A CASE FOR SERVICE SYSTEMS ENGINEERING

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Abstract

A case is made for further developing a branch of systems engineering that focuses on problems and issues which arise in the service sector. We promulgate this special focus not only because of the size and importance of the service sector but also because of the unique opportunities that systems engineering can exploit in the design and joint production and delivery of services. We begin by considering the economic, technological and demographic contexts within which the service sector has flourished; we then address both services, especially emerging services, and systems engineering, followed by a discussion of how to advance the field of service systems engineering, and concluding with several remarks. In particular, a number of service systems engineering methods are identified to enhance the design and production/delivery of services, especially taking advantage of the unique features that characterize services – namely, services, especially emerging services, are information-driven, customer-centric, e-oriented, and productivity-focused.

Keywords: Service sector, systems engineering, information technology, decision technologies, customer-centric, productivity

1. Introduction

A case is made for further developing a branch of systems engineering that focuses on problems and issues which arise in the service sector. We promulgate this special focus not only because of the size and importance of the service sector but also because of the unique opportunities that systems engineering can exploit in the design and joint production and delivery of services. We begin by considering the economic, technological and demographic contexts within which the service sector has flourished (Section 1); we then address both services (Section 2), especially emerging services, and systems engineering (Section 3), followed by a discussion of how to advance the field of service systems engineering (Section 4), and concluding with several remarks (Section 5).

In order to provide a context for considering services, it is instructive to review the critical stages in a nation's economic evolution. As summarized in Table 1, there have been three stages. The first – mechanical – stage focuses on agriculture and mining (i.e., living off of land, air and sea); it seeks to enhance farming productivity, employs mechanical tools that have product life cycles on the order of decades, depends mostly on muscle power, embraces a living standard concerned with subsistence, and is limited in its scope of economic influence – primarily impacting the family or immediate

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locale. The second – electrical – stage focuses on manufacturing and construction (i.e., creating and producing products and structures); it seeks to enhance factory productivity, employs electromechanical machines that have product life cycles on the order of years, depends on both muscle and brain power, embraces a living standard concerned with the quality of goods, and is broader in its scope of economic influence – impacting the region or nation. The third – information – stage focuses on services (i.e., creating and delivering added value that are essentially intangible); it seeks to enhance information (i.e., processed data from a decision making perspective) productivity, employs information (including communications) technologies that have service life cycles on the order of months, depends mostly on brain power, embraces a living standard concerned with the quality of life, and is global in its scope of economic influence. More recently, the words "experience economy" (e.g., tourism, Starbuck coffees, space station visits, etc.) have been employed to highlight the quality of life emphasis of this third stage in a nation's economic evolution.

Table 1 A Nation's Economic Evolution

Characteristics		**Stages in a Nation's Economic Evolution**		
		Mechanical	**Electrical**	**Information**
▪	Economic Focus	Agriculture; Mining	Manufacturing; on-Construction	Services
▪	Productivity Focus	Farming	Factory	Information
▪	Underlying Technologies	Mechanical Tools	Electromechanical Machines	Information/ Communication
▪	Product Life-Cycle	Decades	Years	Months
▪	Human Contribution	Muscle Power	Muscle/Brain Power	Brain Power
▪	Living Standard	Subsistence	Quality of Goods	Quality of Life
▪	Impact Scope	Family/ Locale	Regional/ National	Global
▪	Onset in U.S.	Late 1700s	Late 1800s	Late 1900s

In general, every nation has gone or will go through these three stages of economic evolution: today, the underdeveloped nations are still at the mechanical stage; most (i.e., the developed) nations are at the electrical stage; while the economically advanced nations are at the service stage. Interestingly, the U.S. has seen the onset of each new stage every 100 years or so: in the late 1700s for the mechanical stage, in the late 1800s for the electrical stage, and in the late 1900s for the information stage. On the other hand, other countries – like China – have been slower in moving from the mechanical to the electrical stage; yet they have since been faster in moving to the information stage, perhaps because of the accelerated pace of change in computer technology.

Being a late 20th Century achievement is why information technology is not among the list of the top 20 achievements in the 20th Century, as compiled by the National Academy of Engineering (NAE 2000). While Table 2 lists NAE's top 20 for the last century, we have also added three possible additional achievements for the early 21st Century: information technology, nanotechnology, and, what we define as, "technobiology". (Technobiology emphasizes the contribution of engineering or technology to biological issues, including the development of new drugs, DNA chips, and body parts; in contrast, biotechnology emphasizes the contribution of biology to technological issues, including the development of molecular computers, cognitive ergonomics, and adaptive systems.) Returning to information technology, it should be noted that its key underpinning – computers – has only been in existence for five decades; the first commercially available computer – the Universal Automatic Computer or Univac I – was built in 1951. Nevertheless, computers have already evolved through more than six generations, including the vacuum tube-based computers of the 1950s, the transistor-based computers of the 1960s, the integrated circuit-based computers of the 1970s, the very large scale integrated (VLSI) circuit-based computers of the early 1980s, the ultra large scale integrated (ULSI) circuit-based computers of the late 1980s and early 1990s, and the computer-on-a-chip hardware of today. Alternatively, one could follow the advancement of the microprocessor chip, which continues to be better, faster, cheaper, and smaller. Introduced in 1971, Intel's first chip – the 4004 – revolutionized the electronics industry; the 80286 virtually ran all personal computers (PCs) in the early 1980s; the 386 provided PC users with much enhanced speed and performance in the late 1980s; the 486, launched in 1989, provided the power to run multimedia software; the Pentium, introduced in the early 1990s, processed over 200 million instructions per second (MIPS); and in 1996, the sixth generation chip – the P6 – debuted with an initial clock speed of over 150 megahertz (i.e., the rate at which the microprocessor cycles through programming instructions). Today's chip cruises at several hundred megahertz, while

