Chapter 21
Service Thinking in Design of Complex Sustainment Solutions

L. A. Wood and P. H. Tasker

Abstract Delivering contracted performance levels for service based on the sustainment of complex engineering systems is a necessary but not sufficient condition for user satisfaction. Service is received in a context that is shaped by the state of mind of the customer—perceptions, biases, memories, intentions and patterns of thinking. Service teams need to understand the "mind of the customer", complementing the "voice of the customer" used in requirements development. The chapter considers how service solutions are designed and suggests that the state of mind of the customer needs greater consideration during solution development. The service team functions in the social dimension to understand the customer's mind and harmonises the service solution. The dominant thinking style in social space is characterised as "service thinking", complementing the system thinking style which dominates in the conceptual space of product-service systems.

21.1 Thinking Styles for Product-Service Systems

This chapter explores the need to introduce a new thinking style, labelled "service thinking", for the design of service solutions based on the sustainment of complex engineering systems. These systems can be characterised as one-off (or few-off)

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designs with high engineering complexity, high performance, long life and likely to incorporate in-service upgrades or change of use. Examples include military equipment, large scale infrastructure and installations, major buildings and high value production facilities. The hypothesis is that manufacturers of complex systems who offer end user service based on the assured availability of equipment performance in operation (the product-service system) will be unable to achieve service excellence in the mind of the customer without a paradigm shift in thinking at corporate, team and individual levels. The need arises largely as a result of the maturity of the engineering "system thinking" method (system engineering) used for the development of large scale bespoke products. System engineering tools and thinking style ably address the conceptual space of the manufacturing design and integration process, ensuring that the customer's expectations for system performance are met by providing a structured approach to managing explicit requirements—the "voice of the customer". They are of little help in ensuring a connection with the "mind of the customer" necessary to complete the service solution design in the social space, nor in ensuring that the conceptual and social visualisations are harmonised into an integrated solution which satisfies both the tangible requirement for system performance and the intangible concept of service need in the customer's mind.

The proposition is that for a complex product-service system, service satisfaction resides in the mind of the customer so that the sustainment of fit-for-purpose goods is a necessary but not sufficient condition for customer satisfaction in the overall service. The end state of service is a mental concept that is intangible and its achievement is heavily shaped by the context in which it is received. The context includes the emotional state of mind, its perceptions and preconceptions, its patterns of memory and patterns of automated processing, and plans for the future. Service satisfaction therefore requires the service provider to have a highly developed concept of the mind of the customer; whether the customer is an individual or an organisation, the same principle applies. The desired end state of service provision is trust, wherein the customer habitually seeks more.

This language is unfamiliar in the product domain where achievement of functional performance requirements is regarded as paramount. It is often tacitly assumed that service is an inherent feature of the product, somehow embedded within it: from the perspective of the product developer, the user is an extension of the product. The user's viewpoint is quite the opposite: the product is an extension of the user, sometimes even anthropomorphising certain classes of products. Intel Corporation has established a User Experience Group staffed by anthropologists and ethnographers in order to better understand customer patterns of life that determine how its product offerings are used. This group seeks to understand, for example, how customers (situated users) accept certain products as "symbolic markers of cultural practices, gender and even religious identities".

The system engineering thinking style is deeply embedded in the development of complex systems, especially defence systems where it has become a universal language; systems of regulation and governance are built on it. Notwithstanding the development of soft systems and similar approaches, system engineering thinking is perceived to be inextricably rooted in the product paradigm ensuring a cultural rigidity inhibiting development of the method to accommodate design in the social space necessary for the attainment of service excellence. It is therefore important to develop complementary techniques for service design in the social space based on "service thinking" and the theory of mind, leading to new perspectives on leadership and the building of expert teams.

If service thinking is to be established as a separate and identifiable thinking style that is complementary to system thinking, what is it, and how is it to be implemented in the design of complex sustainment systems? This chapter explores these questions from the practitioner viewpoint by firstly examining features of the established system thinking style, then offering an argument to include the social space in service design suggesting cardinal features of a service thinking style, followed by suggestions as to how the two styles may be harmonised. This inevitably leads to rich research questions and some suggestions for new practice.

21.2 Design in the Conceptual Space: Product-Service Systems

Design of product and processes is a journey through *conceptual space*, while service is a journey through *social space*. They are parallel journeys. Each must take into account the other; effective business solutions seek to harmonise them.

21.2.1 Current Design Methodologies

Like the trend to servitization, product-service systems have evolved over time, with different industry sectors taking different paths. Servitization has been a route to diversification for many manufacturers (Ng et al., Introduction chapter; Neely 2008), adding services to create enhanced value to cope with intensified competition. For some industry sectors, such as automotive, truck and mobile equipment industries, service in the form of maintenance and repair (sustainment) has long been a part of the enterprise business model, often implemented through a franchise relationship with local businesses to enable broad geographic coverage. For other industry sectors, different models have applied. In the civil airframe sector, airline operators for many years have been the maintainers, while more recently third party enterprises have become established as maintenance and repair organisations.

