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Diagnosing Unforeseeable Uncertainty in a New Venture[?]

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Diagnosing Unforeseeable Uncertainty in a New Venture*

Abstract

Many startups undergo major adaptations of original business models before succeeding. When tackling new markets or technologies, *unknown unknowns,* or unforeseeable influences, emerge that cannot be planned for or mitigated by traditional risk management techniques. At the same time, important decisions about the management systems of the startup must be made at the outset, before unknown unknowns reveal themselves. How can this conundrum be resolved?

Based on work in decision theory, we propose that a venture management team can diagnose problem areas vulnerable to the presence of unknown unknowns, although not the influences themselves. A case study demonstrates that a diagnosis of unknown unknowns at the outset of the venture is indeed possible under plausible circumstances. Based on the case study, we propose a diagnosis process for unknown unknowns.

Successful diagnosis of unknown unknowns allows the management team to choose appropriate management systems for the venture. Although one case study is not sufficient to establish generalizability, it suggests hypotheses to be tested and avenues for further work in how to address situations of unforeseeable uncertainty.

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New ventures often do not correctly foresee real market opportunities or the best ways of addressing them, and so are forced to adapt and modify their approach over time, as a classic quote illustrates:

> When a new venture does succeed, more often than not it is in a market other than the one it was originally intended to serve, with products and services not quite those with which it had set out, bought in large part by customers it did not even think of when it started, and used for a host of purposes besides the ones for which the products were first designed. (Drucker 1985, p. 189).

This challenge is often reflected in the contracts between Venture Capital (VC) investors and the entrepreneurs: under high uncertainty, the VC installs control mechanisms that allow for the redefinition of the venture's actions in response to unexpectedly emerging events (e.g., Kaplan and Strömberg 2002). This has also been discussed in the business press ("the challenge is to recognize and react to the completely unpredictable" (Brokaw 1991, p. 54)) and for ventures within large corporations (e.g., Van de Ven *et al.* 1999). Adapting to the unpredictable is difficult – many new ventures fail.[1]

Yet, not all new ventures are so novel that they must deal with the unpredictable – after the 2001 burst of the dotcom bubble, venture capital firms have retracted and tended to invest in later stage startup companies with known management teams, technologies and markets.[2]

Findings in the fields of technology management, innovation, and project management over the last decade have shown that dealing with the "unpredictable", or unknown unknowns,

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[1] In a study of U.S. venture-backed information technology merger, acquisition, and IPO "exits" from 1992 through June 2004, IPOs were 45.5% of the exits and accounted for 60.4% of value. In 2004, IPOs accounted for only 4.8% of the exits but represented 32% of deal value (de Young and Pearce 2004). Of another 383 companies studied between 1969 and 1985, 34.4% experienced a partial or total loss of invested capital, 49.8% returned between 0 and 5x, and 9.8% returned between 5 and 10x; the 6.8% of the investments that returned 10x or more account for half of the ending portfolio values (Sahlman 1990).

[2] Over the last decade, VCs have shifted investments from less-developed firms (startup/seed and early stages) to more-developed firms (expansion and later stage). Venture capital investment in the start-up/seed stage decreased from 16.1% in the first quarter of 1995 to 1.7% in the fourth quarter of 2004 while the share of later stage investments increased from 15.4% to 34.4%. Over the same period, VC investment fell from 24.0% to 18.6% in the early stage and rose from 38.1% to 45.1% in the expansion stage (PricewaterhouseCoopers 2005).

requires management approaches and supporting systems different from those used for classical "plan-and-achieve-target" projects (Mullins and Sutherland 1998). Such management approaches for novel initiatives have been proposed; they include a combination of trial-and-error *learning* (or flexible re-definition of the venture business model as new information emerges, Lynn *et al.* 1996) and *selectionism* (or running multiple parallel trials and choosing the best performing one *ex post*) (De Meyer *et al.* 2002, Pich *et al.* 2002). However, management approaches for a new venture must be chosen at the outset. Therefore, choosing approaches that can deal with unknown unknowns requires that the potential for these unknown unknowns must be *diagnosed* at the beginning, before they emerge.

While we have consistently heard from experienced venture managers and project managers that they believe they have a "feeling" for where their knowledge is limited, such a claim is controversial. Some researchers think that the concept of "diagnosing unforeseeable influence factors" is an oxymoron. Thus, our research question is: *how can unforeseeable influence factors in a new venture be diagnosed at the outset*? The reply, "do a better initial homework to make all influences explicit" (corresponding to risk identification in risk management jargon) is insufficient—many ventures enter new market or new technology terrain where important factors cannot be identified initially, no matter how hard one may try (Drucker 1985, cited earlier).

In the next section, we discuss the nature of uncertainty. In Section 2, we outline existing theory about unforeseeable uncertainty and general methods for managing it identified in previous research. In Section 3, we develop a conceptual approach to diagnosing unknown unknowns that involves decomposing the new venture's situation into sub-problems.

We then present a case study of a startup, Escend Technologies, to explore whether such an initial diagnosis of unk unks is possible under plausible circumstances. In the case study, the *presence* of unknown unknowns was successfully predicted by diagnosing gaps in the team's knowledge about certain sub-problem areas. Based on this exploratory case study, we outline a *process* for systematically identifying the vulnerability to unforeseeable uncertainty.

1. An Overview of Risk, Uncertainty, and Unknown Unknowns

Uncertainty is a fundamental concept that has a rich history of examination in economics and management, and we begin by reviewing its major characteristics.

The simplest form of uncertainty is "risk", or the possibility of several possible outcomes for a situation, each with a probability of occurrence that can be measured (e.g., from experience or experiments). For example, in roulette, black or red may come up, but which one is not known. Yet the probability of 25/51 can be assigned to each (1/51 being the probability of a zero).

Knight (1921) pointed out that often the probabilities are not known. As Keynes (1937) put it later, "there is no scientific basis on which to form any calculable probability whatever. We simply do not know". This more challenging situation is referred to as "Knightian uncertainty", and sometimes as "ambiguity" (the absence of a probability distribution).

Methods have been developed to deal with ambiguity. Savage (1954) introduced the concept of "subjective probability" and showed that a mathematical treatment is still possible when people "guess" their own probabilities. Second, ambiguity can be represented as a probability distribution over a multitude of possible probability distributions (e.g., Camerer and Weber 1992), making possible the mathematical treatment of this extended concept of uncertainty. The discipline of project risk management has developed principles of risk identification, risk prioritization and risk management (preventive, mitigating, and contingent action), and risk incentives (Amit *et al.* 1998) which can deal with ambiguity as long as all important factors (although not their values) and ranges of outcomes are known (e.g., Chapman and Ward 1997, Smith and Merritt 2002).

However, these concepts do not fully capture the unforeseeable uncertainty faced by a novel venture. They assume that the "space" of relevant variables and influence factors, and their possible outcomes and causal connections, are known – only the probabilities are unknown. In a novel venture, management often knows much less. An influential paper in Technology Management characterized it as "the inability to recognize and articulate variables and their functional relationships" (Schrader *et al.* 1993).[3] The "space" of parameters and outcomes is *not* known; there are things out there that are not on the horizon at all. Economists have called this difficult state of affairs "unawareness" or "unforeseen contingencies" (Kreps 1992, Modica and Rustichini 1994), scholars in public policy have referred to "wicked problems" (as opposed to the "tame problems" that we know how to analyze (Rittel and Webber 1973)), and engineering and project management professionals have used the term "unknown unknowns" (expanding the "known unknowns" of Knightian uncertainty), or "unk unks" (Wideman 1992).[4]

When a venture develops a new technology or tackles a new market, unknown unknowns are rampant. For example, Sun Microsystem's Java was conceived as a remote control with operating system for household devices, but it ended up being a programming language for the world-wide web (which had not existed when the project was started; see Bank 1995).