Table 2 Impact of Technology

▪	**National Academy of Engineering's Top 20 Engineering Achievements in the 20th Century:**		
1.	Electrification	11.	Highways
2.	Automobile	12.	Spacecraft
3.	Airplane	13.	Internet
4.	Water Supply and Distribution	14.	Imaging
5.	Electronics	15.	Household Appliances
6.	Radio and Television	16.	Health Technologies
7.	Agricultural Mechanization	17.	Petroleum and Petrochemical Technologies
8.	Computers	18.	Laser and Fiber Optics
9.	Telephone	19.	Nuclear Technologies
10.	Air Conditioning and Refrigeration	20.	High-Performance Materials
▪	**Possible Additional Achievements in the Early 21st Century:**		
21.	Information Technology		
22.	Nanotechnology (Nanomaterials, Nanotubes, Nanoelectronics)		
23.	"Technobiology" (New Drugs, DNA Chips, Body Parts)		

research into both clockless (i.e., asynchronous) and molecular chips promises even faster speeds at much lower power consumption. Indeed, in 1965, Gordon Moore, a cofounder of Intel, conjectured that the density of transistors on integrated circuits – and therefore their speeds – would double about every 18 months; incredibly, his conjecture is still holding true today. Likewise, dynamic random-access memory (DRAM) chips have gone from storing 1,024 bits of data in 1971, to today's several hundred megabits. In terms of general data storage, today's gigabyte (i.e., 10E9 byte) requirements are quickly making room for tomorrow's terabyte (i.e., 10E12 byte), the next few years' petabyte (i.e., 10E15 byte) and the next decade's exabyte (i.e., 10E18 byte) requirements.

Another critical underpinning of information technology is communication networks. Although computers (i.e., mainframes) tended to centralize data and – data-based – decision making in the 1960s and 1970s, the advent of computer networks, together with PCs, have been a decentralizing (i.e., less hierarchical) force. Indeed, information technology has been primarily credited with keeping the U.S. economy vibrant as other nations, especially those in Asia, experienced an economic implosion in the late 1990s; as the “dot-com bubble” burst in 2001; as the September 11, 2001 tragedy unfolded; and as stock prices fell in 2002 because of a weakening economy and a lack of trust in corporate and government leadership. Information technology has helped to identify and correct imbalances between supply and demand far more rapidly than in the past, thus rendering the business slowdowns both shorter and shallower. In the U.S., it has contributed to productivity growth in the non-farm business sector – at an annual rate of 2.5% from 1995 to 2000, as compared to 1.4% from 1972 to 1995. Moreover, productivity growth was at 1.9% in 2001, which, although lower than the 3.3% rate in 2000, was still higher than comparable statistics during previous cyclical slowdowns. With corporate earnings somewhat stalled, if not decreasing, a fair question to ask is: Who have benefited from the productivity gains? It seems that workers have benefited in terms of higher real wages and consumers have benefited in terms of access to better products and services, at lower prices; on the other hand, investors who have held on to their stocks since the mid-1990s have seen their

Table 3 Global Demographics

Continents	**Percent of Population Aged 60 or Older**		**Working Age Persons Per Aged 65 or Older Person**	
	2002	**2050**	**2002**	**2050**
Europe	20.0%	37.0%	3.9	1.8
North America	15.7%	27.1%	5.0	2.8
Asia	8.6%	22.9%	11.1	3.9
Latin America	7.9%	22.1%	11.0	3.8
Africa	5.0%	10.0%	16.8	8.9

Source: 2002 Population Data, United Nations portfolio value increase only slightly.

Indeed, information technology has transformed large-scale information systems from being the "glue" that holds the various units of an organization together to being the strategic asset that provides the organization with its competitive advantage. Thus, the U.S. military is counting on information technology to bring up-to-the-minute data to soldiers in combat on land, air or sea. However, while information technology can transform a data poor situation into a data rich environment, the fact remains that data need to be effectively and efficiently fused and analyzed in order to provide appropriate information for intelligent decision making in regard to the design and production/delivery of services. Today, retailers complain, "We are awash in data but starved for information." Thus, in order to overcome the somewhat embarrassing data rich, information poor (DRIP) problem that Tien (1986) forewarned, it is critical to develop more sophisticated data fusers and data analyzers – as a part of what Tien (2002) calls "decision informatics" – that could yield the information or knowledge for making smart choices (Hammond et al. 1999).

