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INFRASTRUCTURE FOR THE ADVANCED VIRTUAL ENTERPRISE: A REPORT USING A BRAZILIAN-BASED EXAMPLE

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An advanced vision of the virtual enterprise is described, one with distributed control centers. We show how information infrastructure for such a case can be balanced with innovations in "ordinary" infrastructure. Some novel technical ideas are outlined in the context of an example specific to Brazil.

1. INTRODUCTION

1.1 Advanced Virtual Enterprises

The field of Virtual Enterprises has an unlucky blessing in that so many diverse activities use the term. Virtual Enterprises, even those represented at this conference, range from small companies allied for consolidated bidding to advanced supply chains, to even mundane distributed operations. Unfortunately, those of us working to provide VE infrastructure face an unhappy reality that solutions to the simpler cases do not take us closer to solutions for the more advanced types. In fact, the evolutionary approach creates increasingly higher boundaries to satisfying the more interesting and beneficial advanced case.

In order to insure that our work is useful, we focus only on the more advanced VEs, and we believe that these new business models have promise of beneficially revolutionizing the way business is done. Our hierarchy of types of VEs begins with:

- Distributed Enterprises. This of course is the simplest and very common case, whether we are talking about global distribution of production assets or the workers reporting to one location working "virtually" from home or mobile offices.
- Add to this the case where the work is distributed among many different companies. This is also a common situation, whether we are talking about supply chains or partnerships. What makes this case more difficult is the challenge of

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coordinating processes across ownership, policy, legal and corporate culture boundaries. Most of the attention to VE infrastructure is at this relatively simple level because it is what most managers think about, because it is amenable to evolutionary progress, and because it responds well to graduate-student-sized (meaning relatively unambitious) research projects. At this level VEs are a relatively trivial problem.

• Add to this the situation where the VE is opportunistic. Most VEs today are capability-driven, meaning they look at their assets and possibilities and derive products. The "lean" management fad formed small, tight, stable associations of companies who constantly refine their expertise in focused markets. More interesting and profitable is the complement: someone identifies a high value opportunity and then assembles the VE to address it. There are a few cases of this type of VE, usually resulting in the creation of stable joint ventures that often become enterprises relatively independent of their progenitors. Needless to say, opportunistic information infrastructure presents tremendous challenges compared to infrastructure for processes and products which you can anticipate well ahead of time.

• Add to this the ability to allow the VE to be highly dynamic, having the ability to add and slough off partners easily and to have those partners be unlimited. This has been called the "promiscuous" VE, which is quickly assembled to address an opportunity and then dissolved without undo penalty. VE infrastructure in this case depends in part on federating infrastructure of partners who cannot be anticipated or significantly controlled.

• Add to this the dimension of extreme speed. In other words, the windows of opportunity open quickly, have a short period of high profit and then either close or become competitive on price alone, a situation most smart enterprises want to avoid. Obviously, the problem is one of quickly creating infrastructure as well as cheaply. We remind the reader that several paragraphs back we already left the domain where monolithic architectures are viable solutions, even via standards.

• Add to this the idea of normalizing risk and reward of innovation within the VE. This is to say, you have a highly decentralized system, composed of independent entities. Each will have their own selfish interest which will usually not be in the best interest of the system of the whole enterprise. The infrastructure should support evolution of the enterprise, so that any action taken by a partner both improves the enterprise and benefits the partners.

An example of this last behavior is in order. In the military aircraft business, the supply chain is frozen very early in the game, both as a lean practice and due to military contracting rules. But between that early point and full production, key technologies go through many generations. Say the tail section is planned to be made of aluminum and a subcontractor is selected based on cost and quality. Say also that halfway through the design, it is shown (by the prime) that a composite tail would be better. The subcontractor will fight the improvement, and subsequently force the enterprise to pay for them to learn the required skills. This actually happened on a very large program.

In an advanced VE situation, key partners would all be in for a piece of the action. The tail subcontractor will be rewarded for investigating alternatives, even if it means putting itself out of the manufacturing flow. Specifically, the partner will be rewarded for trying, for finding a better alternative, and for gracefully substituting another partner if required.

• Finally, add to this equation the possibility of a partner not only investigating and effecting change within itself for the betterment of the enterprise, but to do so within other partners as well!