In the defence industry sector, where complex, large scale and bespoke systems are typical, sustainment has often been delivered organically by the defence operators. In this situation, the product lifecycle is clearly divided into two very distinct phases: acquisition and sustainment. The historic focus of this industrial sector has been on acquisition, driven by the need for outstanding performance, sometimes at the cost of sustainability. Over time, greater emphasis has been placed on sustainability by applying "design for" constraints, such as *design for reliability*, *design for maintainability*, *design for availability* and many others. The separation of acquisition and sustainment has gradually broken down in recent years, especially in the context of new defence industry contracting policies as exampled by the UK MoD Ministry of Defence in its *Defence Industrial Strategy: Defence White Paper* (2005). Many western defence organisations have adopted similar approaches. An increasing proportion of military sustainment activity is now outsourced to commercial contractors, with outcome-based contracting (Ng et al. 2009) evolving as a preferred commercial approach. Contracting in non-defence sectors is also evidencing similar trends (Johnstone et al. 2008, 2009). Defence companies have long been engaged in sustainment functions for the military, but the outcome-based contracting approach has several important differences. The historic sustainment activity has been for discrete tasks or components within the larger customer organic solution (a traditional logistics support function is based on the deep technical knowledge of the products being supported). In comparison, the outcome-based contracting environment requires that the contractor provide a comprehensive integrated business solution wherein significant contractual risk is transferred to the contractor.

The design of complex product systems is enabled by a comprehensive system engineering methodology and tool set. Similarly, the traditional logistics support activity is enabled by analytical methods (logistics engineering analysis), with design and implementation supported by very detailed logistics support and management processes based on system engineering (Blanchard 1998). A similar situation applies for design and management of the supply chain, and also for maintenance activities, all core elements of a sustainment solution. Business process modelling also has a long history (Williams 1967), with a supporting enabling suite of processes and software tools. Business modelling capability has increased dramatically following the development and routine deployment of software tools, with UML (Unified Modeling Language) and IDEF0 (Integrated Definition function modeling) being among the dominant approaches.

The term "product-service system" is used in outcome-based contracts as they are necessarily service-like in their objectives and approach; the contractor is providing an intangible output to the customer within the user environment. In the defence sector the output is typically the availability of a component of military capability such as trained operators or assured availability of performance. Systematic design of service has been addressed by various authors (Shostack 1982; Ramaswamy 1996). The subject of service design has often been approached through the marketing and management disciplines, where service task elements are identified and connected with adjacent tasks into a network that seeks to produce a common goal, the service output.

Morelli (2006) has described product-service systems as "social constructions", especially due to the value co-production aspects of service design. An important feature of this work is the identification and understanding of the roles of the actors in the network associated with the socio-technical process. The social approach to design has been elaborated by Bijker et al. (1987) who analyse the sociology of technological construction. Bijker (1995) produced three comprehensive case studies of socio-technical constructions (bicycles, bakelite and fluorescent light bulbs). He points out that "society" and "technology" are both human constructs, and that they are inevitably linked. A social approach to design leads to fundamentally different thinking about the nature of design. This basic idea is mirrored to an extent in the product-service literature, where the primary drivers of academic research have been sustainable ecology and economically sustainable business.

Nevertheless, some authors have reported that technical product-service systems are still designed without the benefit of a systematic methodology (Aurich et al. 2006), observing that "service design is frequently performed detached from product design", with very little interaction between the two. This has been described as "intuitive design". Aurich et al. propose a systematic design approach and evaluate its application to a business that produces heavy road construction equipment. In this context, they identify three "dimensions" of technical service design: the product dimension, such as maintenance and spares provisioning; the process dimension, which describes the activities in the service operations; and the information dimension, which describes information gathering and exchange. They then compile an overall process methodology that responds to the top level requirements of the product-service system. Alonso-Rasgado et al. (2004), Alonso-Rasgado and Thompson (2006) have considered the design of systems of hardware combined with a service system, which they term "total care products". They pay particular attention to the customer–supplier relationship throughout the design process of the total care product which they envision as a series of iterative engagements.

