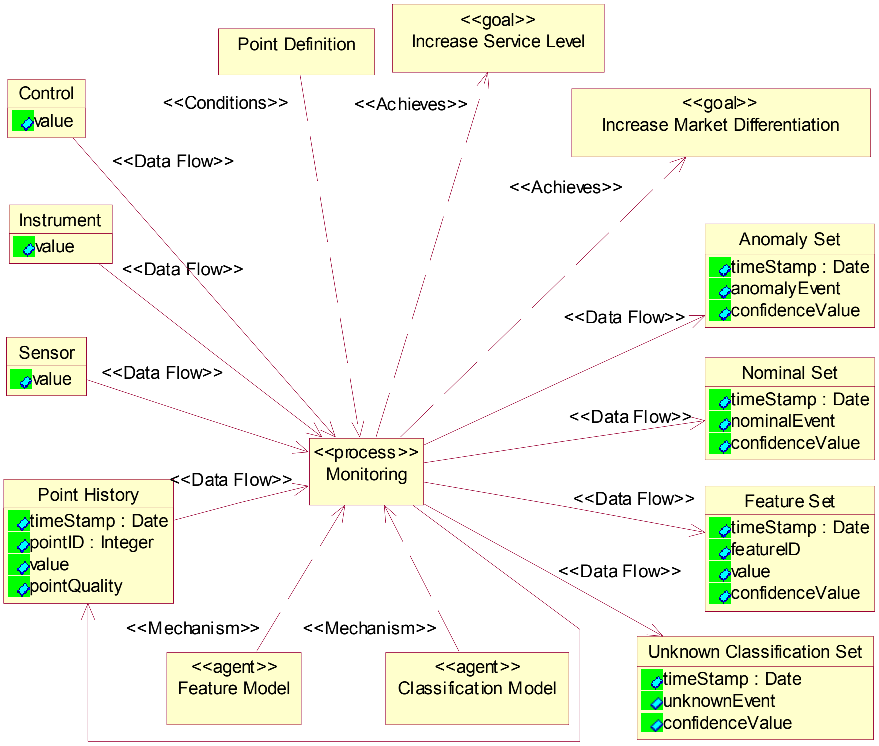

Figure 6. The Monitoring Process.

The monitoring process analyzes operational data collected for the equipment to detect trends, patterns, or anomalies in such conditions that may indicate a maintenance action, degradation in some part of the equipment or an incipient failure in a part or subsystem. The operational data comes from a number of digitized sources including sensors, the equipment controller, instrument systems, laboratory equipment, and manual inputs. The system defines a point for each external input to be tracked by the monitoring process. The model also provides for the long-term storage of previously collected operational data values, where the point history is such long-term point data. Sensors and the controls provide the majority of the operational data in complex equipment. A sensor is a device that responds to a physical stimulus such as heat, light, pressure, magnetism, motion, and sound and transmits a resulting impulse. The resulting impulse is typically considered raw data that needs to be further conditioned before the value can be used in an analytical routine. The equipment controller has output values that specify how the equipment is being operated and may indicate one or more alarm conditions detected by the controller. Complex equipment controls typically supply an I/O (input/output) interface to allow the data acquisition of control values. Instrumentation is employed in the monitoring of equipment when the equipment and controller does not have sufficient sensors and control output values or when high speed data sampling is needed for the analysis of the dynamics of machinery during transient conditions. Instruments are also used in laboratory settings for evaluating the condition of the equipment as in the case of oil analysis for wear of metallic rotating parts. Anomaly set represents the known anomaly events that may have been detected in the operational data, while nominal set represents the known nominal events from the same source. Both sets may trigger the health assessment process. Unknown classification set collects all operational values that were unable to be classified by the classification analytics. The set initiates an alert for the expert to review the data to determine the cause of the unknown operational data value(s). Point definition provides configuration information on the point data, which specifies how the data is to be collected and stored. The point definition consists of attributes such as sampling rate, maximum value, and minimum value. The values of these attributes are used as parameters during the data acquisition and data validation tasks. The model provides for two generic analytics, the feature model and the classification model. The feature model defines the mechanism for extracting features from the operational data, while the classification model analyzes and classifies the features based on predefined patterns.