2. Existing Theory of Responding to Unknown Unknowns

Existing models from project management can help a new venture respond to unknown

[3] As a symptom of the disagreement in terminology across fields, consider that Schrader *et al.* actually called their concept "ambiguity", although that contradicts the use of the term in economics and decision theory.

[4] The term is, in fact, "folklore": it has been widely used in aerospace, electrical machinery and nuclear power project management for decades.

unknowns. A project can be defined as a "unique interrelated set of tasks with a beginning, an end, and a well-defined outcome" (PMI Standards Committee 1996). A venture is like a project that starts with an entrepreneur's idea, obtains funding, follows agreed-upon milestones, and ends when a merger, acquisition, IPO, or a transition to a self-financing and profitable ongoing concern has been achieved – or when the business closes.

Consider a model of decision making in a project or a venture with unforeseeable uncertainty (based on Pich *et al.* 2002 and Sommer and Loch 2004). We conceptualize a venture as an *outcome*, represented by a payoff function $\Pi = \Pi(\omega, A)$ (for example, think of Π as the IPO valuation). The project payoff depends on the state of the world $\omega \in \Omega$ and a *chosen* set of actions A (which represents what the team and the investors do over the course of the venture).

Ω denotes the set of all possible "states of the world" relevant to the outcome of a project, with $\omega = (w_1, \ldots, w_N)$ as a generic element. Each parameter w_i may take any value from its domain D_i. One ω represents one combination of realizations of all parameters. A state of the world may include management team capabilities, resource costs, competitor moves, market demographics, emergence of other technologies, technology difficulty, regulatory changes, and myriad additional influences.

The established discipline of project risk management gives management teams tools to choose a "best" course of action A^*, maximizing the expected payoff $E[\Pi(\omega, A)]$ (or some other risk-adjusted measure).[5] Hedging, buffers, or contingency plans are known tools that maximize the expected payoff in the face of uncertainty in the venture. These methods are powerful when all important elements of the state vector ω have been identified and their ranges are known.

[5] The theory in Decision Sciences is concerned with (possibly imperfectly observed) Markov processes and Bayesian updating (for example, Marschak and Radner 1972, Lovejoy 1991). State of the world, conceptualizable events and probabilities can be mathematically represented with probability spaces. We do not describe the mathematical entities in full here, because we use the model to describe what diagnosing unk unks entails, but not to perform mathematical operations.

However, the presence of unforeseeable uncertainty means that an entire set of influences is unidentified: the management team knows only of the existence of the first *n* influences $\omega_{\text{known}} = (w_1, \ldots, w_n)$. Thus, performance is also conceptualized in a smaller number of dimensions $\Pi_{\text{known}}(\omega_{known}, A_{\text{known}}) = \Pi(\omega_{\text{known}}, \overline{w}_{n+1}, \ldots, \overline{w}_N, A_{\text{known}})$, a function of fewer variables.

The team is unaware of the $(N\text{-}n)$ unk unks, or unforeseen dimensions, and therefore not aware of additional actions that would be available if the team knew of the additional influence dimensions. For these unk unks, the team proceeds under implicit and possibly wrong "default" assumptions, as if they were set to *fixed values* $(\overline{\omega}_{n+1}, \ldots, \overline{\omega}_N)$ (which, except by chance, will differ from the true values that the project will later encounter). Thus, the unforeseen dimensions are taken as parameters, as "given", without being recognized as such.

Consider Circored, a breakthrough facility to convert ore into iron (a key material for steel-making) that was built in Trinidad between 1997 and 1999 as a joint venture between the US company Cleveland Cliffs and the German company Lurgi Metallurgie (Loch and Terwiesch 2002). Careful risk management was conducted, but because the facility used radically new technology, the required scale-up of the chemical process from the lab tests to an industrial facility created unforeseeable uncertainty: material dust cycles occurred where they should not have, material stuck to pipe walls, material flowed differently than expected. The facility was forced into a two-year trial-and-error learning process to stabilize performance.

Unforeseeable uncertainty requires methods that go beyond risk management (Williams 1999). The model outlined above yields two fundamental management approaches, or combinations thereof, that cover the range of possible responses (Pich et al. 2002, Leonard Barton 1995). The first is *selectionism*, or *parallel trials* of multiple approaches, observing what works and what doesn't (without necessarily having a full explanation why) and choosing the best approach *ex post*. For example, pharmaceutical companies use this approach when investing in "backup molecules" for the same target indication to provide insurance if the lead molecule fails. This approach is also possible, on a smaller scale, within a venture, for example, by trying several configurations, user interfaces, or marketing messages to make sure one of them works successfully (e.g., Beinhocker 1999, McGrath 2001, Sobek *et al.* 1999).

The second approach is *learning and adjusting over time*, or "probe-and-learn", and has been documented in technology transfer, innovation, and new ventures (Chew *et al.* 1991, Lynn *et al.* 1996, Thomke and Reinertsen 1998, Van de Ven *et al.* 1999, Pitt and Kannemeyer 2000, Chesbrough and Rosenbloom 2002, Mullins and Sutherland 1998, O'Connor and Veryzer 2001). This approach requires constant questioning about what is known and the flexibility to fundamentally change course if necessary.

A key question for a new venture management team is how to choose between these two management approaches. Previous work suggests that the answer depends on two factors: whether significant unforeseeable uncertainty is present, and the level of complexity of the initiative.[6] Complexity of a system refers to many system elements interacting such that the behavior of the whole cannot be predicted from the behavior of the parts (Simon 1969, p. 195). This means that in a complex venture, events are hard to predict and even hard to correctly interpret in hindsight, because so many influences are conflated that causality is unclear (Pich *et al.* 2002, Kauffman 1993, Rivkin 2000). Therefore, complex systems exhibit "unexpected" behavior that requires vigilance, iteration and flexibility (Weick and Sutcliffe 2001). In other words, complexity can cause unknown unknowns even when no component or influence factor by itself behaves unpredictably.

[6] Of course, costs are important—sometimes pursuing several solutions in parallel is simply not affordable. Or, the time delay associated with experimenting and learning is unacceptable. Most often, however, cost differences are either not clear, or they are dwarfed by the differences in the value potential that the two approaches offer.

To give an example of a startup that faces both complexity and unforeseeable uncertainty (Sommer and Loch 2006), consider a company that produces novel chemical products for industrial sewage purification. Product efficacy is greatly influenced by its composition, temperature, humidity, time, container, sense of responsibility of employees, subtle processing differences across producing labs, inconsistencies in the customers' plants and products, process and technology. All these factors interact in ways that are too complex to be understood. Worse, this list is not complete—not all factors are even known. Therefore, product quality and efficacy are not stable. The company responds to this combination of unforeseeable uncertainty and complexity by pursuing selectionism: it has signed several technology cooperation contracts with institutes and laboratories and routinely tests multiple formulations before launching one, but there are still product failures.

Figure 1 summarizes the circumstances under which each management approach is suggested to have the higher value potential (the decision theory is developed in Sommer and Loch 2004, and empirical support for the theory is offered in Sommer *et al.* 2006).