One aspect of product-service systems that is challenging to incorporate into the design process is customer satisfaction. Although product and service design requirements attempt to capture customer needs, this is difficult to comprehensively achieve. Bullinger et al. (2003) have introduced "service engineering" as a means to systematise the development of services. Sakao and Shimomura (2007) describe service engineering as "a discipline to increase the value of artifacts and to decrease the load on the environment by reason of focusing service", in their view changing the focus of product development from functionality to customer satisfaction. Although engineering practice has arguably already moved to incorporate non-functional aspects, Sakao and Shimomura's approach is of interest in that it seeks to explicitly incorporate the customer state through "receiver state parameters" which may be dynamically assessed. The conventional engineering approach would be to introduce customer characteristics through static requirements that constrain the design. Receiver state parameters apply to a "Persona", an imaginary target user. Persona data is divided into two classes: demographic data; and psychological data (values and life style). The latter includes such parameters as sense of belonging, relationships, self-fulfilment, enjoyment, respect, and excitement. Although this is directed at traditional service industries, it is a significant attempt to incorporate intangible values into a service design methodology. A different approach, through the "design" of expert teams, is suggested later.

Earlier steps to include psychological functioning were made by Hollnagel and Woods (1983) (also Rasmussen et al. 1994). In the context of safety–critical nuclear power plant operations, they sought to go beyond the conventional approaches of "man–machine systems" (or human–machine interfaces). Using what they termed "Cognitive Systems Engineering" (CSE), they incorporated the psychological factors of operators in addition to the conventional physical and physiological factors. They use the term "cognitive" to incorporate a spectrum of psychological factors, including emotions, as well as attitudes, aspirations, motives, etc. The sense is clear—"a different interdisciplinary synthesis is required". Hollnagel and Woods continue:

> The central tenet of CSE is that a [man-machine system] needs to be conceived, designed, analysed and evaluated in terms of a cognitive system. Like the Gestalt principle in psychology, a [man-machine system] is not merely the sum of its parts, human and machine. The configuration or organisation of man and machine components is a critical determinant of the outcome or output of the system as a whole.

There are numerous instances of failure due to humans being forced to interact on the machine's terms. The CSE approach has attempted to avoid such problems through a design process that accounts for human thinking characteristics. While cognitive systems engineering was developed for the machine-human operator design case, it has some parallels with customer thinking in product-service systems, where the customer can be conceived in the place of the operator.

The range of functions in complex product-service is one the challenges in the architecting of solutions. There is a growing literature on the architecting of complex systems (for example, Rechtin 1991). Many of the concepts are borrowed from software engineering, which in turn draws extensively on system engineering. Further, software architecting is itself established within the software engineering discipline (Shaw and Garlan 1996). As a professional methodology, architecting draws heavily on professional practice rather than academic theory. Architectures are the "bones" of a design, a higher level of abstraction, upon which the design may be "fleshed out", but it is not the actual design. Architecting is often described as an "art", as opposed to a science (Maier and Rechtin 2002). It makes extensive use of heuristics derived from experience, underscoring the professional practice origins of architecting. Operating at a layer above design, architectural requirements are less precise and more interpretive, capturing concepts and principles rather than specifics. There are now various frameworks developed for architecting complex systems; widely used one is the US DoD Architectural Framework or DoDAF (now at Version 2.0, US Dept of Defense 2009). It is quite general in its potential applications and may be used in any enterprise, public or private, to develop enterprise architectures. Importantly, it incorporates a service perspective alongside systems, defining a "Systems and Services View" as one of its four views. DoDAF enables the visualisation and understanding of complex, large scale systems and underlying processes of almost any type, including product-service systems. The authors know of several instances where it has been used to devise sustainment solutions which have significant service features.

Service-oriented architecture is a particular IT industry approach to business architectures that incorporates customer, user and provider views (Allen et al. 2006). The approach recognises services as significant, not secondary to the technology. Nevertheless, the services considered are software services, not the broader total solution approach required for output-based contracts.

This brief overview of existing design approaches has highlighted a number of parallel streams of development, all developed with different objectives and from different origins:

- Conventional product design, where after-sales service is added
- Product-service systems, developed with environmental objectives in mind
- Service engineering, developed with customer satisfaction as the key focus
- Cognitive systems engineering, developed for safety critical systems with humans in the loop
- Complex systems architecting, derived from professional practice
- Software as a service

It is apparent that there are many methods, practices and tools already available that may be brought to bear on complex engineering service systems, including the design of service processes. Yet in many instances there is often not a designated "chief designer" for the business solution. As Maier and Rechtin (2002) point out, a notable feature of successful unprecedented systems is that they have a "clearly identifiable architect or a small architect team".

21.2.2 System Thinking and System Engineering

> System: a complex whole; a set of connected things or parts; An organised body of material or immaterial things (The Concise Oxford English Dictionary, 8th Edition 1990)

System thinking has different meanings for different professional disciplines—it is heavily loaded with interpretations. In the design of technical products, system thinking is equated to "design thinking"; in other contexts, it is limited to "holistic thinking". Both are valid in context, but it is important to understand the context.

Engineering professionals would describe system thinking as the dominant thinking style in complex product systems. Its specific implementation is *system engineering*; it has become a ubiquitous methodology, a universal language, especially for defence systems. This language, not in itself complex and certainly easily learned, is nonetheless regarded as arcane and therefore not widely understood beyond the discipline of engineering. For practitioners, system engineering is *the* generic engineering method that enables them to manage complexity.