The reference model associates two goals to the monitoring process: increase service level, a service business goal, and increase market differentiation, a customer goal. Both goals can be decomposed into more detailed sub-goals. Ideally, the monitoring process should identify all anomalies before a failure occurs; but in practice this does not happen. The development of better algorithms and techniques is an on-going research area. Success in improved analytics is the driving factor for achieving these goals. The monitoring process may be configured from the following seven tasks: clock, acquire point set, condition point set, validate point set, update point history, extract feature, and classify feature. Depending on the goals that are being achieved the monitoring process is configured accordingly.

The health assessment process is responsible for determining the health of the equipment and to identify certain conditions in the equipment that may warrant some service action. The health of the equipment is assessed by comparing the current operational state of the equipment with predicted values or knowledge about how the equipment should be performing. The health assessment process evaluates the measurements, the features, and other indicators from the monitoring process to detect any degradation in the performance of the equipment. In the case in which degradation has been identified, the process attempts to estimate the extent of the degradation. However, an accurate determination of the extent of any degradation may require more direct techniques such as inspection or testing. The health assessment process measures and analyzes the state of the equipment to identify faulty conditions that may indicate an early warning of some failure. This type of fault is classified as an incipient fault. This capability is a key to proactive service delivery in which the service provider anticipates problems and takes action before the occurrence of some unplanned outage event due to a failed system, subsystem, or component. However there may be situations in which one or more faults have already occurred but the operator may not be aware of the condition or may not know the source of the fault. In this situation, the health assessment process should identify the fault with the cause of the fault and alert the appropriate personnel. Upon identifying degradation in the performance of the equipment, the indication of an incipient failure in a system, subsystem or component, or some failed part event, the health assessment process attempts to identify or localize the source of the abnormality.

The prognosis process is primarily responsible for making projections on the future health state of the equipment and the remaining useful life of the equipment given its projected operational profile (Thurston 2001 [14]). The condition of the equipment is based on the measurements collected by the monitoring process, on the features produced by the monitoring process and on any fault sets determined by the health assessment process. The condition reflects the current health state of the equipment. The prognosis process analyzes the condition of the equipment together with the knowledge about the equipment to estimate how much longer the equipment may be operated at specific operational level(s). The future health state and the remaining useful life may be predicted for systems, for subsystems, for individual components or a combination thereof. A health assessment process may diagnose a known fault condition or may detect degradation in the health state of the equipment, while the prognosis process further assesses the diagnosis to forecast a failure and to estimate the time to failure (Leger et al 1999 [10]).

The service decision process makes recommendations to the appropriate personnel for service actions based on data and information from various sources, including the monitoring process, health assessment process, prognosis process, service policies, maintenance manuals, service agreement terms and conditions and regulatory requirements. It may also be augmented by an economic model, a financial model or other decision support system to determine service actions for the decision maker. The types of information required for such decision making depends on the sophistication of the equipment, the understanding of the equipment, the impact of the decision, the level of experience and knowledge of the decision maker, the internal, external, contractual constraints, and other factors. Some typical decisions include correcting the equipment, compensating the equipment, executing a field operation and performing no service. The correction, or repair, may be to replace or overhaul a degraded or failed system, sub-system or component and may result in an outage event. The decision to compensate the equipment pertains to modifying the operational settings of the equipment or adjusting the degraded or faulty system, sub-system or component so that the equipment can continue operating safely but at some reduced level of performance. The decision to execute a field operation represents those service actions that initiate change to some procedure or process. For example, through the analysis of data, it may be determined that the operator is using an incorrect or sub-optimal control setting. The execution of a field operation may result in instructing the operator on how to improve the performance of the equipment with the correct control setting. There also may be a decision to perform no service at all. In the case of a degraded component, the result of such a decision implies running the equipment to failure. Maintenance philosophies may also influence the service decision (Thurston 2001 [14]); typical ones include condition-based maintenance, preventative maintenance, and run-to-failure maintenance. Complex processes may have elements of all three.