Consequently, information technology is a necessary, but not sufficient, condition for robust and timely decision making; the sufficient condition is one based on decision informatics or real-time, information-based decision making. Clearly, information/communications and decision making technologies together, provide for a supportive environment within which services can continue to flourish. This has been strikingly demonstrated by Wal-Mart with its point-of-sale, information system, which is at the heart of its service value chain; the system has had a significant impact on the company's productivity gains, cost controls, service quality, and ultimately growth.

Table 4 Employment in Service Sector

Nations	Service Sector Employment as Percent of Total Employment		
	1980	**1999**	**Change**
United States	67.1%	80.4%	19.8%
Canada	67.2%	73.9%	10.0%
Japan	54.5%	72.4%	32.8%
France	56.9%	70.8%	24.4%
Israel	63.3%	70.7%	11.7%
Italy	48.7%	61.1%	25.5%
China	13.1%	26.4%	101.5%

Source: 2000 Statistical Yearbook, United Nations

A third context within which to view the future of services is to consider global demographics. As summarized in Table 3, the world's population is aging at an alarming rate; it is projected that over a quarter of the population will be aged 60 years or older in 2050, over twice the comparable ratio in 2002. Consequently, the demand for both health and non-health services, especially those required by the retired and the elderly, will increase significantly in the next several decades. Table 3 also suggests that there will be fewer workers to support those aged 60 years or older; barring large-scale immigration and dramatic changes in retirement policies, this situation will be particularly acute in Europe and North America, where the economies are primarily service-oriented. Thus, it is critical that service productivity be significantly enhanced so that the quality of life will not diminish in today's economically advanced, service-oriented nations. Certainly, employing a systems engineering approach to the design and production/delivery of services will lead to significant gains in service productivity.

Table 5 Scope and Size of U.S. Employment

Industries	Employment (M)	Percent of Total
Wholesale & Retail	30M	22.9%
Business & Professional	14	10.7
Education	12	9.1
Government (Except Education)	11	8.4
Health Care	10	7.6
Finance, Insurance & Real Estate	8	6.1
Transportation	4	3.1
Communications	2	1.5
Other	12	9.2
SERVICE SECTOR	**103**	**78.6**
Manufacturing	18	13.7
Construction	6	4.6
Agriculture	3	2.3
Mining	1	0.8
GOODS SECTOR	**28**	**21.4**
TOTAL	**131**	**100.0**

Source: U. S. Bureau of Labor Statistics, 1998

2. Services

The importance of the service sector cannot be overstated. As indicated in5

, the service sector employs a large and growing proportion of workers in the industrialized nations. What constitutes the service sector? It can be considered "to include all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced and provides added value in forms (such as convenience, amusement, timeliness, comfort or health) that are essentially intangible…" (Quinn et al., 1987). Implicit in this definition is the recognition that service production and service delivery are so integrated that service production/delivery can be considered to be a single, combined stage in the service chain.

As reflected in Table 5, the service sector includes a number of large industries; indeed, service employment in the U.S. is at about 80 percent, while the remaining four economic sectors (i.e., manufacturing, construction, agriculture, and mining), which together can be considered to be the "goods" sector, employ the remaining 20 percent. In practice, the delineation lines between the different economic sectors are blurred; this is especially true between the manufacturing and service sectors, which are highly interdependent （Tien and Berg 1995, Berg et al. 2001）. Clearly, the manufacturing sector provides critical products (e.g., autos, computers, aircrafts, telecommunications equipment, etc.) that enable the delivery of efficient and high-quality services; equally clear, the service sector provides critical services (e.g., financial, transportation, design, supply chain, etc.) that enable the production, distribution and consumption of effective and high-quality products. Such traditional manufacturing powerhouses like GE and IBM have become more vertically integrated and are now earning an increasingly larger share of their income and profit through their service-oriented operations. The interdependence and complementarity of services and manufacturing are significant. Indeed, many of the recent innovations in manufacturing are relevant to the service industries. Concepts and processes such as cycle time, total quality management, quality circles, six-sigma, design for assembly, design for manufacturability, design for recycling, small-batch production, concurrent engineering, just-in-time manufacturing, rapid prototyping, flexible manufacturing, agile manufacturing, distributed manufacturing, and environmentally sound manufacturing can, for the most part, be recast in service-related terms. Thus, much of the engineering and management concepts and processes employed in manufacturing can likewise be used to deal with problems and issues arising in the service sector.