Like many useful words, *system* is a widely used term across many fields, often carrying qualifying words, such as health system, library system, or as a qualifier for another term, such as system biology or system ecology. Although retaining its core meaning throughout, each application of this very versatile word usually carries with it additional nuances that give it specific meaning and usefulness within that application. Some systems approaches, such as general system theory (Bertalanffy 1962) focus on holistic behaviours at system level. Service is fundamentally concerned with system level behaviours, at the level of the outputs to the customer. Because of its focus on system level behaviours, general system theory is sometimes cast as an antithesis of scientific reductionism.

The system engineering method is *both reductionist and holistic*. This is an important point. Product design requirements are reduced through several levels to component requirements, always taking into account the interfaces that influence behaviours at each level (and thus ultimately at the system level). The system design has meaning at every level, and is rigorously verified at every level. Furthermore, the physical instantiation of the design is integrated from its components and at each level the physical design is validated by test. The devolution of requirements is often not visible to observers external to the system engineering process (hence is poorly understood), but until this reductionist phase is complete, the highly visible physical integration and test phases cannot commence.

The system engineering process is often symbolised by the icon “V” that illustrates both reduction and integration. From the top left of the “V”, system level requirements are reduced to fundamental units of design; they are then integrated through a verification and test process upwards to the top right. The physical instantiation of the design is integrated as the deliverable system. Understanding the properties and behaviours of subsystems is critical to managing risks to performance at the level of the delivered system. Product design is tightly choreographed by the system engineering process, and is closely coupled with the processes of business management (especially project management). The system engineering process enables comprehensive budgets and schedules to be developed and risks to be identified and mitigated; system engineering and project management are intertwined in execution.

When invoked in the business literature (including the services literature), system approaches usually focus on the properties and behaviours of the whole system. It is when we set out to describe product-service systems that systems terminology becomes challenged. For service systems supporting safety–critical technical products (such as a fleet of aircraft or power generation assets), confusion over language must be assiduously avoided. The system engineering language is the language of the technical regulatory environment and it is reflected in the contracting environment. It is the language of customer requirements and of project management. It is ubiquitous in the defence sector. The integrity of the language is critical to product safety as well as product performance, and understandably, there exists an inertia of deeply embedded meanings.

Although diverse and even intangible constraints may be incorporated through the requirements process, its default style is to consider constraints in product (machine) terms. An example is human factors engineering (Stanton et al. 2005), where product design is influenced by ergonomic requirements, both physical and cognitive. Product performance and other requirements are elicited from the customer before commencing design. Griffin and Hauser (1993) and Blanchard (1998) describe requirements as the “voice of the customer”, enabling designers to

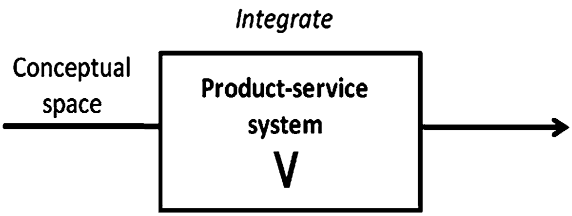

Fig. 21.1 Top level depiction of the design of a product-service system. Design occurs in conceptual space; its physical realisation is inferred rather than explicitly depicted here. "Integrate" is used as the primary verb describing the design activity. "V" is a symbol for the system engineering process. It is also symbolic of "Voice of the customer"

understand customer intentions. Mostly it is an early activity in the design process, enabling a requirements baseline to be struck. Once the baseline is set, the "voice of the customer" becomes an historical recording. This is very different to service, where there is a continuing dialogue between the customer and service personnel.

Here we focus on the design of the product-service system which comprises the product and the technical service system that supports it. The act of service delivery will be considered in a later section of this chapter. The system engineering approach is as valid for this product-service system as it is for the product system and is routinely applied. In Fig. 21.1 where the design of a product-service system is symbolically depicted, the same symbol "V" is used to describe the design process in conceptual space (in contrast, service is conceived in social space). "Integrate" is used as a verb to capture the idea of assembly of the product-service system from its many product and process components. "V" is also conveniently symbolic of "voice of the customer", the customer's requirements for the design.

There are numerous published variations on the generic system engineering process in product design (and undoubtedly even more unpublished variations), but the ideas of eliciting and evaluating customer requirements, developing a design concept, validating the design against the requirements and integrating the design are all core. The generic process uses a defined and structured language, supported by project dictionaries, to provide an appropriate degree of linguistic precision. In contrast to engineered products, natural systems such as biological systems (for example) are not "constructed" or "integrated" in the same sense as product. The engineering language of construction is not paralleled in the system language employed for natural systems. The systems biology language is predominantly focused on the need to preserve existing system level behaviours, rather than to construct them.