The reader will have noted the difference between this situation and that of current e-commerce. At this writing, there is a rush to link up business-to-business partnerships via the internet. These are mostly procurement brokers and supply chain managers. But in both cases, processes remain invisible behind the wall of the offering firm. There is no shared risk-reward; there is so system-level optimization of product or process; there is in fact no means at all to provide a product that is not already commoditized. The advanced VE is far from this model, and it is just as well. Commoditized products compete on price; opportunistic products compete on timeliness and appropriateness and are much more profitable.

1.1 Information Infrastructure as Trade-offs from Other Infrastructures

We've been sponsored to perform detailed studies of various types of existing VEs (Goranson, 1999):

• The US 19th century whaling industry: an extremely long-lived, community-based environment. This VE displayed agility in both opportunity and threat, including a remarkable chapter of creating a widespread need for a ridiculous but successful product (the corset).

• The current US film industry: a similar community-based VE environment. It is highly profitable and opportunistic. Evolutionary products are common.

• Silicon Valley: a startup oriented environment, with heavy capital fluidity, non-technology orientation and a tradition of evolutionary product development.

• Iranian Food Distribution: a non-loan oriented value chain where value is determined at final sale and percentages are adjudicated by religious authority.

• Diamond Exchange: an interesting enterprise based on adding value through distribution. It relies on extreme trust, family legacies, and specialized skills.

• Russian Mafia Enterprises/US Urban Illegal Drug Distribution: an opportunistic class of evolutionary enterprise. Adjudication can be by death, and extremely high profits can be achieved.

• Italian Textiles: also project oriented, with very small partners, and a closed, stable support community.

From these (and others of course), we have discovered three key needs that a VE infrastructure would support. We'll adumbrate these in the next section. But first an important observation: each element of information infrastructure supplants and extends infrastructure that exists in a less capable way in a non-infrastructure way. For example, a mundane VE information infrastructure is the telephone which simply extends the physical infrastructure which supports interactive conversation.

All of the cases which we studied were localized or brittle VE's that are restricted by a lack of information infrastructure. Our method was to determine the underlying infrastructure needs that were unique to the VE condition and to extend those into more capable information infrastructure that can be applied in a generic case. All this was overseen by a large, long-lived industry advisory board.

2. THREE BASIC VE INFRASTRUCTURE NEEDS

All successful VEs use some version of the following three principles. It appears that for the more advanced cases that we list above, some acceleration or extension of these needs must be accomplished by information infrastructure. This need defines our research agenda to provide support to eliminate barriers to advanced VEs. One should note that we recognize that any revolutionary information infrastructure carries risk, even when it mirrors existing practice. Therefore, any business entity will mitigate risk by limiting its infrastructure risk by employing the new information structure only in the places where the alternatives are not viable. Our Brazilian example below will illustrate this.

The three main areas of infrastructure unique to VEs are:

• Agents for certification of opportunities, products, partners, infrastructure, binding methods and processes,

In essentially all current cases, these agents are trusted humans in relevant communities. Some examples are:

•• Specialized consulting firms, in-house marketing departments and some divisions within ad agencies help identify trends and instances of new products. Some are based on coolness or styling, some from advances in product or process technologies and some from demographic shifts. For example, Nike and Sony support product brainstorming teams that have substantial authority as agents.

•• In some VE environments, special certifying agents broker unknown partners. This is well established in Hollywood, where a dense fabric of artist agents filter capabilities of individuals and labor unions certify teams in the trades. Specific legal responsibilities fall on these certifiers, in some cases exceeding that of the actual performers. In Silicon Valley, the certifiers are informal, but still powerful as certain persons act as (usually paid) certifiers of technical and/or business acumen of key players. In the mainstream manufacturing economy, the agency is highly informal, and often supplemented by blunt methods (Dunn and Bradstreet, ISO 9000, word of mouth…).

•• Certifying agents for infrastructure take the form of key analysts in the investment sector, in special consultancies and consortia. To a growing extent, the agency in information infrastructure is moving from huge companies ("if IBM adopts this approach, it must be the best, or can be made so") to disembodied notions of "open systems."

• Lightweight binding methods (usually based on contracts) for establishing ordinary and novel risks and rewards, together with their monitoring and adjudication. This is the dynamic complement to the agents: agents will leverage these methods to evolve the VE to optimize returns for both the enterprise and its partners.