Table 6 provides an additional comparison between the goods and service sectors. The goods sector requires material as input, is physical in nature, involves the customer at the design stage, and employs mostly quantitative measures to assess its performance. On the other hand, the service sector requires information as input, is virtual in nature, involves the customer at the production/delivery stage, and employs mostly qualitative measures to assess its performance. Moreover, to further underscore.

Table 6 Economic Sectors Comparison

Characteristics	Goods Sector	Service Sector
▪ Essential Input	Material	Information
▪ Value Chain	Physical	Virtual
▪ Customer Involvement	At Design	At Production/ Delivery
▪ Performance Measures	Mostly Quantitative	Mostly Qualitative
▪ Activity Distribution For:		
--"Machine Purchased Candy"	100%	0%
--"McDonald Purchased Hamburger"	50%	50%
--"Physical Examination"	0%	100%

the complementarity of the economic sectors, Table 6 also illustrates how three different activities might be distributed in terms of attribution to the goods versus service sector; actually, almost every activity involves both goods and services – thus, although a physical examination can be exclusively considered to be a service, it may still involve the use of medical goods or tools. Interestingly, since service sector performance is to a large extent subject to customer satisfaction and since, as Tien and Cahn (1981) postulated and validated, "satisfaction is a function of expectation," service performance or satisfaction can be enhanced through the effective "management" of expectation. Parasuraman et al. (1998) employed the gap between expectation and actual service to evaluate service quality, as defined by reliability, tangibles, assurance, responsiveness and empathy; although the questionnaire-based evaluation tool was developed for retailers, it has had wider applications. Such demand management schemes are further discussed in Section 3 (Systems Engineering).

As we consider the future, it is perhaps more appropriate to focus on emerging services. Emerging services are almost totally dependent on information technology; they include, as examples, financial services and banking, airline reservation systems, and consumer goods marketing. The introduction of the Universal Product Code (UPC) and the optical scanning of these codes have not only, for example, shortened checkout times but also yielded critical data for undertaking marketing research. Further, the UPC has been critical to the coupling of the production and logistics stages in the supply chain. The Global Positioning System (GPS) is bringing significant productivity improvements to the world's transportation and emergency service (i.e., police, ambulance and fire) agencies, as well as to other dispatch-oriented industries (e.g., taxicab companies, delivery services, and maintenance services). Of course, the World Wide Web or Internet is the world's data superhighway in which businesses can interact with their far-flung offices, or with other businesses; consumers can buy goods and services; and individuals can exchange e-mails or surf for information. Despite the recent "dot-com bubble" burst, the Internet is here to stay and e(lectronic)-services is continuing to grow, as is e-commerce.

As indicated in Table 7, the emerging service enterprises interact or "co-produce" with their customers in an electronic (including touch-tone, voice mail, e-mail, and Internet) medium, as compared to the physical environment in which the traditional or bricks-and-mortar service enterprises interact with their customers. Similarly, in comparison to traditional services, the emerging services are typically lower in labor and inventory requirements, but higher in their requirements for self-service, transaction speed, and computation. In regard to data sources that could be used to help make appropriate service decisions, both sets of services rely on multiple data sources; however, the traditional services require homogeneous (mostly quantitative) sources, while the emerging services require non-homogeneous (i.e., both quantitative and qualitative) sources. Paradoxically, the traditional service enterprises have been driven by data, although data availability and accuracy have been limited (especially before the pervasive use of the UPC); likewise, the emerging e-service enterprises have been driven by information (i.e., processed data), although information availability and accuracy have been limited, again due to the aforementioned data rich, information poor (DRIP) problem. Consequently, while traditional services – like traditional manufacturing – are based on economics of scale and standardization, emerging services – like emerging manufacturing – emphasize economies of knowledge and adaptiveness. The result is a shift in focus from mass production to mass customization (whereby a service – or product – is produced and delivered in response to a customer's stated or imputed needs); it is intended to provide superior value to customers by meeting their unique needs for services – and products. It is in the area of customization – where customer involvement is not only at the goods design stage (as indicated in Table 6) but also at the manufacturing or production stage – that services and manufacturing are merging in concept. Another critical distinction between traditional and emerging services is that, although all services require decisions to be made, the former services are based on predetermined decision rules, while the latter require decisions in real-time; that is why Tien (2002) has advanced a decision informatics paradigm that relies on both information and decision technologies.