		Complexity	
		Low	High
Unforeseeable Uncertainty (gaps of knowledge)	High	**Trial-and-Error Learning:** flexibility to fundamentally re-define business plan and venture model	**Selectionism after "full information":** best trial selected only *after* unk unks have become known, e.g., after full blown market tests
	Low	**Planning:** execute target business plan with risk management (buffers and modifications or contingencies)	**Selectionism:** Parallel trials with *ex-post* selection of the best

Figure 1: Comparing the management approaches for responding to unknown unknowns

When both unforeseeable uncertainty and complexity of the venture are low, neither selectionism nor learning is necessary, and neither should be used because each is expensive. Instead, a classical planning approach with risk management is sufficient to achieve a high-performance outcome for the venture.

Complexity pushes for selectionist trials: if the problem is so complex that one cannot plan for a "best" solution, sending parallel attacks (and at some point settling on the most promising one) is the best course of action, as long as there is little vulnerability to unknown unknowns.

If major unforeseeable uncertainty is present, but complexity is not high, trial-and error-learning is most appropriate because it allows the team to adjust to the shifting ground under its feet and achieve high performance even under a substantially changed context.

The most difficult situation is when high levels of unforeseeable uncertainty and complexity combine. Learning is no longer the best answer because even after substantial redefinition, a single trial runs the risk of getting stuck on a "local optimum", a result that cannot be improved by making further moderate changes but is in a generally inferior region of the "search space". Selectionism, on the other hand, is useless if the "best" parallel trial must be chosen before the unforeseeable uncertainty is resolved, before the previously unforeseen influence factors have emerged. Selectionism is the best solution if the parallel trials can all be kept alive until information about the initially unforeseeable factors has revealed itself (for example, customer needs or behavior in an unknown market is revealed by market testing of fully functioning prototypes, including product mix and promotional mix).

Of course, one can never be sure whether all unknown unknowns have emerged until well after the novel product has been established in the market. However, as the venture gains a deeper and broader understanding of the business, one can still conclude that unk unks loom less. These predictions have been empirically supported in a study of 65 startup companies in

Shanghai (Sommer *et al.* 2006, Loch *et al.* 2006b).[7]

When a management approach has been chosen for the various parts of the venture—planning, selectionism, and/or learning—management systems must be put in place to achieve effective execution. Appropriate management systems include how to plan, what to monitor, and how to evaluate team members (Figure 2).[8]

	Planning and Risk Management	**Trial & Error Learning**	**Selectionism (before or after information availability)**
Planning System	• Plan tasks & targets • Buffers & risk management	• Overall vision • Plan first round of experiments • Decision power to change plan	• Overall vision • Potential of individual projects
Monitoring System	• Target achievement • Progress tracking (e.g., % complete, or deliverables)	• Track *experimentation cycles*. • What has been learned? Can problem be sharpened/ re-defined: What to solve next?	• Relative potential (stopping criteria) • Can selection occur (is there grounded confidence that unk unks have been reduced)?
Evaluation and Incentives	• Target fulfillment • Output	• "Process quality" incentives • Upward incentives on output	• "Process quality" incentives • Shared incentives on output

Figure 2: Management systems to support the management approaches

Management systems must differ depending on the chosen management approach (planning, selectionism, or learning). For example, in a part of the venture with low vulnerability to unknown unknowns, a detailed plan can be developed, targets can be set and enforced, progress monitored, and fulfillment evaluated. However, in a learning sub-project, the plan and targets may fundamentally change. Therefore, only iteration loops can be planned up to the resolution

[7] Each startup completed a ten-page questionnaire and engaged in a 2-hour follow-up interview. Unforeseeable uncertainty, complexity, success, and the degree of usage of planning, selectionism and trial-and-error learning were measured (ex-post), as were links between startup success and planning, selectionism and learning, conditional on the presence of unknown unknowns and complexity.

[8] Figure 2 is based on Loch *et al.* (2006a), where detailed configurations of management systems adapted to the management of unknown unknowns are proposed. As with Figure 1, it is never possible to be sure; the point is to resolve unkown unkowns until a judgment can be made on whether and/or how to proceed. We thank an anonymous reviewer for helping us to stress this insight.

of a major question, and then new and original planning must be undertaken (not only execution and refinement). Thus, only the resolution of the iterations can be monitored ("questions answered"), and employees cannot be evaluated on success alone (it is not fully under their control), but the process and effort must also be taken into account.

In a selectionist part of the venture, where multiple solution candidates are pursued in parallel, sharing of information must be encouraged, and criteria must be set for when a trial is considered out of the race (and discontinued), and when it is declared the "winner". All participating parties must have a stake in the total outcome, otherwise they will not collaborate.

3. Diagnosing Unknown Unknowns

Section 2 summarized existing knowledge that has been developed about management responses to the presence of unknown unknowns. However, the theory summarized, and the management approaches identified, require a venture management team to be able to recognize at the outset whether unknown unknowns are present (or possible), although unknown unknowns cannot be identified initially (by definition!)—they *emerge* over time. Whether the presence of unforeseeable influence factors is diagnosable at the outset is precisely our research question. If the management team diagnoses the potential presence of unknown unknowns, it needs to consider the use of selectionism and/or learning.

3.1. Previous Approaches to Diagnosing Unknown Unknowns

Two proposals have been made in previous work about how to diagnose unk unks. First, *information gap decision theory* proposes to address "severe uncertainty" when no probability distributions, or even ranges, for certain important influence variables are known (for example, the number of clients, or future market prices, see Ben-Haim 2001, Regev *et al.* 2001). Information gap theory develops a mathematical method of dealing with the situation where the variation of the parameter around its believed value is unbounded.

In the terminology of Section 2, this corresponds to the management team knowing the elements of the state of the world ω, but not possessing probability distributions, or even ranges, for certain parameters w_i. Similar to ambiguity as discussed in Section 1, the *variables* influencing the venture are known, although their ranges and distributions are not. While useful, this is not sufficient to diagnose the presence of true unforeseeable uncertainty.

Second, *discovery driven planning* proposes to explicitly acknowledge that unknown unknowns exist and to uncover them with four analyses (McGrath 1995, McGrath and MacMillan 2000): (a) a reverse income statement calculates what market share and revenues must be achieved to reach a given return target, (b) a pro forma operations specification shows the key steps for producing the desired output and asks whether these steps can be performed with "normal" process capabilities (or whether heroic feats are required for successful execution), (c) an assumptions checklist compares the plan with experiences in similar situations or with expert advice (e.g., "we assume the average selling price to be around $1.60—is that justified?" See McGrath 1995, p. 51) and (d) milestone planning anticipates the points at which risks can be eliminated so that the next investment round is justified.

Steps (a) and (b) of discovery driven planning, in the terminology of Section 2, propose to carefully examine the planned effect of the action set A^* on the payoff function Π for inconsistencies: is this plan economically realistic, or have parameters been overlooked that are required for the causal mapping to be true? Step (c) corresponds to questioning parameters in the performance function Π and, thus, the causal effects of the actions built into its structure, or whether upon further probing the parameters can be influenced. Step (d) recommends explicitly learning about and eliminating risks as a condition for continuation. This approach is consistent with a body of work that explains how testing hypotheses and examining unexplainable outcomes that contradict initial assumptions can build knowledge and *reduce unforeseeable uncertainty* over the course of a venture (e.g., Thomke 2003).

Discovery driven planning is useful and influential. Our approach is complementary to it: what if the lack of knowledge is so severe that management cannot "calculate backward" from the desired end result, nor check consistency of assumptions? For example, suppose the desired return cannot be translated into a market share goal, not to mention operational milestones, because the market is too new and emerging.

Our proposal is to do something more basic: *make explicit* that the lack of knowledge is so severe, and ask *what part* of the venture is in danger of being affected—technology, market, regulations, etc. Our case example establishes that it is at least *possible* to guide the choice of the management approaches with these basic questions.