The infrastructure for this need is more sophisticated in the current VE context. In some strong VE communities (Italian textiles, Hollywood, Diamond trade, Iranian food distribution) the binding mechanism is one of person-to-person trust which works because of a strong adjudication mechanism. Sometimes these are religious or family authorities; in the Hollywood and whaling instance the infrastructure consists of robust case law so that very concise letter contracts can be used. Generally, there is some trusted retrospective adjudication authority.

• A "High Concept" to harmonize the partners at the feature level, or better the "value" feature level. In simple terms, all these diverse partners, who are unfamiliar with each other and perhaps even the collective product, need a common, shared vision around which to coalesce the collective action. We use the term "High Concept" because that is the well-studied technique that the film industry uses (Wyatt, 1994).

Current infrastructure for this role is primitive in all the cases we studied. All the VE examples we encountered relied on a heavy human interaction and high cultural homogeneity. The "high concept" description depended on references and jargon specific to the niche culture supporting the VE culture. Of course this has the effect of excluding any potential partner from outside of the established community.

In the non-VE context of the aerospace and automobile industry, we have the phenomenal success of the digitized, annotated 3D model which is shared by many players. This information technology innovation serves as an unambiguous focus for the enterprise. In this case, the product itself is the unifying goal; of course this only works when the product definition is rather stable. Indeed, we have studied the apparently common case where this much celebrated infrastructure limits the flexibility of both the enterprise and the product.

These three VE requirements are each amenable to enhancement by advances in information technology. We think that some enhancements are likely to occur without our research, and therefore are not targeted in our work:

• Partner Certifying Agents. We may see services that certify individual companies that sell standard capability (like machine shops). These may be "pull" services, sponsored by assemblers of VEs, or "push" services more like annotated Yellow Pages. In either case, the certification needs to be dynamic, showing available capacity and historically how well the company stretched into unfamiliar territory.

• Product Certifying Agents. We will see internet-based services that analyze huge demographic/purchase databases to identify niches and predict trends within those niches (possibly using epidemiological meme-based methods). This will open huge, temporary profitable product opportunity windows.

We assume that identifying product opportunities and potential partners is just a matter of brute force, not requiring revolutionary elegance and so while likely profitable is not an interesting problem domain. Instead, two domains of the remaining problems interest us.

• The first are techniques to quickly and cheaply federate manufacturing execution and business process infrastructures without resorting to oppressive frameworks or in fact any undue intrusion on the innovative, independent nature of the potential partner. Standards are largely counterproductive here as they promulgate obsolete boundaries. Object oriented techniques, quite popular for application development, are also a problem in this space as they hide abstraction details. Our results in this area are extensively reported elsewhere in the VE literature (Goranson, 1997).

• The second area addresses a way to define the "high concept" in a way that the value added by any action of a partner can be measured and presumably recompensed in a novel risk/reward strategy. This is the infrastructure reported in this paper.

3. OUR INFORMATION INFRASTRUCTURE SOLUTIONS

Our application service provider (ASP) strategy provides two primary services:

• The modeling of "Value Features" which functionally characterize the elements of the product which the customer values together with a mapping through "Product Definition Features," "Enterprise Process Features," and a set of "VE Management Features." All are functionally linked, with the first three tracking and rewarding the value that each VE element contributes to the VE value in a steady state. The last tracks partner value in evolving the VE.

• A distributed infrastructure that allows each partner's process to essentially effect change in the VE based on independent initiative.

These are outlined below. The two together provide the infrastructure foundation for the three VE needs previously noted.

3.1 Value Features Drive the VE

The VE needs some definition of what the VE is all about, the "High Concept" that we described above. The old way of satisfying this need is for a division in the enterprise to translate the customer values into a product and present the product, or its definition, to the VE for design and production. A breakdown of the work is a breakdown of the product in this way of linking philosophy. There is absolutely no mechanism for someone on the process end to know if a process-driven improvement will improve the product's real value without consulting the marketing division to confirm their guess. As a result, the product is prevented from generally evolving based on new insights within the enterprise, and specifically prevents effective insights from the manufacturing partners.

We provide the infrastructure to create and support this set of value features, depending on VE experts to determine the features using methods external to our system. Though over time, we would expect a standard reusable "built-in" vocabulary to emerge. This may evolve into a consulting service, but for the present, we focus on products whose features will be outside any given vocabulary since those are the high-profit mercurial windows for VEs.