Table 7 Traditional and Emerging Services Comparison

	Service Enterprises	
Issues	**Traditional**	**Emerging**
▪ Co-Production Medium	Physical	Electronic
▪ Labor Requirement	High	Low
▪ Inventory Requirement	High	Low
▪ Self-Service Requirement	Low	High
▪ Transaction Speed Requirement	Low	High
▪ Computational Requirement	Medium	High
▪ Data Sources	Multiple Homogeneous	Multiple Non-Homogeneous
▪ Driver	Data-Driven	Information-Driven
▪ Data Availability/Accuracy	Poor	Rich
▪ Information Availability/ Accuracy	Poor	Poor
▪ Size	Economies of Scale	Economies of Knowledge
▪ Service Flexibility	Standard	Adaptive
▪ Focus	Mass Production	Mass Customization
▪ Decision Time Frame	Predetermined	Real-Time

As the service sector has grown in the U.S. economy, so has the attention paid to it by both institutions of higher learning and government at all levels. As examples, the Fishman- Davidson Center for the Study of the Service Sector was established in 1984 at the University of

Pennsylvania, and the Center for Services Research and Education was established in 1990 at Rensselaer Polytechnic Institute. Additionally, courses and textbooks (Fitzsimmons and Fitzsimmons 2001) on "Services Operations Management" have become popular. Likewise, given the earlier discussion regarding the complementarity of manufacturing and services, manufacturing systems type courses have been expanded in scope to include service systems; thus, courses with titles like "Information and Decision Technologies for Industrial and Service Systems" and "Models for Production Control and Service Logistics" are becoming a part of engineering curricula. In order to bring better focus on services-related research, the National Science Foundation formally established in 2001 a multi-million dollar funding program in "Service Enterprise Engineering".

Interestingly, despite the growing role that services play in the U.S.'s economic well-being, productivity in the service sector has shown limited growth. This seeming paradox is at least partially due to Baumol's disease; Baumol et al. (1989) recognized that the depressed service productivity is itself a key reason why services – especially government services (see Table 5) – constitute a large part of the economy; that is, the lagging (until recently) service sector productivity caused it to absorb the labor supply that was no longer needed in the more labor productive sectors. Indeed, manufacturing productivity has risen significantly, averaging 4 percent per year over the past decade. Another paradox lies in the fact that while the U.S. is experiencing an increasingly negative balance of payments in the goods sector (especially due to the large quantities of imported oil), it has always had a positive balance of payments in the service sector. However, this positive balance is steadily eroding as other countries become more competitive in producing/ delivering services. Clearly, the U.S. must significantly improve its service productivity – through the appropriate application of systems engineering.

3. Systems Engineering

A systems or holistic approach to tackling problems and issues dates back to early history, especially in the conduct of wars. However, it was Ludwig Von Bertalanffy who introduced the concept of general systems theory in the early 1940s and, in a series of writings that was compiled into a book (1969), he applied it to biology, psychology, economics and social science. Norbert Wiener also made several early and seminal mathematical contributions to systems theory, including the concept of cybernetics (1948), which helps to regulate or control a system.

There are a number of definitions for systems engineering. The U.S. Defense Systems defines it as: "The application of scientific and engineering efforts to (a) transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation; (b) integrate related technical parameters and ensure compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design; and (c) integrate reliability, maintainability, safety, survivability, human engineering, and other such factors into the total engineering effort to meet cost, schedule, supportability, and technical performance objectives". The Electronic Industries Association defines it as: "An interdisciplinary approach encompassing the entire technical effort to evolve and verify an integrated and life-cycle balanced set of systems, people, product, and process solutions that satisfy customer needs." The Institute of Electrical and Electronics Engineers defines it as: "An interdisciplinary collaborative approach to derive, evolve, and verify a life-cycle balanced system solution which satisfies customer expectations and meets public acceptability."

The above three definitions for systems engineering are somewhat lengthy and, in regard to the claim of being an interdisciplinary approach, somewhat optimistic. Unfortunately, while systems engineering is underpinned by a number of disciplines (and therefore it is, by definition, a multidiscipline), it has yet to evolve into a true interdiscipline. A more concise and realistic definition is that provided by Tien (1979), who defines systems engineering as: "A multidiscipline that addresses a system from a life-cycle, cybernetic and customer perspective."

Table 8 Systems Engineering: Underlying Concepts

Concepts	Definition	Attributes
System	An assemblage of objects united by some form of regular interaction or interdependence.	▪ Types (natural or built, physical or conceptual, closed or open, static or dynamic) ▪ Elements (components, attributes, relationships)
Engineering	Applied science.	▪ Definition ▪ Synthesis ▪ Analysis ▪ Design ▪ Test ▪ Evaluation
Life-Cycle	Series of stages of a system between successive recurrences of the initial stage.	▪ Needs Assessment ▪ Design/Development ▪ Production/Construction ▪ Utilization/Support ▪ Phaseout/Disposal
Cybernetics	Kybernetics is the Greek word for steersman or governor.	▪ Feedback (through evaluation of performance relative to stated objectives) ▪ Control (through communication, self-regulation, adaptation, optimization, and/or management)
Customer	A consumer (i.e., individual or entity) of goods and/or services.	▪ Needs/Requirements ▪ Expectations ▪ Satisfaction