3.2. Diagnosing Unknown Unknowns by Decomposing the Problem

From the discussion in Section 2, we see that a new venture's performance function Π typically is complex but the specification appears to be at least partially decomposable. We suggest dividing the overall problem of structuring the venture into sub-problems of highly interdependent influences within the sub-problem, but with fewer interactions across sub-problems. In other words, overall performance can be written as a function of K sub-problems, $\Pi = f\left(\Pi_1(S_1), \ldots, \Pi_K(S_K)\right)$. Each sub-problem depends on some subset S_i of the entire state of the world variables ω, not on all variables in ω. For example, sub-problems relate to different modules of the product or service to be developed, the customer approach, financing structure, and so on.[9] If the overall problem is perfectly decomposable, the sets S_i do not intersect – each sub-problem can be solved in isolation from the others. While perfect decomposability is rare, sub-problems are often identifiable that have only a small number of interactions with the other sub-problems (variables in the intersections of the S_i).

This opens the possibility of estimating the potential for unknown unknowns qualitatively without demanding as much information as information gap theory or discovery driven planning require: *at the level of the sub-problem, managers can estimate how much knowledge and experience they have*, *how many of the known influence variables have been encountered before, how many are new, and how many tests have been performed.* In other words, it is reasonable to consider that a nominal scale of knowledge gaps can often be estimated, analogous to the nominal scale used in information gap theory (only there, it is applied to a specific parameter). This allows the danger of unforeseeable uncertainty to be identified at a broader level than checking the consistency of the team's causal model or probing whether specific parameters are, in fact, variables. The price of this broader approach is that individual unk unks will not be identified, only their possible presence will be indicated. Still, this can be sufficient to decide whether planning, selectionism or learning should be used in the new venture in question.

The theory and evidence described in Section 2 does not illuminate whether this reasoning about the *diagnosis* of unknown unknowns applies in reality. Therefore, we conducted an exploratory case study with a Silicon Valley startup company, Escend Technologies. While one case study is not generalizable, it can demonstrate that something is possible in principle and provide a basis for further systematic testing.

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9 Decomposability is a key principle of system design in engineering, see, for example, Suh 1990, and it has also been a topic in organizational theory for 40 years, from principles of specialization and integration to evidence that organizational structure is closely related to the architecture of the system developed (Sosa *et al.* 2004).

4. Case Study: Diagnosing the Unforeseeable at Escend Technologies

The case study was prompted by a conversation between Escend's CEO, Elaine Bailey, and her co-authors, two academics with whom she regularly exchanged ideas. Elaine, a Novus Ventures General Partner who had just stepped in to "turn around" the struggling Escend, asked, "What should I do? Some of the problems and urgent moves are crystal clear. But I have no idea where the real fundamental problem lies. Perhaps it's just execution, but perhaps it's something to do with the industry. It's all opaque, like trying to see through a rock." This situation represented an opportunity to explore the validity of our ideas about diagnosing unknown unknowns.

A case study was the appropriate research tool, as our theory was insufficient for making predictions about effort required and the effect of diagnosing unforeseeable uncertainty. Elaine and her co-authors met regularly, looked at status reports and company internal and external documents, and made detailed notes of the decision situation, following a participant-observer approach (Yin 1994, p. 13, 79).

4.1. Background

Escend Technologies was founded in 1999 to enable semiconductor and electronic component manufacturers to connect and collaborate with their extended sales force, the manufacturers' representatives (reps) that sell their components to electronics OEMs (Figure 3).[10]

During the 1990s, component manufacturers, OEMs, distributors, and contract manufacturers in consumer electronics were becoming increasingly fragmented and disconnected due to outsourcing and globalization. There was a need to create a common customer record that tracked new products through the design, prototype, and manufacturing phases across the

[10] OEM stands for "Original Equipment Manufacturer". OEMs sell products to the end consumer. OEMs often perform marketing and system design, but outsource component design and manufacturing.

multiple companies involved.

In response to inconsistent and changing customer need statements, Escend's business model had already changed several times. The founding team in 1999 had been aware that Escend was attempting to exploit a complex industry opportunity but conceptualized the opportunity as *collaboration* among industry players who would want to be part of Escend's B2B community.

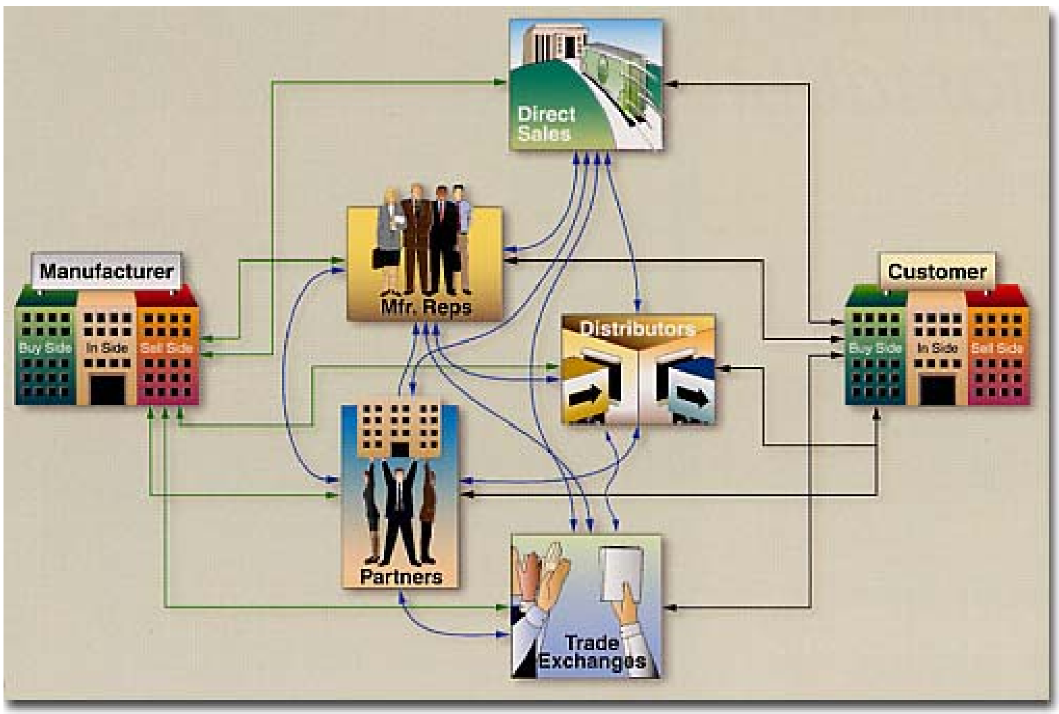

Figure 3: Initial View of the Extended Sales Organization from Escend's Business Plan

This conceptualization had been evolving – Figure 4 displays three successive descriptions of Escend by previous CEOs, an illustration not of sloppy market research but of the fundamentally unmapped terrain that Escend faced. The implication was that Escend needed to resolve this unforeseeable uncertainty; otherwise, all other phases of the turnaround would be futile.

By mid 2003, Escend was floundering, having burned through $16 million in venture funding and asking for $6 million more to continue operations. Escend's customer base consisted of four manufacturers and 20 rep firms. Sales had stagnated a year earlier, and the cash burn rate had grown to $650,000 per month. The CEO had no convincing plans for improvement, only vague promises. Each month, the CEO reported progress on the product and pipeline and maintained that it was only a matter of time before the company would be on its feet.