The service agreement creation process produces and executes a service agreement. In a proactive service delivery business, this process is complex in terms of data and information consumed, mechanisms to carry out the tasks, and conditions that control the tasks. The complexity of the process depends primarily on the agreement itself. In industries that typically have standardized service agreements, this process is simple in that it requires little information and may involve only the customer and a service provider representative. In other industries such as power plant equipment, the service agreement may be highly customized, involving numerous people during the process. The typical activities involved with this process include collecting customer and equipment information, analyzing the information to estimate the costs, the price, and the operational impact, drafting the agreement, reviewing and finalizing the agreement, and then approving and executing the agreement. The time to complete this process for a complex and highly customized agreement may take on the order of months or even a year. The model provides the requirements including information and the process for creating the service agreement typically found in the complex equipment businesses, and outlines the complexity of this process.

The service agreement management process is responsible for overseeing the service related activities from the perspectives of equipment operations and performance, service related costs and expenses, contract coverage and compliance, and reporting on such to the appropriate stakeholders. When a service agreement consists of terms and conditions such as reliability, availability and performance, the process evaluates the data and information collected from the equipment together with service reports to ensure that the equipment operations and maintenance are sufficient to meet those requirements. The service agreement management process also monitors the financial impact of the service activities to determine whether or not the service agreement was priced accurately and the charges are being incurred and billed appropriately. The service agreement management process generates numerous types of reports as dictated by the service agreement. The regulatory agency may require periodic reports on the emission levels from the equipment and insurer may require reports describing the maintenance activities performed on the equipment or unscheduled outages due to a problem with the equipment. The customer should be notified periodically with summarized information including the equipment performance, the services rendered, costs savings, important issues, and any other information as specified in the service agreement. This process may be considered a quality control activity in which the service delivery is measured, analyzed, improved and controlled to meet the needs of the customer.

E. Use of the Model

The details, such as data items and the object representation of the above structure are documented by Dausch (2002) [2]. We now describe briefly how a particular goal is used for configuring a service agreement and for defining the process requirements. As depicted in Figure 7, the user starts by identifying one or more goals that are to be achieved either from the service provider's perspective or from the customer's perspective. The model will guide the user to evaluate each child goal associated with the goal(s) designated, until reaching leaf nodes. When the user evaluates a particular goal, the model will provide for relationships between the goal and components of the service agreement. These components dictate the service standards to be incorporated in the service agreement. Likewise, in evaluating a particular goal, the model may through relationships prescribe one or more processes required to achieve such a goal. The user can continue the evaluation process by examining each of these processes. Depending on the goal or goals of interest, the model defines the configuration of the process including the process steps, the inputs, the outputs, the mechanisms to execute the process or steps, and any controls or conditions needed.