Inasmuch as there are a number of textbooks on systems engineering (Hall 1962, Rouse 1980, Boardman 1990, Sage 1992, Blanchard and Fabrycky 1998), it is not the object of this section to review the broad field of systems engineering. However, it is helpful to highlight certain aspects of systems engineering. First, as indicated in Table 8, the underlying concepts include system (i.e., an assemblage of objects united by some form of regular interaction or interdependence), engineering (i.e., applied science), life-cycle (i.e., series of stages of a system between successive recurrences of the initial stage), cybernetics (i.e., a governor or controller), and customer (i.e., a consumer of goods and/or services). A system can be natural (e.g., lake) or built (e.g., government), physical (e.g., space shuttle) or conceptual (e.g., plan), closed (e.g., chemicals in a stationary, closed bottle) or open (e.g., tree), static (e.g., bridge) or dynamic (e.g., human). In regard to its elements, a system can be detailed in terms of its components, composed of people, processes and products; its attributes, composed of the input, process and output characteristics of each component; and its relationships, composed of interactions between components and characteristics. Engineering includes the steps of definition, synthesis, analysis, design, test, and evaluation. Life-cycle includes the stages of needs assessment, design/development, production/construction, utilization/support, and phase-out/disposal. Cybernetics includes feedback (through evaluation of performance relative to stated objectives) and control (through communication, self-regulation, adaptation, optimization, and/or management). A customer, if an individual, can be characterized by his/her needs (including desires), expectations and satisfaction, and, if an entity, by its requirements, expectations and satisfaction. Further, as indicated in Section 2 (Services), there is a relationship between expectation and satisfaction.

Second, as indicated earlier, systems engineering is a multidiscipline, including, as listed in Table 9, the underlying disciplines of electrical engineering, mathematics, statistics, operations research, management science, computer science, decision science, human-machine systems, industrial engineering and bioengineering. Example, systems engineering-related methods within each discipline are also identified in Table 9. Suffice it to say that the set of methods employed depends on the nature and scope of the system, and typically relates to what Bahill and Gissing (1998) refer to as the SIMILAR process -- an acronym for Stating the problem, Investigating alternatives, Modeling the system, Integrating, Launching the system, Assessing performance, and Re-evaluating. A number of systems engineering methods that are especially relevant to services are discussed in Section 4 (Service Systems Engineering).

Third, in regard to the underlying technologies, it is interesting to note that systems engineering in the 21st Century is driven by the same set of technologies that has driven – and will continue to drive – services; more specifically, information (including communications) and decision technologies. Thus, it is natural to combine services and systems engineering, especially as we seek to enhance service productivity.

Fourth, it should be noted that systems engineering has played an important role in the development, production, performance and assessment of products (including ships, space shuttles, circuit boards, etc.) and service systems (including telephony, transport, healthcare, etc.). More importantly, it has helped to make them better, faster and cheaper; that is, it has enhanced their effectiveness and efficiency, or productivity. Interestingly, where systems engineering has distinguished itself most has been when the infrastructure or components of a system are in place; they are then systems engineered into a productive system – and, over time, the system is re-systems engineered into a more productive system (e.g., increasing throughput, raising occupancy rate, enhancing customer satisfaction, etc.). Thus, systems engineering is a critical tool for productivity improvement.

Table 9 Systems Engineering: Underlying Disciplines

Disciplines	Example Methods
Electrical Engineering	▪ Cybernetics ▪ Networks
Mathematics	▪ Probability ▪ Modeling
Statistics	▪ Data Mining ▪ Visualization
Operations Research	▪ Optimization ▪ Simulation
Management Science	▪ Quality Management ▪ Information Management
Computer Science	▪ Neural Networks ▪ Genetic Algorithms
Decision Science	▪ Game Theory ▪ Risk Analysis
Human-Machine Systems	▪ Human Factors ▪ Cognitive Ergonomics
Industrial Engineering	▪ Manufacturing Systems ▪ Scheduling
Bioengineering	▪ Bioinformatics ▪ Systems Biology

Fifth, systems engineering, as a profession, was initially organized in the early 1960s as the "Professional Group on Systems Science and Cybernetics," which subsequently merged with the "Professional Group on Man-Machine Systems" in 1970 to form the Society on Systems, Man, and Cybernetics (SMC) within the Institute of Electrical and Electronics Engineers (IEEE). The IEEE itself was formed in 1963 through the merger of the American Institute of Electrical Engineers (founded in 1884) and the Institute of Radio Engineering (founded in 1912). A number of other systems engineering entities have since been organized: in 1972, the International Institute for Applied Systems Analysis (IIASA) brought the joint efforts of East-West scientists to bear on world wide systems problems; in 1989, the Worldwide International Systems Institutions Network (WISINET) was established; and in 1990, the corporate-oriented International Council on Systems Engineering (INCOSE) was formed, with strong representation from the aerospace industry. Moreover, like the IEEE, several of the other professional organizations (e.g., American Institute of Aeronautics and Astronautics, American Society of Mechanical Engineers, Worldwide Institute of Software Architects, etc.)

have at least an interest group in systems engineering. Courses, curricula and academic departments in systems engineering have likewise flourished in institutions of higher education (e.g., United States Military Academy, University of Virginia,, University of Pennsylvania, Rensselaer Polytechnic Institute, Tsinghua University, University of Waterloo, Technical University of Wroclaw, etc.) Finally, as information and other technologies seek to interlock both the natural (e.g., ecological) and built (e.g., economical) systems of the world, it is not surprising that there is a renewed focus on systems engineering to provide for sustainable and productive growth. Thus, like Climate Systems Engineering (White 2001) and Systems Biology (Kitano 2002), there is a strong need to apply systems engineering to the service sector, resulting in an intellectual and productive focus on service systems engineering.