However, a high level taxonomy of Value Features remains constant, consisting of:

• Market Features: Cost, quality, timeliness, reliability, and similar quantitative product aspects. Simple numeric vectors and matrices are employed here.

• Direct Features: these are specific to the product, measuring the "direct" functionality of the product. In the Brazilian example VE described below, direct features for the Reliability Monitoring and Enhanced Throttle System would include how many functions are sensed, the fidelity of the sensors, the completeness of the data fusion process, the spectrum of conditions covered, the percentage of fuel savings, the percentage of equipment failures that can be predicted, and such features. The list could be quite large, collectively measuring the direct benefit of the product. Generally, these measures are derived from external contexts, so are usually quantitative, like the Market Features. But in some cases, such numbers are derived from mathematically sophisticated analyses. When the functions can be isolated we import the whole function.

• Cultural Features: These are specific to the cultural context into which the product is inserted. If the product is athletic shoes, then this set of qualitative features might track "coolness." the extent to which the product helps define a person's self-worth, or perhaps helps define an identity. Cultural Features are by definition "soft." A Situation-Theoretic formulation is used, where the "situation" tokens are adapted to represent unknown functional dynamics (Barwise, 1983).

Each of the four feature sets (Value Features, Product Definition Features, Enterprise Process Features, and VE Management Features) draw from and interface with external systems provided by others. Value Features are a new concept so there are few analytical programs with which to interface. This is not so with the next set: the Product Definition Features follow the ontology established by the external Product Data Management System being used. Or in the case that the product is amenable to decomposed product definitions, these features relate to the multiple external PDM systems, providing an integrating common set.

As noted elsewhere, the novelty of the approach has four elements:

• An integrated middleware based on the "federating mechanism" defined in previous work (Goranson, 1992) that merges and normalizes abstractions of external applications with enterprise states.

• Some Category-Theoretic techniques for managing and manipulating these abstractions, in particular for topologically-founded concept clustering (Asperti, 1991).

• All abstractions are based on functional types (as a foundation for the above-mentioned categories) and are lazy (to allow for the distributed action infrastructure described below).

• We incorporate soft notions of value (like coolness) as first class citizens in the functional logic.

The value we add with the elements we've described so far is the ability to integrate "vertically," for the first time allowing for a formal definition of customer value and formal linkages from that to product features. Below, we take this further to actual manufacturing processes in a functional way. In other words, someone deep in the VE would have an idea that if she could make her element a nickel more costly it wouldn't matter at all, but if she made it 2% more capable in some direction the value to the customer would zoom 10%. More: the VE would know some important things:

• That the value to the customer just went up, so presumably more cost can be demanded, resulting in higher profit.

• The VE would know exactly what features were improved. Presumably, these features are drawn in a consumer-friendly way, so the VE knows how to advertise the improved value.

• The VE knows who to reward for this windfall.

• The VE knows now to look for similar feature linkages elsewhere in the VE.

But value is also added "horizontally" as this medium of features provides the most primitive means for federating among the various presumably heterogeneous infrastructure of the partners.

Staying with the first two feature environments for a moment, the architecture is centralized and usually interfaced by humans through a thin, browser-based internet client. Information exchange and fusion among external systems, like Customer Relations Management or Product Data Management systems is a different matter. We have a conventional generic interfacing method that maps external objects to the internal feature functions of the system, so if the external system appears to be object-oriented the wrapper is trivial. Standard labor-intensive and otherwise imperfect methods are used to interface to poorly formed external systems — there's no magic bullet for that.

There are two novel ideas in this half of the infrastructure:

• The abstraction space employed (in both halves actually) is functional in the programming sense. Functional abstraction is a method of programming that instead of figuring out the steps the computer must take, it focuses on defining the world of the problem space, its functions. Functional thinking is a non-intuitive approach for those not used to it, but is an extremely powerful and natural way to capture transforming relationships like our features and (more importantly) the relationships among features.

• An environment which supports dynamic multi-methods and multi-inheritance is important to the internal mechanics we use. The feature elements need to be functional, but the external system behavior needs to be object-oriented. Fortunately, our typing method is very clean in differentiating between external object behavior and internal features and provides simple methods for wrapping (federating) to external object environments, by CORBA where convenient. We are also fortunate in having a language and development environment specifically designed to merge object and functional methods, Dylan (Shalit, 1996). More ordinary environments can be used with some tradeoffs.