February, 2000 Escend builds Business-to-Business Communities that connect manufacturers with their outsourced sales channels and distributors through its Sales Information Network.
May 2001 Escend provides the only System that overcomes the competitive disadvantages of a many-to-many business environment by: speeding communication, normalizing data interchange, and connecting an entire industry.
September 2001 Escend provides the only online Customer Resource Management (CRM) application that includes the infrastructure and data exchange translator required for independent companies to collaborate on any aspect of the order lifecycle.

Figure 4: The evolution of Escend's business model before 2003

When the initial reaction to the $6 million request was not positive, the Board (comprising the key investors) thought that the message, not the business or the management team, was the reason. They rewrote the executive summary and venture capital presentation and made additional contacts with potential investors, but without success.[11] Clearly, for the company to survive, major changes had to be made, but what these were was not obvious. In July 2003, Elaine Bailey took over as interim CEO to assess the company and recommend next steps.[12]

Elaine had three weeks to decide whether to recommend that Novus Ventures participate in another round of financing. Deciding "yes" would give Escend a chance to fix its problems, become successful, and provide Novus a positive return on its investment. A "no" decision would end Escend's existence when the remaining cash was spent, losing Novus' investment.

[11] The investors, buying into top management's view, thought maybe that the Escend story was just not being told well and they, led by Elaine Bailey, rewrote the executive summary, generated a "VC presentation," and taught the CEO how give the presentation. The result was zero interest by potential new VC investors.

[12] Elaine's experience running her own rep firm in the 1980s made her the logical choice and meant that she knew the "right" questions to ask—or that she would discover what they were.

4.2. Diagnosing the Unforeseeable

Initially, Elaine interviewed each of the 30 employees and the four existing customers. Not satisfied with what she had learned, she then examined the company's expense reports and telephone records. She soon realized what a mess she had inherited. The CEO had invited buddies into the management team who drew large salaries but seemed to have no interest in growing the business. The application (the product) had significant usability and reporting deficits (for example, in specifying custom reports); the architecture made the application extremely rigid, causing even small changes to generate up to 200 hours of QA;[13] and the Oregon-based design team was naïve and uncooperative. The phone logs revealed that the sales people spent little time talking to customers and prospects and the $15 million pipeline was grossly inflated (the actual figure was $256,000). Additionally, morale had hit rock-bottom.

In order to start diagnosing unk unks, she began to examine each part of the business and identify open issues. In other words, she identified *sub-problems* of the overall turnaround problem and examined them for how much the management team knew about them. What those sub-areas were quickly became clear. Some, such as reducing the burn rate and the headcount, were obvious for an experienced VC. She began to realize that the fundamental problem area was not within the company but was a question of, "Is this a viable business?" Delineating the problem areas, after some consultation and iteration, led to Figure 5.

Problem area 10 wasn't a problem at all; rather, Elaine discovered that the customer support team was a key asset of the company. Problem areas 4 through 9 were relatively straight forward―they contained risks, but what had to be done was quite clear. Problem area 3 was more difficult: how to plug the product's functionality gaps seemed like an area of unknown

[13] QA stands for Quality Assurance; this refers to software changes "cascading" to other parts of the code because of many complex interfaces.

unknowns. However, a proposed "fix" was already on the table that would temporarily meet the market requirement for speed and flexibility while the application was completely reworked.

Problem Area (sub-problem)	Situation	Uncertainty
1. Customer need (external)	Would customers buy Escend's products? Why? What is the customers' pain?	High potential for unk unks
2. Industry readiness (external)	No successful collaboration software play; minimal competition, slow adoption.	High potential for unk unks
3. Product functionality (external)	Holes in functionality, too rigid, based on once-per-day batch mode when customers wanted real-time product	Foreseeable, possible unk unk
4. Cash burn rate (internal)	$650,000 per month	Variation
5. Executive management team (internal)	Complacent and dishonest, risk of lawsuit	Foreseeable
6. Sales team (internal)	Not sufficiently active; inflating results	Foreseeable
7. Head count (internal)	30 employees (70 at the high point, including 50 software developers), lack of performance	Foreseeable
8. Geographically dispersed operations (internal)	Sales offices in Alaska, California, Massachusetts, New Hampshire, and Texas; development team in Maine, Nevada, Pennsylvania, and Oregon	Foreseeable
9. Development team (external & internal)	Either outmoded or inexperienced, uncooperative	Foreseeable
10. Support team (external & internal)	Strength of the company	Not a problem

Figure 5: Problem areas with uncertainty profile[14]

Fundamental knowledge gaps lay in areas 1 and 2. The technology enabling Escend (XML, Rosettanet) had not existed before 2000. XML made collaboration possible from one data base to another, and Escend aimed at connecting the global demand creation activities with supply chain management. A few small competitors offered pieces of the solution, but analysts had not yet defined the problems that existed on the demand side of the semiconductor and electronics manufacturing industry nor were they following the segment. Thus, if the market existed, it was

[14] It is not untypical that the areas of highest uncertainties are the ones identified here. However, this is by no means universal and needs to be ascertained case-by-case.

still early enough to be a significant player, but because customer needs were undefined, the willingness of the channel players to collaborate on opportunities via common software was uncertain. Therefore, the required functionality was unknown. Customers could articulate their problems but not their needs, and different players would name mutually incompatible benefits because no one understood where the product would ultimately create the most value and who would pay for whatever product (which is typical in new markets, O'Connor and Veryzer 2001).

Identifying significant sub-problems can be done systematically, following a "natural" structure of the overall problem, but there is no "scientific process". Analysis has to be complemented by experience and experimentation. No "process" can guarantee that all relevant sub-problems and potential unk unk areas are identified. What we can hope to achieve is to greatly improve our odds by systematically searching.

4.3. Following the Diagnosis to Let the Unknown Unknowns Emerge

The unk unk problem areas (1 through 3) required Elaine to assess the viability of the business opportunity and to determine if the company was funded and managed correctly: could the business provide an acceptable venture capital return? This involved an open-ended search with an unknown result, requiring "switching gears" as compared to the execution mode that characterized the other problems (and most of what Elaine as a VC partner usually did).[15]

In parallel to the areas for which a planning approach was used, the knowledge gap around customer needs and the readiness of the industry became a *learning project*. Elaine reserved part of her and the team's time to reflect and gather information from multiple parties about these

[15] The open-end process worked because Elaine was the person in charge. When she became CEO, Escend's morale was so low that no amount of cajoling was effective. After laying off most of the employees, Elaine got the 5 remaining employees to make decisions by consensus (via daily and weekly meetings), which created a cohesive team that accepted both responsibility and accountability.

sub-problems, not knowing what to expect. She might find nothing of significance, or something that might fundamentally change the business model—or even a reason to shut Escend down.

During her first three weeks as CEO, Elaine traveled to interview enterprise firms, end customers, analysts, consultants, VCs who did not invest (not believing in either the management or the business model), managers of different collaboration start-up companies, and academics. She searched and probed for reasons why collaboration solutions had not succeeded, the needs of the enterprise customers, and the problems that the complex industry structure really posed.

In face-to-face meetings, people opened up and provided useful non-verbal cues—information that could never be obtained by only attending Board of Directors meetings. Slowly, information emerged, but kept changing as the process evolved. Figure 6 exemplifies how Elaine and her team diagnosed the unk unks, erasing and re-covering the whiteboard daily.

After three weeks of intense probing, Elaine concluded that: (a) demand existed for Escend's product, (b) the potential market was large enough to possibly generate a sufficient return on investment, (c) competitors were far enough behind that the opportunity had not yet been tapped, and (d) Escend represented one of the last remaining large enterprise software "plays" remaining for VC investors. Elaine recommended that Novus invest additional funds, and in August 2003, Escend closed a $7 million round from Novus and NIF Ventures.