4. Service Systems Engineering

Perhaps an appropriate definition for service systems engineering is to expand Tien's (1979) concise and realistic definition of systems engineering; thus, service systems engineering is “A multidiscipline that addresses a service system from a life-cycle, cybernetic and customer perspective”. In this regard, the underlying concepts of service systems engineering are the same as those identified in Table 8, with the added concept of services as defined and discussed in Section 2 (Services).

Service performance is, of course, a bottom-line issue; that is, a service should be developed and delivered to achieve maximum customer satisfaction at minimum cost. How to measure or evaluate service performance remains a difficult problem. Table 10 provides a list of such measures, partitioned into the four categories promulgated by Tien (1979) – namely, input, process, outcome and systemic measures. In general, the input and process measures serve to “explain” the resultant outcome measures. Input measures alone are of limited usefulness since they only indicate a program's potential – not actual – performance. On the other hand, the process measures do identify the program's performance but do not consider the impact of that performance. The outcome measures are the most meaningful observations since they reflect the ultimate results of the provided services. In practice, as might be expected, most of the available service evaluations are fairly explicit about the input measures, less explicit about the process measures, and somewhat fragmentary about the outcome measures. The fourth set of evaluation measures – the systemic measures – can also be regarded as impact measures but have been overlooked to a large extent in the evaluation literature. The systemic measures allow a service's impact to be viewed from a total systems perspective, including, as identified in Table 10, the service's consistency, equity, reproducibility and sustainability.

As we apply systems engineering to services, we must be cognizant of the unique characteristics of services that are especially amenable to our new and evolving methods. Table 11 identifies these unique characteristics and evolving methods, which are grouped into those that are underpinned by information/ communications technologies and those that are

Table 10 Service Systems Engineering: Example Evaluation Measures

Categories	Example Evaluation Measures
Input	▪ Demand ▪ Supply ▪ Cost
Process	▪ Performance (Quality, Reliability, Speed, Throughput) ▪ Productivity (Efficiency, Effectiveness) ▪ Safeguards (Privacy, Security, Safety)
Outcome	▪ Customization ▪ Satisfaction ▪ Convenience (Availability, Accessibility) ▪ Robustness (Comprehensiveness, Adaptability, Flexibility)
Systemic	▪ Consistency ▪ Equity ▪ Reproducibility ▪ Sustainability

underpinned by decision technologies. As alluded to throughout Section 2 (Services), services are distinct or unique in at least four respects. First, services are information-driven; thus, the creation, management and sharing of information is crucial to the design and production/delivery of services. Second, services are overwhelmingly customer-centric; indeed, customers are generally a co-producer of the services (i.e., leading sometimes to self-service), customers require a certain degree of service adaptation or customization, and customers must be satisfied with the rendered services. Third, services are becoming more e(lectronic)-oriented; in turn, e-access, e-commerce and e-customer management are crucial to e-services. Fourth, given its proliferation and the aging global population, services must become more productivity-focused, based on the twin pillars of efficiency and effectiveness. In our course on "Service Operations Management", we employ the acronym CHIPS – co-production, heterogeneity, intangibility, perishability, and simultaneity – to characterize the production/delivery of services.

In regard to information/communications technologies that can address service issues, Table 11 lists several evolving methods. Collaborative Software provides Web tools for employees and business partners to work together to create goods and services that are better, faster and cheaper. Business Intelligence Software enables companies to analyze the raw data stored across their enterprise to yield information that could be employed to optimize revenue-generating strategies, enhance cost-efficiency, and improve customer relationships. Synchronization Software obviates the need for ubiquitous connectivity to centralized data banks; reflecting the way humans work, it allows users to freely edit a copy of a document or database and then having the edits automatically propagate to all copies – the Palm operating system, with its "HotSync" button, is an example of such synchronizing software. Autonomic Computing's objective is for computers, like biological systems, to monitor themselves and to allocate and manage resources as required; as an example, demand for extra mass storage devices

Table 11 Service Systems Engineering: Unique Characteristics and Evolving Methods