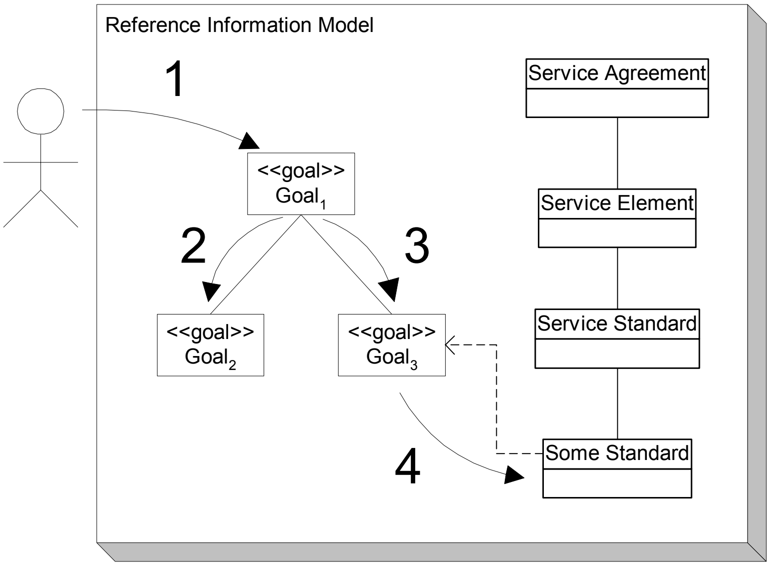

Figure 7. Use of the Reference Model.

The model also provides for other usage patterns. The user may identify certain core technologies or capabilities that the service organization possesses or may identify certain core technologies that the service organization plans to develop. These capabilities are then mapped to one or more processes, which provide a starting point for the model usage. With the knowledge of the processes required and their relative roles in the proactive delivery of the service committed, with respect to the particular goals stated, the customer can assess the service agreement in the way of quality assurance and value. The provider can also assess the same, in addition to using the model to guide the planning, design and configuration of its enterprise systems toward satisfying the commitment. When each edge of the structure (in an object representation of the model) is also associated with certain risk and cost measures, alternative configurations can be assessed, as well. The derivation of risk functions and cost functions is beyond the immediate scope of the paper.

IV. Validation of the Reference Model

In validating the reference information model from a contents perspective, we applied the model to a test case for evaluating the correctness and completeness of the model. This test case involves a business closely related to the three businesses used in the empirical study. We selected GE Power Systems Generator business.

A. The Design of the Case

The design of the test case follows a two-phase approach. The purpose of the first phase is to inform the interviewee on the objectives of the interview session, the contents of the model, and the different usage patterns for the model. During this phase, the interviewee was provided with a set of diagrams organized by the two levels of the model including the service agreement, strategic views, entity views, and process views. Also another set of diagrams was provided that depicted the following usage patterns: goal driven, opportunity driven, and organizational usage. The interviewee indicated that the model's organization and structure was easily understood and seemed logical.

The second phase involves the actual usage of the model. The interviewer assists the interviewee in selecting views, retrieving more detailed information, and traversing the model between levels and within levels by following associations. The intent is to determine the usefulness of the model, the completeness of the model, and the applicability of the model to the particular business selected for the test case. During the second phase of the test case, we asked the interviewee to access various views of the model and to provide feedback on the correctness, the completeness, and the applicability of the model to the service business in which the interviewee is employed.

The interviewee began by applying the goal driven usage pattern as shown in Figure 8. The intent was to retrieve the requirements for processes to achieve the particular goal. The guarantee availability goal was selected. This goal is directly associated with the health assessment process and the prognosis process.