3.2 The Process Control Infrastructure

The second half of the infrastructure is more complex, the additional complexity resulting from:

• The specific capturing of causal mechanics as we move into the operations of making and improving the VE's product, and making and improving the VE itself.

• Support for the revolutionary notion that basic control of the VE is distributed in the simple sense (local control over processes), but also in the more impressive sense of one process controlling or directing action or change in a remote cell or domain.

The ASP implementation in this second case is as a broker to fat clients, integrating with the infrastructure of the first half, consisting of:

• Value and product features
• Links to external opportunity and partner brokers.

The integrating type abstractions are functions again, but this time concerned with functions more purely capturing the causality of state change. The problem of distributed control with late binding is well known and as we work with functional abstractions we rely on the mechanism of lazy evaluation. Our intent is to exploit the distributed functional environment Erlang developed in the telecom industry. Our novelty is:

- In the simple case, a careful functional grammar and the mapping of those functions to external control agents or decision support systems.
- In the more complex case, the functions are structured in a non-hierarchical layer of abstractions, where each layer employs a different internal ontology, each layer contains abstraction functions for the layer below, and all layers employ exactly the same apparent representation. This is based on group categories, and the purpose is to have useful worlds for each layer of interest in the VE from the enterprise to each partner's cell. The requirement is because the behavior of any enterprise is not a simple aggregation of its components and this reality is acute in the advanced VE case.

The wrapper ontology that relates internal features to external process software (such as enterprise resource planning and manufacturing execution system applications) is based on the Process Specification Language (Schlenoff, 1998). The state-introspective kernel, Darwin, is based on Mach, though other public source kernels promise to develop similar capabilities. In fact, every external component of the environment is based on open or public domain sources.

- Dylan: <http://www.gwydiondylan.org> < http://www.functionalobjects.com>
- Erlang: <http://www.erlang.org> <http://wwwbluetail.com>
- PSL: <http://www.nist.gov/psl/>
- Darwin/MACH: <http://www.publicsource.apple.com/projects/darwin/>

Our value added is the aforementioned "vertical" integration which ties customer values through product design to manufacturing and support activities, as a sort of value added based management. The horizontal integration allows each cell visibility into how its actions affect every other cell or process as arbitrary levels of aggregation and how each activity contributes to the customer value features. It is perspective sensitive: any user can see the world as it flows from their own perspective, rather like those joke maps which make your home city the center of a vanishingly small world as the distance increases from home.

The general benefit is that this allows any player to see the "big picture" or any domain subset and perform system optimization from their perspective. A specific benefit is that the value improvements are auditable — that is, they can be tracked and rewarded. An advanced functionality is to develop causality fabrics from any node, via features to another node. A meta-analyst can then work in the concept space to look for, or create clusters. Our novel use of structured abstractions allows us to use topological transforms of types to look for clusters. One application is to discover linkages for metaprocesses, and we have developed specific agility metrics from this capability (Goranson, 1999).

Now we will introduce an example and walk through various functions with the intent of describing how the infrastructure is constructed.

4. DEVELOPING ECONOMIES AND THE CASE FOR BRAZIL

We believe that this approach would work well as a suite of internet-provided applications because the abilities of the application will evolve over time — all users should get the benefit of insights developed through work with any user. The internet model lowers costs in general and may provide for logical partnerships with internet-based partner and opportunity registrars. Cross-partner scheduling and planning services will follow as they are technically trivial.

Furthermore, we believe this business model of an advanced VE will first find great utility in the more mature emerging economies. We base this conclusion on an extensive study done for the U. S. military on barriers to advanced VEs (Goranson, 1999). A primary barrier is in how financiers seek collected assets: it is more attractive to finance Ford for a year's worth of cars than to finance a temporary affiliation of 5,000 small companies, with distributed assets to do the same work.

G7 economies suffer from an unhappy accident in the evolution of business. A quirk in the mechanics of capitalism created an equivalence between the activity that collected capital and the activity that managed the enterprise. So Ford managed the enterprise of manufacturing cars, and also managed the enterprise of collecting and allocating capital. The great revolution of VEs is not that complex items can be made at much less cost, or markets addressed that are currently overlooked, or that innovation will explode, or that workers will be more empowered and individual creativity more rewarded. All those are probably true, but the real revolution is that for the first time we have a mechanism for managing the complex enterprise independent of the management of capital.