21.3 Case Example of a Complex Sustainment Solution

This case example is used as an illustration of a complex sustainment system. The Lead-in-Fighter In-Service Support Contract for the Royal Australian Air Force (RAAF) is a performance-based contract involving the sustainment of an aircraft fleet and requiring availability of mission-ready aircraft on a daily basis. It is similar in many respects to the UK MoD Tornado support contract (NAO 2007).

This contract is for the sustainment of the Hawk fast jet training fleet operated by the RAAF at bases on the east and west coasts of the continent. Under the terms of the contract, the contractor provides:

- Deeper maintenance for on- and off-aircraft equipment, at two bases
- Engineering services for management of the aircraft to military airworthiness standards
- Logistics supply support

There are several output measures of contract performance, the principal measure being the availability of a contracted number of mission-capable aircraft to meet the RAAF's daily flying requirements. The contract is relevant here because of the extent of the skilled engineering and maintenance operations, the nature of the availability measures and the nature of the relationships between the stakeholders: contractor, customer and the independent military airworthiness regulator. As an early performance-based contract, it was established in a "product thinking" environment within both the customer and contractor communities and has to consciously incorporate "customer-oriented thinking".

The role of the independent airworthiness regulator should be noted. While it is not party to the contract, it is a stakeholder in the technical systems aspects of the solution and places hard constraints on the solution space. It functions as an independent authority, setting engineering and maintenance standards that are applied to both parties in the contract. It is typical for safety–critical engineering sustainment systems to have an independent regulator as a stakeholder.

The original design for the Hawk training aircraft was conducted in the UK many years prior to its service in Australia, although like many aircraft the type has been subjected to continuing development over many years. The variant in-service with the RAAF was developed specifically to meet its requirements as a lead-in fighter trainer. Engineering support is provided by a small team of engineering personnel in Australia who have access to a larger engineering support organisation in the UK. All maintenance and logistics support is delivered on-site in Australia at the end of a global supply chain.

In this example of a complex sustainment solution, teams of highly skilled personnel function in tightly controlled and highly regulated environments to deliver the contracted outputs. Some of these personnel have "back office" roles with little direct contact with the military customer, while others ("front office" personnel) have frequent and crucial contact. Project managers, senior engineers, maintenance managers and integrated logistics personnel have direct customer contact. Front office personnel requires appropriate social skills to perceive the customer's intentions and to manage the complex relationships among the stakeholders. But back office or front office, all are part of the delivery team.

21.4 The Social Construction of Service

Personnel responsible for service delivery in the case example typically employ a social language of description for service activities. They may talk of "a journey with the customer", "an evolving relationship", "understanding the customer's thinking", or similar term. These terms are suggestive rather than precise and are in contrast to the structured and categorised descriptions necessarily employed in the design of the aircraft product-service system.

21.4.1 Importance of the Social Dimension

If product system design requires the "voice of the customer" to be heard, then service requires the "mind of the customer" to be understood. Many contractor "front office" personnel in the case example are in daily face-to-face contact with their customer counterparts. This may be to manage defined tasks and plans that have been routinised (such as flight training missions), or to negotiate variations to standard programs (such as fleet maintenance schedules), or to review status of major work tasks and plans. Arisings that occur from routine operations may require the attention of both contractor and customer personnel to devise work-arounds; these may have flow-on effects to other standardised tasks that will then also require attention. Especially in the defence sector, the customer may impose urgent (or surge) operational requirements (National Audit Office 2007) that necessitate significant changes to the design of the sustainment solution, possibly requiring suspension of an existing solution element and inclusion of a new element. To meet these urgent needs, there may be insufficient time to meticulously define the requirements in the usual manner of system engineering; in these circumstances it is essential that the contractor be able to "read between the lines" of the sparse urgent requirement. When the relationship is mature and validated, the contractor can rapidly infer the customer's intentions and act accordingly.

As social beings, we create representations of the minds of others based on schemas of our own mind (Rizzolatti et al. 2001; Frith 2002; Gallese et al. 2004). The brain is an organ of adaptation, and developing a mental model the mind of others is part of its work; this model is sometimes called "theory of mind". Neural measurements have provided clear evidence that our capacity to develop an image of the mind of others is related to our capacity to develop an image of our own mental processes (Decety and Chaminade 2003). The fact that a mind can develop a model of itself may be the basis of consciousness, and thereby the basis of social cognition (Damasio 2000); without a sense of self it is impossible to develop a sense of other. Building representations of the minds of others incorporates not merely their focus of attention, but also their desires and intentions, beliefs, attitudes, memories, emotions, patterns of thought and perceptions. Theory of mind is mindful of the future consequences to others of current actions. Insensitivity to consequences is an indicator of an undeveloped theory of mind, or an immature relationship.