5. Conclusion of the Case Study

Section 5 summarizes how Elaine managed Escend after the unk unk areas had been diagnosed, following a probe-and-learn approach, and demonstrates that the initial diagnosis was useful and had identified the right areas of vulnerability. While not the core of this article, Section 5 completes the case example and illustrates one of the management approaches from Section 2.

Escend was creating a large and untapped market "where no one had gone before". Unk unks had to be lurking in the unmapped terrain. The goal had to be to turn unk unks into known unknowns (foreseeable uncertainty). This cannot be done in a classical straightforward "analysis"; it is a process of discovery over time. The table below shows some of the questions that Elaine and her team used to investigate assumptions and to jump-start the discovery process.

The table has a column for Customer Assumptions that Escend was relying on. Escend's Value Proposition was initially only a "guess". Elaine and the team initiated the discovery process that eventually led to the development of the Probing Questions. Two example assumptions, and a few probing questions, are listed in the table. The full list covered a large white board, which they maintained in a meeting room. The management team met daily at first and then weekly over a period of 1-2 months to nail down the unk unks. They reserved part of their time to reflect and to gather information from multiple parties about problem areas, not knowing what to expect. Escend's Board remained open to finding nothing of significance in this inquiry or something that might prompt them to fundamentally re-think the business model—or even to shut Escend down.

Customer Assumptions	Escend's Value Proposition for its Customer (Component Mfgr.)	Probing Questions
Component is designed into OEM products; it is not a commodity	Convert more design-wins to orders. *(Customer need statement: "I'm losing orders from design win to production.)*	Once you have a design win, what's the likelihood that you'll get the order?
		How much do you lose (leave on the table) for design wins that don't materialize into orders?
		What influence does your channel play in securing the order once it is designed in?
		What impact do you have in moving it from design win to order? (scale 1-10; least -most)
		What needs to happen to improve your design win to order conversion rate? (… and so on)
Sales is unable to forecast demand	Provides global visibility into all customer activity *(Customer need statement: "My reps are talking to my customers every day, but I don't know what they are saying.")*	On a scale of 1-10, how much visibility do you have into your customer base?
		What types of information is it important to know about your customer?
		What type of service (questions) are your customers requiring/demanding?
		What information is the customer requesting that is out of the control of the sales department?

In October 2003, Elaine convened a "No Good News" Board meeting. Letting the unk unks assume form takes time. Through the systematic asking of questions and seeking answers, the unk unks had begun to take shape and she had come to believe that the initial value proposition of the business was not in alignment with the market. She told the Board that the original business model was not viable but that she thought they had an even better alternative. She committed to return in 30 days with a new business plan based on the team's new findings. The table with assumptions and questions was erased and rewritten again and again as new information was uncovered. As Elaine put it, "we kept putting our ear to the ground, and we heard nothing. Slowly, we began to hear some faint hoof beats, then they became louder and louder. By November, we knew that we had it – we knew how to make the company a big success."

Figure 6: Tuning Your Ear to the Unk Unks

5.1. Tackling the Planning Subprojects with Foreseeable Uncertainty

Managing foreseeable risks represents "standard fare" for a competent operational VC who knows how to plan and manage resources.[16] In addition to being foreseeable, these risks also have consequences that are primarily internal to the firm, and the typical VC risk management process is sufficient. Elaine threw her experience and forcefulness behind solving the foreseeable risk problem areas (4 through 9). For each, she set targets, time lines, and progress metrics, following time-proven project management principles. Elaine executed this part of the turnaround working "part time", delegating and monitoring.

Her first task was to "right size" the company. Elaine moved immediately to isolate and then remove the top management team, after gathering evidence of negligence (avoiding severance payments).[17] On the product development front, she side-lined the Oregon team and tasked them with maintaining the existing application. Fixing the burn rate was a methodical, "hunt-search-and-kill" process that resulted in slashing all budgets; consolidating operations/eliminating locations; and letting go 25 non-performers out of 30 employees, securing signed releases in exchange for two weeks severance pay.

She then hired two senior software architects and a database architect to design a solution to the product problems. After several analysis and brainstorming sessions, a powerful and elegant solution emerged: Escend would develop a web shell around the functional kernel, which facilitated ease of use and allowed adding functionality (such as real-time customized reports) without having to change the base code. In September 2003, the shell could be tested with the

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16 During the dot.com boom days, a MBA degree and Wall Street experience was often enough to secure a VC position. An *operational* VC has had hands-on, day-to-day experience running a company (or companies).

17 Elaine kept the Business Development VP, two customer service managers who were holding the operations together, the HR manager who helped with the downsizing, and the CFO. During the interviews, every employee told the same story: each was not at fault but didn't know any solutions, and the market, economic times, or "9/11" was to blame. Each person's anger showed through, and each "broke ranks," revealing to Elaine their information about product problems and top management integrity issues.

first enterprise firms, and they liked it. Escend had solved another hurdle—customer retention.

5.2. A Probe and Learn Approach to Respond to Unforeseeable Uncertainty

For problem areas 1-3, Elaine Bailey adopted a learning approach (see Section 2).[18] It proved correct that unknown unknowns resided only in those three areas. Over the next 12 months, two influences that changed Escend's strategy emerged that could not have been anticipated before.

First, Elaine learned that the electronic components market was quickly becoming global. For Escend to add value, the "technical vertical" it served (industry speak for the end user industry application) had to be a complex product that was global in nature.[19] This implied a global platform and design-win tracking for component manufacturers bidding to get their components into end products, but developing this platform, another product redesign, would consume precious funds and resources. Thinking that potential competitors also would have to redesign their product, Elaine decided to bite the bullet, hopefully putting Escend in the lead. The redesign incorporated multiple languages, multiple currencies, and multiple access points per customer but indicated that Escend's target customers and growth strategy had changed.

Second, any firm in the industry network (Figure 3) had limited visibility of the entire network. Component manufacturers, through their rep firms, could not track either sales or the process and, thus, could not ensure full and timely payment. OEM buyers cared about the design win but not about tracking it. Wanting to buy at the lowest possible price but having to give extra profit margin to the contract manufacturers and design-win firms, OEM buyers often used *different* manufacturers who offered lower costs *after the design was "won."* As a result,

[18] Elaine almost threw in the towel in the run-up to the recommendation. The situation was very confusing. The discussion of unk unks and flexible adjustment highlighted the possibilities, and gave her the will to continue.

[19] This hypothesis was confirmed in August 2004 by a report from industry experts that Escend commissioned for $40,000. Elaine concluded that "experts are good at messaging what you already know, but not at what you don't know." So she convened the Board together to brainstorm about unk unks for other vertical markets.

component manufacturers were changing the way they sold products, shifting from reps to distributors and taking back some of the activities that reps had performed. Therefore, Escend would have to build distribution functionality into the product and, in October 2003, produced a prototype that offered shipping and debiting, samples management, and pricing and quoting functionality. Coding would take another 12 months; the plan was to go live in January 2005.

In late October 2003, Elaine's search for information uncovered another start-up (funded by a competitor VC) whose collaboration software product covered the demand cycle of the industry. The two had the potential of forming a perfect match if their products could be made to work together. Elaine was confident that the two software products could be made interoperable (this was a problem area with foreseeable uncertainty). But the merger fell through because the investors of the other startup had recently gotten some of their money back and wanted out.