American and European capital markets have trouble being convinced of this, we can reliably report. But Brazil, for instance has a different twist. They desperately seek infusions of foreign capital, but the only mechanism they currently have is to accept huge prime contractors at the same time. So to get capital into the automotive sector, for instance, they get a Mercedes plant. But it's not Damlier-Chrylser money, it's investment money that the lender likes to "attach" to a large company's plant. What results is an economic colonialism where Brazil can never get ahead. The high end work is done elsewhere, and profits inevitably flow away.

An alternative is an advanced VE, where the small Brazilian suppliers can directly add value, moving faster than the big companies to develop niches. Greater innovation and lower operating costs can generate high profit that stays with the small companies and fuels ever-increasing VE activity. Brazil is especially attractive for our example because:

- Brazil has a very robust, modern auto sector, mostly concentrated in one region. It is overbuilt because only recently did Brazil open its market and everyone rushed in. They did so because there is a huge market, bigger than US and Europe by some estimates (because of the expected first-time buyers that will eventually appear) and they couldn't afford to be left out. It serves as a sort of business practice laboratory for many of the US/European manufacturers there.
- We expect Brazil to be the new Pacific Rim-like phenomenon in high tech manufacturing: there is a pent up, underutilized capability of what Americans used to call "Yankee ingenuity" and what Brazilians call "Jeito."

• The Brazilian legal system is more modern than that of the U. S. or Europe, being a recent "third generation" legal system. As such, it makes the kind of "instant contracts" we need easier. Also, the tort system is more rational.

• We may see help of various kinds from World Bank/IMF/Brazilian authorities because the VE is the only way out of the economic problems there without establishing a vexing "economic colonialism."

• There is already a maturing, university-based VE lab and incubator in the state of Sao Paulo, with connections to similar, industry-connected labs elsewhere.

5. A BRAZILIAN EXAMPLE

5.1 Background

The following is presented as only an illustrative example. The product domain of the example is integrated consumer information systems for automobiles. The most vital sector of the consumer economy is the computer/consumer electronics market for personal use. The largest sector of the manufacturing economy is the automotive sector. In recent years, computer-like control systems have been standard in cars. And of course the automobile has always led in promoting radio/tape/CD players. But the introduction of consumer-side electronic technology in cars is far less than the apparent demand, and far, far less than is feasible and profitable.

Why so slow? Big enterprises are slothful. There are fundamental labor union barriers, but the primary reason is that whatever they do has to appeal to millions of users. A market of tens of thousands could be profitable, but is not worth the effort to the behemoths. Another problem is that there are many product options in this auto-electronics space and it is not known with certainty what will really catch fire with consumers. The big guys cannot afford to try a lot of things to see what works, but that's exactly what VEs are good for.

Our example would establish several tiers:

• At the "top" would be an Application Service Provider to provide elements of the VE information infrastructure and a few other elements of infrastructure through consultants and advisors.

• At the next level would be a stable set of VE agents. These will be agents with high levels of trust in the relevant domains. The trust mechanism is not discussed here, as it employs known principles. These agents will be co-located, either at the distribution end (North America and Europe) or the VE end (Brazil), but divide time between both. The roles of the VE agents are:

•• An engineering/product facilitator, responsible for identifying product candidates and engineering partners.

•• A manufacturing facilitator, dealing with the obvious.

•• A platform facilitator, concerned with what car/truck models are supported and customer demographics supported. This person is partnered with the marketing partner facilitator.

•• A legal agreements/trust facilitator, who is the most important person, insuring that agreements are lean but risk/rewards are just and serve the goals of the enterprise. This may involve managing "third party" adjudicators, and certainly links with a legal advisor.

•• A logistics facilitator, who does not manage logistics directly, rather the logistics partners. This person sets the scalability of finances.

•• A marketing partner facilitator, who handles the end which presumably will use ecommerce and marketing partners (big retailers with auto shops: Kmart, Walmart, Sears and perhaps repair franchises. If partnered with an automaker, liaison with their service group.) Also manages public relations. One would assume that the VE be extremely open about the model and encourage competition to blunt concerns about the new business model.