Living organisms move with intention and by possessing a theory of mind can build maps of intention of others, enabling them to attune and adapt to their perceived internal states (Siegel 1999). Secure social relationships are an essential enabler of this construction and develop when a state of trust exists. Trust is a mutual state; it can be expressed as confidence in the intention of others, and, in the context of contracts, supported by sustained prior performance and behaviours. The social aspect of relationships acknowledges the influence of emotional processing together with abstract reasoning; cognition and emotion are not independent and each influences the other (Damasio 1996). In most instances of typified by the aircraft availability example, the execution of relationship tasks requires many-to-many—as opposed to one-to-one—relationships. Teams of people create the relationship structure (relationships between networks/groups), although of course it incorporates many one-to-one relationships. Extension from one to many is common in cognitive science. For example, Hutchins (1995) in a detailed study of team performance in maritime navigation tasks defined the boundary of the cognitive unit as the team, not the individual. The team was evaluated as a socially distributed system of cognition.

Milo et al. (2004) proposed the idea of superfamilies of networks (sociological, biological and technological) and explored patterns within the networks—"network motifs". In biological systems, recurring patterns were associated with local circuits to perform key information processing tasks. Similar pattern behaviours were found in all three types of networks, but it is this feature in the sociological network type that is relevant here. Greenfield (2008) observed certain aspects of functional scalability between individual neurons, individual brains (networks of neurons) and groups (networks of brains). Cozzolino (2006) has made similar observations of cascading networks in the context of psychotherapy, introducing the idea of the "social synapse" to describe communication between brains. Sensing across the social synapse enables the construction of a theory of mind. This functional scalability enables the understanding of human relationships at the level of the mind-to-mind dyad to be applied at the level of teams.

21.4.2 Design in Social Space: The Creation of Expert Teams

The delivery of service is achieved by integrated teams of skilled personnel. In the aircraft availability example, these teams comprise personnel from many disciplines, including engineering, maintenance, logistics, supply chain, contract management and project management. They employ the product-service system in combination with their domain expertise and social skills.

Effective teams exhibit socially distributed cognition. Hutchins (1995) conducted his extensive study of team expertise and performance in the framework of social cognition, and in the complex context of the workplace characterised by

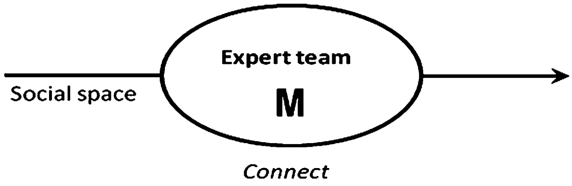

Fig. 21.2 A top level depiction of design in the social space. The symbol "M" represents the primary task to perceive the "Mind of the customer". "Connect" is the primary verb describing the team activity. A *rounded shape* distinguishes it from system design in the conceptual space (Fig. 21.1) which uses *squared corners*

changing and stressful circumstances. Not all teams composed of experts become expert teams (Hackman 1990), so clearly there is more to effective teams than individual expertise which is where the concept of socially distributed cognition becomes important. Neuroimaging has provided supporting evidence that social cognition results in altered neural connections at the level of binary (one-to-one) relationships; the progression to relationships among many is a natural extension. Salas et al. (2006) have summarised evidence from studies of teams in business, aviation, healthcare and military environments. They categorised the characteristics of expert teams as follows:

- Expert teams hold shared mental models and anticipate each other's needs
- They optimise resources by learning and adapting
- They have clear roles and responsibilities
- Expert teams have a clear, valued and shared vision
- They engage in a cycle or discipline of pre-brief, performance and de-brief
- Expert teams have strong team leadership
- They develop a strong sense of collective, trust, teamness and confidence
- They manage and optimise performance outcomes
- Expert teams cooperate and coordinate

This instructive list demonstrates a strong sense of reflection, assessment of the states of others and adaptation to those states. This summary does not specifically address the states of those outside the team (for example, an external customer team) but the ability to develop representations of other minds is generic. This is then coupled with the concept of social cognition that enables a shared understanding to be achieved. Arguably the most important skill set of the team comprises the social skills of attunement and adaptation to the intentions of others. This is supported by observations and anecdotal evidence from industry practice and the case example.

Thus, the primary hypothesis offered here is that, for complex engineering systems, design in the social space is about the creation of expert teams, and the primary skill set of expert teams is the ability to develop a "theory of mind" of others. For this reason, in Fig. 21.2 the symbol for design in the social space is chosen to be “M”, for “Mind of the customer”. This has some symmetry with the symbol “V” employed in system design which represents the “Voice of the customer”. The team “connects” with the cognitive state of the customer, attunes and adapts its actions to the customer’s perceived intentions.