The flexible way of proceeding, including repeated unplanned product changes and three major strategy changes (counting the aborted merger), was very stressful but made possible because Elaine, combining the roles of Chairman, CEO, and partner of a major investor, was leading it. While Elaine had authority, access to investors, and prior operational experience, the new Escend management team implemented the process. Elaine assembled a new team in the late summer of 2003, but also made further changes, for example, replacing the VP of sales again in June 2004. Over time, the team became fully engaged in the learning process. "Unk unks" became a commonly-used term, reflecting the new mindset Elaine instilled in the company.

Escend's business model slowly crystallized. Figure 7 is taken from a Spring 2004 Escend white paper and has a clarity that stands in sharp contrast to the complex Figure 3. Tracing the flow of the design-win process is easy in Figure 7, and the demand cycle and demand fulfillment (i.e., supply) cycle is also clearly delineated. Over time, the unknown unknowns have emerged and are now known: the industry structure looks understandable, and the effect of actions taken can be traced. Through learning, unforeseeable uncertainty has been transformed into risk.

In the Fall of 2004, Escend seemed to have turned the corner and was becoming an excellent bet for investors. At the end of October, the company obtained another $3 million from the existing investors, Novus and NIF Ventures. Daiwa Securities translated the product into Japanese and went into Japan in December 2004, targeting 12 Japanese companies. Customer interest started taking off, and by the end of June 2005, the sales pipeline had grown to over 50 companies, with cash flow breakeven by the end of the year. Elaine, signaling her confidence, replaced herself as CEO. Escend is still successful at the time of writing of this article.

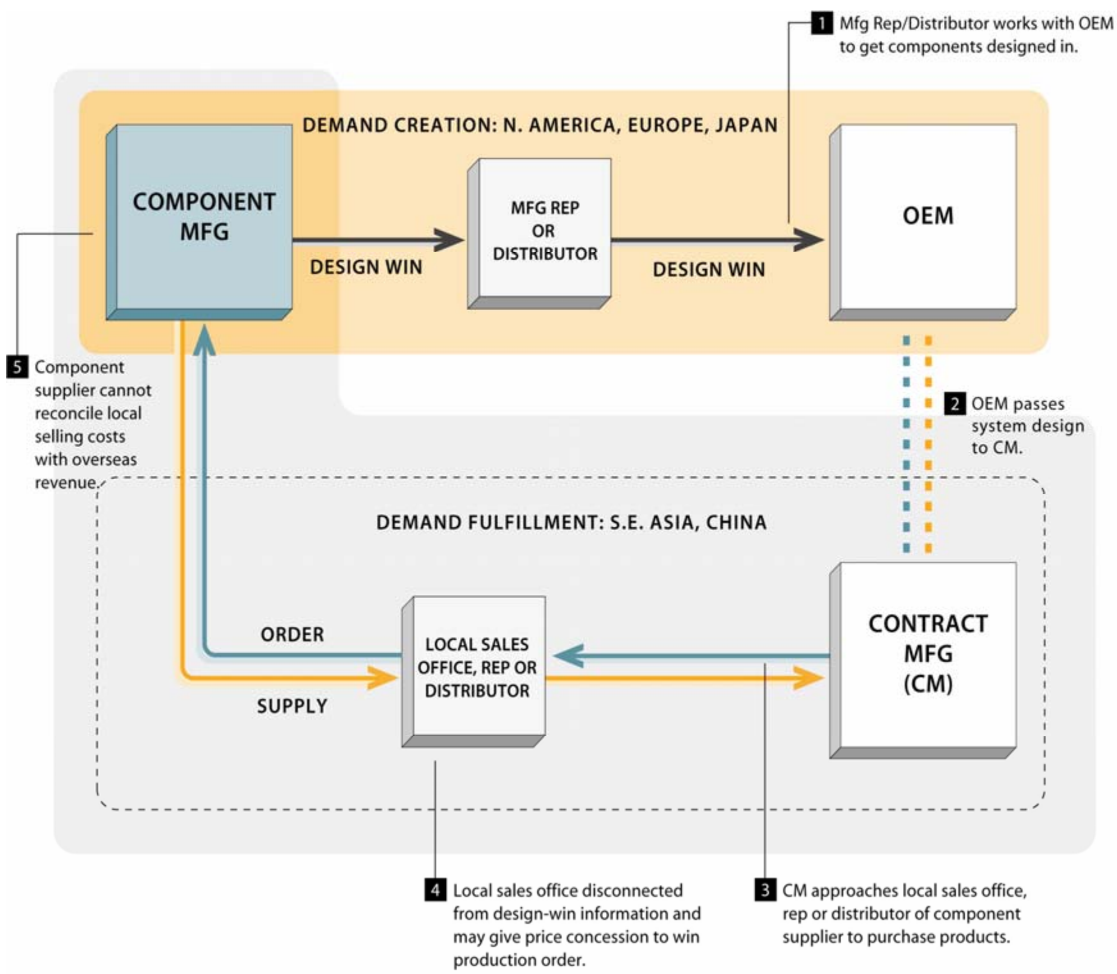

Figure 7: Description of the industry network, Escend White Paper, Spring 2004

6. Proposing a Process of Diagnosing Unknown Unknowns

6.1. Discussion: Identification of Patterns

This exploratory case study illustrates that it is indeed possible to diagnose the presence of unknown unknowns as proposed in Section 3: the overall venture management problem was divided into sub-problems, and a qualitative assessment of knowledge gaps, and vulnerability to unforeseeable uncertainty, was made. While generalizing from a single case study is difficult, it does demonstrate that the observation of patterns in light of the theory yields a diagnosis *process*, the validity of which can be tested in future studies.

Elaine Bailey and her team found it natural to divide the venture into sub-problems with different types of uncertainty. While we hoped that this would be so because decomposition is widely used in systems engineering and organizational design (see Section 3), verification was needed. The case also shows that a qualitative assessment of general knowledge gaps per problem area is possible – indeed, after the management team had "digested" the concepts, it made the assessment of knowledge gaps part of its annual reviews. Unknown unknowns were uncovered in the vulnerable problem areas and not in the others.[20]

After having been diagnosed, the areas vulnerable to unknown unknowns were "attacked" with management approaches adapted to the type of uncertainty. As the venture progressed, new information emerged, and the problem pieces and approaches were updated and modified. This process was iterative and gradual, tracking the evolution of the industry (Figures 3 and 7).

How uncertainty changes as information emerges can be represented by *uncertainty profiles* (De Meyer *et al.* 2002). Figure 8 depicts graphically where management sees the greatest amount of uncertainty, whether variations (deviations from planned schedules and budgets),

[20] Of course, there is no guarantee for identifying knowledge gaps. As we have stated in Section 4.2, no method can reduce the challenge of unforeseeable uncertainty to anything "programmable."

foreseeable uncertainty (where contingent planning and risk management methods apply), or unforeseeable uncertainty (the potential for unk unks). Uncertainty profiles can be drawn for each major problem area of the startup company, with Figure 8 representing how uncertainty evolves over the typical stages of development.