•• A capitalization facilitator, whose job not only includes the conventional issues of external financing, but sets the rules for internal rewards in the case that partners develop a superstar innovation that takes the VE to an initial public offering or acquisition. This person is partnered with the trust manager.

• The next level are the VEs proper. As there will be many products and many distribution relationships explored, there will be many specific VEs. These will be casually formed and dissolved based on product and market probes. The purpose of our example VEs is to develop several different types of products and perform a market triage on them:

•• Those that don't find a profitable market. These will be cheaply dissolved.

•• Those that find a profitable market. These will continue as formed, evolving naturally using the risk/reward infrastructure.

•• Those that turn out to be "superstar" products. These enterprises will have been formed with an exit strategy, either an initial public offering or a sale to a large manufacturer or a merchandiser.

The target products are not entertainment electronics; that need is already well served and doesn't require the kind of cross-disciplinary system engineering our VEs will leverage. More about this: the application will specifically target electronics which require engineering and manufacturing of either the electronics, an automotive component or both. Possible applications include such things as:

• Embedded computer control in drive trains

• Installation of additional sensors and a supplementary control and reporting computer to the fuel injection/transmission system

• Radar spoofing (has to be built into body)

• Advanced situational/global positioning satellite cruise control advisor, sensing surrounding vehicles

• Vibration monitoring for reliability (quite attractive in bus/truck fleets)

• Biometrics recognition/adjustments/fatigue aid

The VEs will avoid safety-related items that will carry liability (brakes, road lights, airbags). The strength of the VE is that it will quickly assemble experts to integrate and manufacture between the disciplines of electronics (sensors and computers) and mechanical auto parts. The experts will be in different firms of course, and the engineering and manufacturing is expected to be done across many small firms.

The VE marketeer would go for early adopters and the highly paid professionals who already has $50k+ in their vehicle. Each of the products are a significant engineering problem since the mechanical parts involved will be of many different types (from different models) and because care must be taken to not disrupt factory-installed systems to prevent voiding of warranties. The VE would take care to shake out which auto models and years to support; that would depend on which manufacturers to partner with. An example partner mix would involve some engineering and manufacturing in the state of Sao Paulo Brazil, and perhaps a marketing relationship with Fiat/Ferrari/Porsche distributors.

Indigenous partners in target markets would be found or invented for much of the legal and logistics activities. We've separately authored a study on the community requirements for the core VE agents (Goranson, 2000a) This experiment does not depend on the existence of such a campus, but the core team must be based in one place.

5.2 Walking Through the Brazilian Example

This notional example is based on infrastructure currently in construction, and whose components have separately been validated in other projects.

Let's suppose that someone in Italy has a business idea based partially on innovation and market knowledge. She suspects that there is a small but highly lucrative market in Saudi Arabia for custom drive chains for Ferraris. The number of customers is only 500-800, but at very high profit based on normal design and manufacturing costs. But the one-time costs of identifying, financing and integrating a team make the project unfeasible. No one knows whether the business has a long-term future after the initial opportunity. This is perfect for the advanced VE.

The players in this example are:

- the Idea Originator in Rome. This person does not have the skills to run a company.
- the VE facilitator team based in New York and (the city of) Sao Paulo.
- the Application Service Provider (ASP) based in Virginia, the United States.
- the Platform Customer, Ferrari in Turin. Many VEs will not have an intermediate customer like this, but it makes the example more interesting.
- the VE design and manufacturing partners in the state of Sao Paulo, drawn in this case from a prequalified pool maintained by a local university.
- the Customers. Anchor customers are in the monopoly states in the Mid-East, with possible but unknown continuing markets elsewhere, wherever superluxury cars are sold.

The Idea Originator logs onto the ASP and goes through an automated process of evaluation. This initial process is rather complex in itself, and is partly described below. At the end of that process, the idea is judged to be worthy of proceeding, and a matchup has been made of the originator in Rome, some financiers (whose location is irrelevant), and the VE facilitator group in New York. The New York group already has a good idea that a Brazilian-based VE would work well.

Note that we already are talking about several VEs: the group in New York which is a VE of sorts (whose product is VEs) and the pre-existing group in Sao Paulo who operates notionally as a VE, but which subsets as operational VEs. We'll have the VE of the Rome plus New York plus Sao Paulo assets. And we have the larger VE which includes Ferrari (a group of Fiat) who markets the product, performs the final assembly after order, and supports delivery.