21.5 Service Performance: Harmonising the Social Space With the Conceptual Space

Service performance via a heterogeneous socio-technical system combines (“harmonises”) the intangible social cognition of the service team with the tangible product-service system to achieve the solution. A symbolic representation of harmonisation is depicted in Fig. 21.3. Some members of the service team in the case example speak of judgment and creativity as critical enabling skills but these skills often cannot be reliably replicated elsewhere as they are context-dependent. They must always be used in conjunction with highly developed technical skills.

This chapter offers the idea of connecting with and modelling the minds of others as central to service thinking for complex engineering service solutions. It enables teams to attribute desires and intentions to others and to evaluate and explain their likely actions. In a repeating cycle of attunement, evaluation and adaptation, teams learn to anticipate customer aspirations and can adapt in advance. When the cycle becomes habitual, backed up by technical performance (delivering value), the customer develops confidence in the values (future performance) of the team and a state of trust is achieved. In this sense, service satisfaction may be described as *value underpinned by values*.

Three phases can be synthesised in the construction of representations of another’s mind for the purpose of deciding on future courses of action (after Siegel 2007):

- Attunement—this involves orienting the focus of attention on the internal world of another, free of judgmental bias, to perceive signals relating to their intentions. These intentions may then be mirrored internally. Interaction styles may be classified as: mature/regulated; disorganised; ambivalent; dismissive. A mature/regulated style is essential if signals are to be correctly sensed. Effective attunement provides motivation and energy for downstream action.
- Evaluation—evaluation is a deliberative conceptual activity that appraises the received perceptions to classify or categorise likely responses into schemas of action. Expert teams will have established patterns of practice that facilitate rapid and routine (but effective) responses, but the evaluation must consider whether the required response fits the pre-existing schemas. If not, then adaptation is required.
- Adaptation—when the need for change is identified, the team must then re-align its activities accordingly. Expert teams will adapt quickly to achieve resonance with the customer’s intentions, although a degree of negotiation may be required.

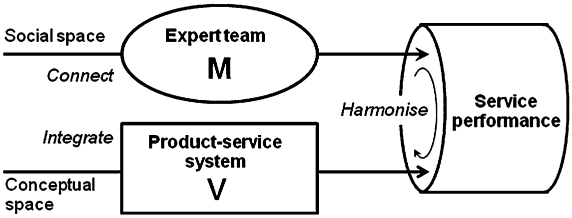

Fig. 21.3 Combining "mind of the customer" (M) with "voice of the customer" (V): a symbolic depiction of solution delivery as actions *Integrate/connect/harmonise*. A situated solution in a field setting would be a chain of recurring activities symbolised in the figure

Effective adaptation requires persistence beyond the initial connection so that harmonisation occurs in the long term.

The idea of Fig. 21.3 recurring on a regular (even daily) basis to generate a chain of attunement, evaluation and adaptation has some similarity with "appreciative systems" described by Checkland and Casar (1986) and attributed to Vickers (1965). Vickers referred to the interacting flux of events and ideas over time (a "two-stranded rope"). The social features of appreciative systems highlighted by Checkland (2000) are judgment and relationship management. Checkland separates judgment into two aspects: judgments about reality (the world in being), and judgments about values (distinguishing good from bad). Judgment in both senses is present in the harmonisation chain, but arguably theory of mind is a richer description than relationship management. Both are living, open systems.

21.6 The Need for Service Thinking as a Style Distinct From System Thinking

We have developed, at least an initial argument, that the success of service systems design and operation is as much dependant on consideration of the social dimension as the more conventional conceptual approach using system engineering methods. This is of critical importance to ensure that the expert team is configured to understand the "mind of the customer" and hence deliver on the expectations held in the customer's own mental model of service excellence. It is proposed that an extension of current systems thinking and system engineering cannot for the foreseeable future successfully address this need as the reductionist method is too deeply embedded in the development of complex systems. A new complementary thinking style needs to be developed to design expert teams able to achieve service excellence in the mind of the customer.

The president of Fuji Xerox Co. has been quoted in the daily business press as acknowledging the difficulties in trying to shift his business model to a service-oriented company: "it is a struggle to shift his back office experts from their customary focus on manufacturing QCD (quality, cost, delivery) and indeed to shift them out of the back office altogether. He wants his experts in the sales force, developing solutions for clients and customers, and understanding that their copier manufacturing company is becoming a service provider" (Alford 2009). There is anecdotal evidence that other companies making similar shifts are experiencing similar challenges.