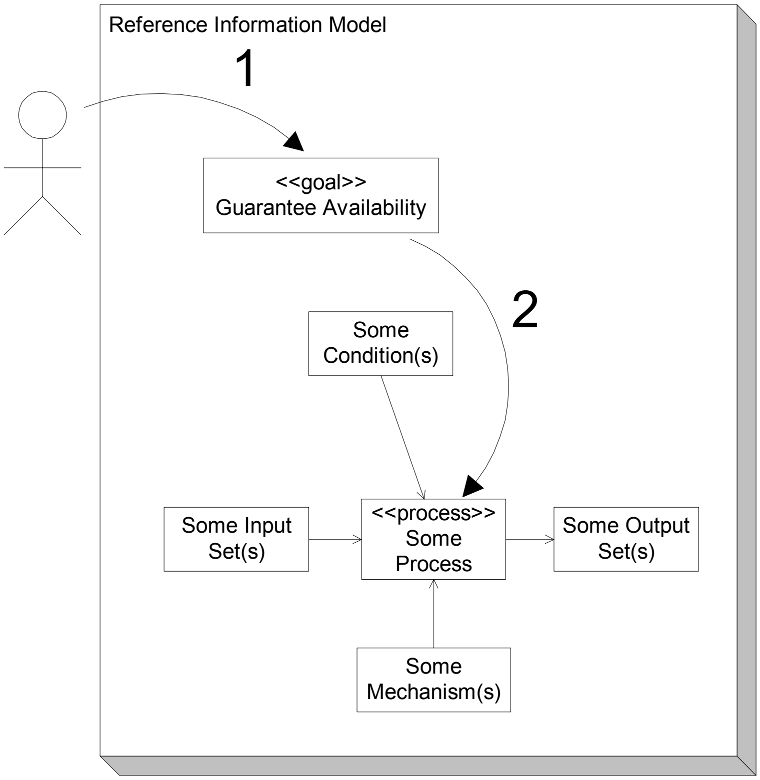

Figure 8. Beginning with Guarantee Availability goal.

B. The Application of the Model

In evaluating these two processes, the reference information model prescribes the following: inputs, outputs, mechanisms, conditions, process steps, and for each step, the inputs, outputs, mechanisms, and conditions. For brevity, we only shown the high level detains of the health assessment process

Inputs	Outputs	Mechanisms	Conditions
Point History Feature Set Anomaly Set Nominal Set Unknown Classification Set	Health Condition Set Fault Set	Reasoning Mechanism Diagnostic Model	Reasoning Parameter Modeling Parameter

Table 1. Details of Health Assessment Process

Step Number	**Step Name**
1	Diagnostics
2	Root Cause Analysis

Table 2. Health Assessment Process Steps

Inputs	**Outputs**	**Mechanisms**	**Conditions**
Point History Feature Set Anomaly Set Nominal Set Unknown Classification Set	Health Condition Set Fault Condition Set	Diagnostic Model	Modeling Parameter

Table 3. Details of Diagnostics Step

Inputs	**Outputs**	**Mechanisms**	**Conditions**
Fault Condition Set	Fault Set	Reasoning Mechanism	Reasoning Parameter

Table 4. Details of Root Cause Step

Next the reference information model provides for downward traversal to children goals in order to prescribe additional processes that may be associated with the children goals. In this scenario, there are none. The model then provides for traversal upward to parent goals, which are contributed to by the lower level goals. As shown in the Figure 9, the guarantee availability goal contributes to the increase service level goal. The model retrieves the requirements for all of the processes associated with this parent goal.

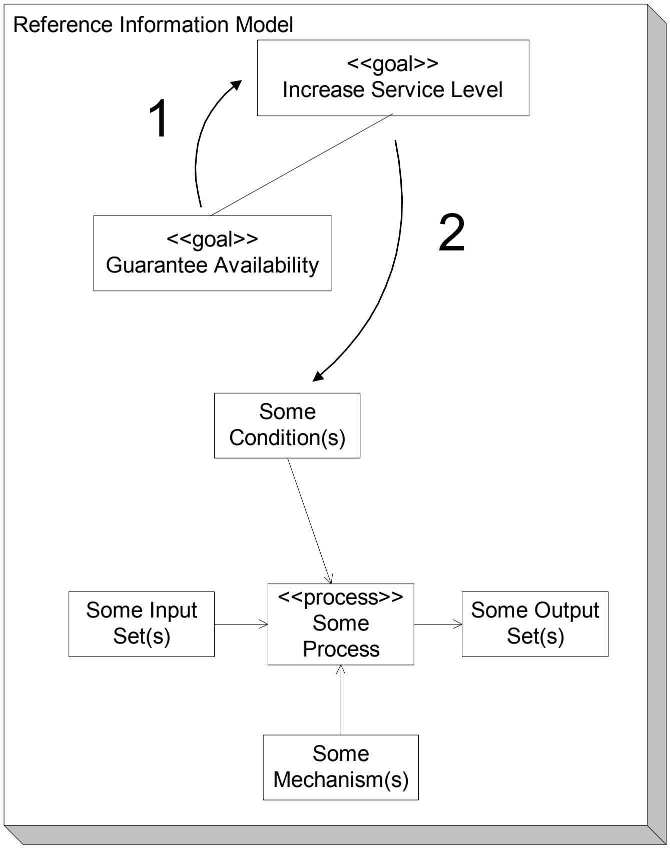

Figure 9. Goal Hierarchy Traversal

For the increase service level goal, the following four processes are specified to achieve this goal: monitoring, service decision, service agreement creation and service agreement management. Again for brevity, the details are omitted from this discussion.