The initial evaluation involves modeling, sometimes superficial, of processes within the VE agents among all of the VEs noted above. Indeed, multiple simulations in an agent space were what were used to evaluate the idea and match up the tentative partner groups.

Within the ASP we need models to run the simulations that build and optimize the VE. We use the same model types to manage operation of the VE. Some components come with models, some do not; in the latter case we create rudimentary models by asking structured questions. For instance, we model the idea as it comes in by a structured query. Practically, the Brazilian candidates will be adequately modeled, Fiat will present a structured process for integration and the VE facilitators will also be well modeled. Of course, inherited models will vary as to methodology and veracity. In our scope, we do not worry about updating remote models because the project horizon is so short.

We deal with three levels of model. We have the actual models that the agents use, or that we have created (and have stored). From those, we abstract a metamodel which indexes the value features and captures certain structure of the model. This step serves three purposes: it allows us to federate among different models, it allows us to manage and affect the customer value by relating every process element to that value, and it allows us to use the graph segments as agents in agent simulations (after another mapping).

This translation is made by reference to an annotated PSL, the standard for process ontology. The annotations are based on a sparse "speech act" performatives. This is possible because we are concerned with process to process optimization rather than optimization within a process. Source models are stored as relational information in mySQL. The mapping to graphs is performed in an object space by simple application of methods, using Python and related object stores. (The mySQL and Python tools are used because everything is administered via web.)

So we have the models and their structured graphs. All of our direct control is via the graphs. But we maintain a third abstraction as well. This is a relaxation of the objects into functions, and for this we depend variously on the object/functional languages we noted. Once we have the graphs as semantically active functions, we can apply them to agent spaces.

There we can try different combinations of ideas, facilitators and performers. Essentially all interesting behavior in this space is non-linear, so many and continuous agent simulations are required to advise on VE creation and operation.

Back to the example. The idea is one of several presented by the originator and of hundreds of similar ideas evaluated. We report back on expected success based on certain remedial business tasks (for example a specific financing strategy), on different facilitating and partnering configurations. This evaluation is done on the agent level; there is no control at this point.

We broker the arrangements to finance and license the idea to the New York facilitators, based on evaluated value added by each partner. Those value metrics provide a basis for risk-reward adjustments in payments as the VE evolves. For instance, if one of the Brazilian partners goes beyond expectations and greatly adds value, even by decreasing it's own role, it can be fairly recompensed.

The VE facilitators reference very similar simulations via web in forming the design and manufacturing VE in Brazil. But this stage simulates control functions as well. Prior history with the partners calibrates the simulations. Once the VE partners are selected, the work begins.

The work is managed through the ASP, relying on the value tracking. Our experience is that a considerable advantage of VEs is their ability to adapt once the work begins. So in addition to tracking work flow, we have to monitor, induce and reward evolution.

What the idea originator sees is a lengthy modeling process, followed by reports of agent simulations and recommendations. She needs to be in the operational loop for evolutionary change in the product and indications of derivative ideas.

What Fiat sees is a single subcontractor. What the customer sees is a commercial response to particular needs. The Brazilian small partner sees three things: the coop run by the local university that characterizes, precertifies and educates them for VE readiness; the VE facilitators in New York, one group in several who draw on their pool, and the temporary VE created to design and make drivetrains.

In this case, if the Brazilian partner creates some intellectual property at its cost that helps the VE, it gets more reward. If perhaps the exit strategy for the VE is to transition to a stable supply chain for Fiat, then that partner gets to license the new process or design to the enterprise.

6. SUMMARY

The Advanced Virtual Enterprise is poised to become an important component of the economic landscape. Web-enabled infrastructure is required, but the demands are extreme. We need to evaluate the non-linear behavior of many combinations and strategies for feasibility and optimization. We need to quickly federate diverse information infrastructures, and manage system-wide value to support trust.

Speech act-based graphs can be feasibly used in mundane internet systems to support these requirements, but we need to employ some open source mechanisms, some standards. We also need to exploit some fairly exotic techniques of functional agent abstraction from object systems.

Brazil is a good candidate for the operational partners for the first recurring instances of advanced virtual enterprises.

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