It is difficult to change patterns of activity when existing schemas have served well over long periods. Such is the case with system thinking as the dominant cognitive style in the domain of complex product design implemented in system engineering: it is too deeply embedded to support cultural change through incremental development. The intention is not to reduce its effectiveness, but to complement it with a distinctively different style. Making yet another adjustment to the plethora of existing instantiations will probably mean that, in professional practice where it really counts, its value will be depreciated merely by association with the familiar. Variations and enhancements to such a dominant style, no matter how important, tend to be subsumed within entrenched patterns of practice. If we contend that service thinking is indeed critical to service delivery, then the lesson from this account is clear: it must be offered as a distinctive style that stands on its own, clearly distinguished from system thinking which, for system designers, is equated to system engineering. Education is easier to achieve than re-education.

For the purposes of contrasting the two styles, systems thinking, driven from the product paradigm, is characterised by:

- A product approach, with the customer at arm's length
- Creation of a technical design solution and is an episodic activity
- Segregation of solution design from delivery
- Understanding of how things connect, incorporating mainly objective requirements
- Incorporation reductionist method, supporting both holistic and elemental views

At a basic level, service thinking requires the service provider to account for customer thinking, and availability contracts will usually (even if indirectly) incentivise this behaviour. Managing the customer relationship becomes a critical success factor in these contracts and it is here that social features (beliefs, attitudes, memories, emotions, etc.), which cannot be encoded in product design, are highlighted. Consequently, and as a comparator against systems thinking, service thinking is characterised by:

- A social activity wherein the customer co-creates and co-delivers the solution
- Describing a business solution within which design is a continuing activity
- Integrating design and delivery which are closely coupled
- Understanding how minds connect and incorporates social content
- Not yet amenable to method, supporting only holistic views

These comparisons of thinking styles are heuristics. Product system practitioners are accustomed to using heuristics, which is probably why they find these contrasts to be useful. Heuristics are common in practical system architecting as noted earlier. Service thinking has strong social and business flavours. It recognises affective content in solution delivery, something that does not fit comfortably with system thinking which presents as an entirely dispassionate and objective process, yet, the authors have found that among experienced systems practitioners, when offered as a style distinct from system thinking, service thinking has achieved acceptance.

The concept of co-production of service drives the need for service thinking. In the context of complex engineering service systems, co-production is a continuing activity where the contractor team repeatedly engages with the customer to determine customer intentions. In contrast, requirements elicitation is an episodic activity at arm's length, rendering design requirements as historical records that may be occasionally updated. Compared with product design, service is forward-looking and gauges the intentions of the customer. It achieves this in the social space where the service team seeks to connect with the mind of the customer. This is a rich idea, involving both the person-to-person and team-to-team dyads, as well as recognising the non-deliberative functions of the mind, including emotion. Service design is about creating expert teams that generate shared awareness of customer intentions, and acting on that shared cognition. The generation of trust in service provision requires that the team deliver service performance, but it also requires that the customer has confidence in the future performance of the team, which in turn requires discernment of customer intentions.

Consideration of the case example offers some basic insights into the application of these thinking styles to practical service systems. The face-to-face protocols of the aircraft availability contract in the case example are centred on technical processes which utilise system thinking, but the relationships extend beyond that. A cultural appreciation is required for customer fleet management, maintenance and engineering operations, all of which must be conducted in strict compliance with the regulations of the military technical airworthiness management system. Contact between the contractor and customer occurs daily and the social demands in relationship management are important. The cultural and social demands of the contract are very real and critical to service satisfaction.

21.7 Chapter Summary and Questions

Based on professional experience and observations from current practise, this chapter has offered some practical insights regarding the nature of service system design for complex services. Some pragmatic suggestions can be made for the design of future complex service systems to more nearly achieve "service excellence" in the mind of the customer:

- A product-service system must have a clear "chief architect" who is attuned to working in the social and conceptual space, and who is equipped to understand the mind of the customer and contractor

- The service solution must be co-developed with the customer with openness and honesty so that both customer and contractor can understand each other's mind. The expert (delivery) team needs to include the customer as a joint enterprise and needs to be initiated when the service need is identified—it is difficult to see how successful service can be procured through competition
- The concept of measuring "service excellence" through system engineering methodology is illusory—the social dimension needs to be considered, possibly using team behaviours as an indicator

The key concepts of social construction of service, namely, service thinking, designing expert teams, and discerning the mind of the customer, offer a rich field for future research. The chapter suggests several research questions:

- Service thinking: what are the differentiators for service thinking which enable excellence in service delivery?
- Expert teams: how do expert teams harmonise the social and system dimensions in complex sustainment solutions, what are the characteristics that enable it, and how can they be embedded in practice?
- Theory of mind: how do teams capture and use the mental models of others, particularly with regard to intentions, to enable mutual trust and service satisfaction?

Further work needs to be done to review and re-analyse case study material to provide more specific evidence and further practitioner interviews are required. It is nevertheless proposed that service thinking is sufficiently different from system thinking (and important) to warrant a separate identity. Achieving its acceptance by practitioners will still require patient explanation and example. As former industrial practitioners, the authors recommend the pragmatism of this approach.

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