C. Service Agreement Configuration

To achieve the guarantee availability goal, the reference information model prescribes the following configuration for the service agreement. The major elements are shown in the first column of each table and each subsequent column decomposes the prior element into more specific elements.

Service Element	Service Context	Party (Customer)	
		Party (Service Provider)	
		Service Purpose	Service Reason
			Service Intent
			Service Benefit
		Service Scope	Service Coverage
			Service Restriction
		Service Assumption	
		Service Contact	
		Service Summary	
	Service Description	Service Coverage	
		Service Restriction	
		Organization (Customer)	
	Service Standard	Service Availability Standard	Availability of Equipment
			Availability of Service Personnel
			Availability of Equipment for Servicing
		Service Responsive Standard	Response Time
			Problem Resolution Time
			Recovery Time
		Service Timeliness Standard	On-time Delivery
	Service Delivery	Customer Requirement	
		Claims for Compensation	
	Service Termination		

Table 5. Service Element Configuration

Managerial Element	Service Tracking		
	Service Reporting		
	Service Review		
	Service Change		

Table 6. Managerial Element Configuration

Financial Element	Pricing		
	Pricing Schedule		
	Deductible		
	Incremental Cost		
	Compensation		

Table 7. Financial Element Configuration

Administrative Element	Title		
	Signature		
	Date		
	Revision History		
	Table of Contents		
	Glossary		
	Reference		
	Appendix		

Table 8. Administrative Element Configuration

The interviewee agreed with the general contents of the model and recognized the usefulness of the model for the planning and the designing of proactive service delivery for heavy industrial equipment. The interviewee did not provide any comments regarding the completeness of the model; however, no gaps were identified.

V. Conclusion: Mass-Customization of Service Agreements

We have studied the requirements of proactive delivery of service for heavy equipment through General Electric Corporation, and generalized the results into a reference model for the development of service agreements in the field. Current results support different perspectives of service agreement design, including for example corporate strategy, organization, processes, and behavior; and unite them toward the logical structuring of service delivery. The logical structure prescribes the information contents and the execution processes underlying the service, and the enterprise systems that develop and implement the service. The model has been tested satisfactorily with some GE users. These results are presented in the paper.

On-going work further develops the assessment of relative risks and costs of alternative configurations, validates the model with additional GE divisions, GE clients and IT service providers. Furthermore, we call for similar studies at other manufacturers, or direct application of the proposed model thereof, to develop an industry-wide knowledge base, which could include a common reference model, a standard, or bench-marking. Toward this end, the development of a methodology for mass-customization using a reference model and a software implementation of the model would be beneficial. This line of research presents many opportunities for empirical studies to expand, generalize, and improve the model and its application.

The complexity of heavy equipment service is among the top of all manufacturing product services; thus, the resultant reference model should have direct applicability to other equipment service agreements and contribute to this significant sector of economy. However, the potential contributions go beyond this domain. We expect that the continuing research will yield sufficient results for engineering service agreements for IT outsourcing and some ASP type of e-business in non-manufacturing domains. The technical characteristics of the service products studied here, such as the reliance and emphasis on browser-based computing, extended enterprises, and re-usable, re-configurable enterprise processes and information resources and systems, are rapidly permeating into a much larger portion of the economy. As the applicability of this approach expands, the opportunity for major productivity gains in service through mass customization becomes more realistic, too.

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