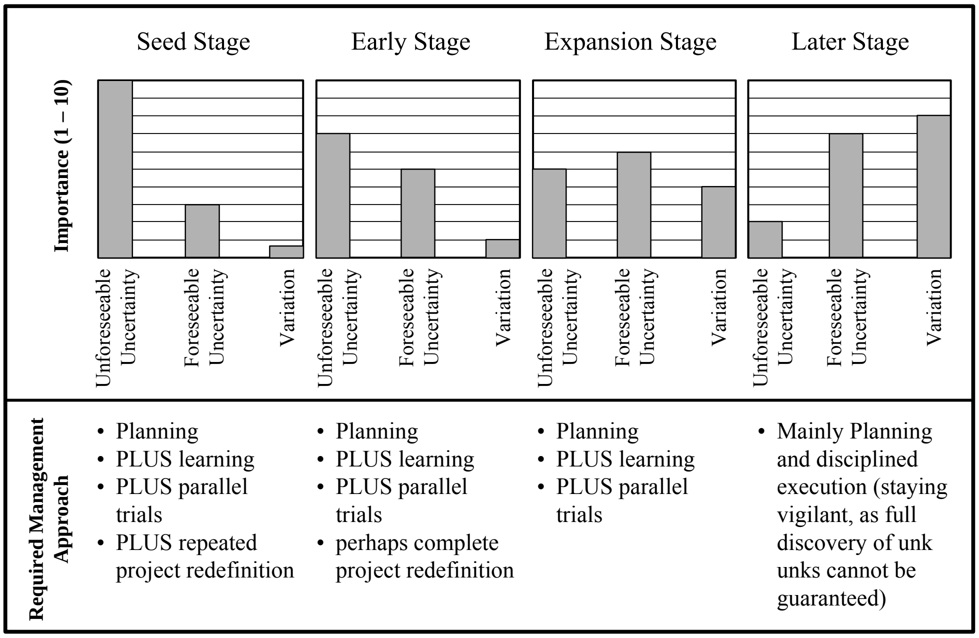

Figure 8: Uncertainty Profiles and Management Infrastructure by Venture Stage

While planning was a critical foundation in all stages,[21] chaos reigned when Elaine took over – Escend had to completely abandon previous assumptions and re-define its business model. The uncertainty profile shifted toward foreseen uncertainties when customer needs became clearer and customers reacted positively to targeted product changes. Later, when a clear model was to be executed and Elaine was planning to step down, standard project management methods were sufficient. This evolution of Escend is, in fact, similar to the development stages of typical ventures (seed, early, expansion and later stages).

[21] Without planning, a team has no baseline from which to judge deviations; this is strongly demonstrated in major engineering projects in Miller and Lessard 2000.

6.2. A Process of Diagnosing Unknown Unknowns

The manner in which Elaine Bailey diagnosed unforeseeable uncertainty, explored and managed the problem areas in parallel using differing approaches, and altered the management style as the uncertainty evolved, follows a systematic pattern that is outlined in the *diagnosis process* in Figure 9. This process uses systematic problem solving tools, namely categorizing uncertainty by problem area (Figure 5), asking probing questions (Figure 6),[22] and evolving the uncertainty profiles (Figure 8). By tools, we mean structured approaches to solving problems that with suitable modification may be transferable to other ventures or situations.

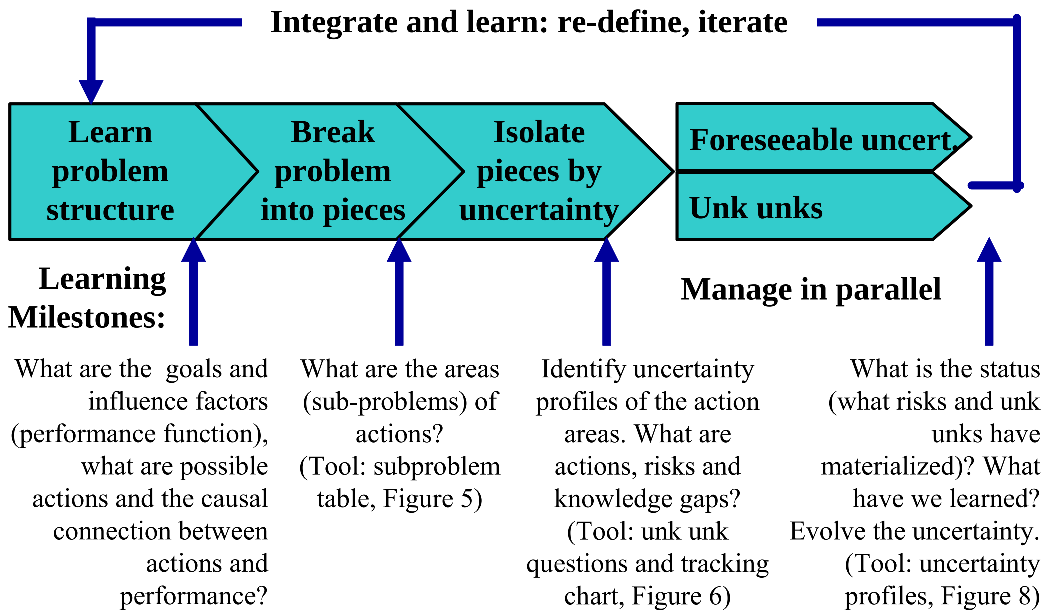

Figure 9: A process for diagnosing unforeseeable uncertainty

Elaine Bailey had identified the problem structure (what must we accomplish, and what causal connections do we understand?) in her initial examination of Escend. Next, she broke the overall

[22] This process is also consistent with empirical observations of strategic alliances. Alliances also represent projects (usually, alliances end when the learning or growth goals have been achieved), which have to navigate unexpected events as new territory is entered. Less structured mutual discovery processes have to stand alongside approaches for well-understood parts of the alliance. See Doz 1996.

problem (how do we maximize the return on investment in Escend?) into sub-problems, such as software functionality, management, sales force problems, etc. For each sub-problem, she questioned what she knew; estimating knowledge gaps and, thus, the potential for unknown unknowns to emerge. Then, she managed the pieces in parallel, using different management approaches according to the uncertainty category: iteration and learning, for the pieces that were threatened by unforeseeable uncertainty, and more structured approaches for the pieces with foreseeable uncertainty. Finally, she updated the uncertainty categorization as new information emerged, changes were carried out, and the correct business model crystallized.

Again, we need to caution: first, although we use the term "process" because a *systematic* search for unk unks is indeed possible, this always requires experience, flexibility and adaptation to unforeseen events. This can never be reduced to a "mechanical" and delegated process. Second, this process of diagnosing and managing unforeseeable uncertainty does not come for free. Novus Ventures invested a large amount of resources, including making one of its partners CEO. Elaine Bailey, in turn, invested a large amount of Escend's resources in the form of her and her team's management time, budgets for extensive travel and for several external investigative reports, and social capital by visiting customers and "picking their brains".

7. Conclusion

Although perhaps not directly generalizable, the Escend Technologies case study does illustrate how the diagnosis of unknown unknowns, as proposed in Section 3, can proceed. In particular, the case study suggests that a decomposition of the overall venture management problem into sub-problems is feasible and natural to managers, that a qualitative assessment of knowledge gaps and vulnerability to unknown unknowns is possible at the broader sub-area level rather than checking individual influences, and that a structured, "process-like" way can be used to identify sub-problems, determine their uncertainty profiles, and update the uncertainty profiles.

While the process identified in the Escend case seems to be idiosyncratic to this venture, the conceptual steps can be applied to other ventures that are vulnerable to unknown unknowns. The components of the diagnosis process proposed in Figure 9 are general enough to suggest that ventures facing potential unforeseeable uncertainty can benefit from its application: a successful diagnosis of unknown unknowns can help a venture to apply selectionism and/or learning in a targeted way. Evidence already exists that applying selectionism and learning increases venture success (Sommer *et al.* 2006). The prediction that our diagnosis process increases venture success can be tested in future systematic empirical research.

A venture whose management team masters diagnosing unknown unknowns and flexibly working through them will still suffer failures (that's the nature of the beast), but we contend that such a venture will tend to extract more value from its investments. You cannot control fate, but you can load the dice.

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