Unique Characteristics	Evolving Service Systems Engineering Methods: Information/ Communications Technologies	Evolving Service Systems Engineering Methods: Decision Technologies
Information-Driven		
▪ **Creation**	▪ Collaborative Software, Business Intelligence Software	▪ Data Mining, Decision Informatics
▪ **Management**	▪ Synchronization Software, Autonomic Computing	▪ Data Mining, Decision Informatics, Index/Pointer Scheme
▪ **Sharing**	▪ Peer-to-Peer Networking, Distributed Computing, Extensible Markup Language	▪ Index/Pointer Scheme
Customer-Centric		
▪ **Co-Production**	▪ Intranet, Extranet, Internet	▪ Demand Management, Decision Informatics, Adaptive Techniques, Artificial Intelligence
▪ **Customization**	▪ Software Agents, Synchronization Software, Peer-to-Peer Networking	▪ Data Mining, Decision Informatics, Adaptive Techniques, Artificial Intelligence
▪ **Satisfaction**	▪ Software Agents	▪ Demand Management
E-Oriented		
▪ **E-Access**	▪ Wireless, Internet-on-a-Chip	▪ Decision Informatics
▪ **E-Commerce**	▪ E-Procurement, E-Fulfillment, E-Supply Chain, E-Outsourcing, E-Auction	▪ Supply Management, Economic Value Added Analysis
▪ **E-Customer Management**	▪ Customer Management Software	▪ Demand Management
Productivity-Focused		
▪ **Efficiency**	▪ Customer Management Software	▪ Data Envelopment Analysis, Reengineering
▪ **Effectiveness**	▪ Customer Management Software	▪ Demand Management, Life-Cycle Analysis

can be flexibly and adaptively met as the amount of data and information increases. Peer-to-Peer (P2P) Networking allows for serverless file sharing that enhances collaboration and resource sharing; indeed, the Napster online music-file-sharing program promulgated this new technology – other companies (e.g., Gnutella, Kazua and Intel) are extending the technology and expanding its applicability. Distributed Computing is actually an aspect of the P2P sharing scheme; it aggregates the unused processing power of individual computers on the network and employs it to work on subdivided parts of a large computing task, resulting in decentralized computing and lower costs. Extensible Markup Language (XML) is a meta-language modeled on the Standard Generalized Markup Language (SGML); it separates the structure and semantics of data from its presentation (i.e., how it looks on the computer screen), and it is a powerful software technology that can facilitate both the sharing of data/information and the future growth of the Web. Likewise, the co-production of services can certainly be facilitated by the existence of Intranets (which handle communication tasks within enterprises), Extranets (which handle communication tasks between enterprises and their business partners), and the Internet (which handles communication tasks between the providers and the ultimate, revenue-producing customers). Software Agents are smart software programs capable of evaluating hundreds of user-related factors linked by probabilities, causes and effects in a vast web of contingent outcomes, so as to infer the likelihood that a given decision on the software's part would lead to the user's desired outcome; in this manner, customization of goods and services could be both greatly enhanced and provided in real-time. Wireless – in its forthcoming third generation (3G) form – will enable high-bandwidth Internet access by cellular phones, laptops or personal data assistants; such ubiquitous access will allow for real-time connectivity from any where and at any time. Internet-On-A-Chip contains all of the protocols necessary for Internet connectivity; it makes possible for the promulgation of a great variety of sensing devices (i.e., for use in maintenance and monitoring services) that could interact with each other, report ambient conditions or receive instructions over the Internet. E-Procurement, E-Fulfillment, E-Supply Chain, E-Outsourcing, and E-Auction are just some software technologies that make E-Commerce a reality – and a growing part of global commerce. Finally, Customer Management Software includes a host of software packages that help enterprises track their customers (in terms of individual sales activities and other contacts), provide for better customer services, and customize their marketing campaigns.

In regard to decision technologies that can address service issues, Table 11 also lists several evolving methods. Data Mining refers to a range of techniques, including data fusion, data analysis, fuzzy logic, pattern analysis, data visualization and data management. In practice, data mining can be thought of as reverse engineering; that is, it seeks to discover and understand the underlying phenomena that are generating the observed data. Thus, by reverse engineering sales data, customer profiles can be constructed (Adomavicius and Tuzhilin 2001), as a first step towards mass customization. Although statistical in nature, it has also been embraced as a management science tool (Cooper and Giuffrida 2000).

Decision Informatics, proposed by Tien (2002), is a paradigm for making real-time, information-based decisions. That is, the nature of the required real-time decision (regarding the production and/or delivery of a service) determines, where appropriate and from a systems engineering perspective, the data to be collected (possibly, from multiple, non-homogeneous sources) and the real-time fusion/analysis to be undertaken to obtain the needed information for input to the modeling effort which, in turn, provides the knowledge to support the required decision in a timely and intelligent manner. The feedback loops between the steps of analysis, modeling and decision making are within the context of systems engineering; they serve to refine each of these steps. Decision informatics is, as a paradigm or framework, generic and applicable to most, if not all, decision problems. Further, since any data analysis or modeling effort should only be undertaken for the purpose of some kind of a decision (including the design of a product or a service), all analyses and modeling activities should be able to be viewed within the decision informatics framework. Thus, the framework can be very appropriately applied to critical issues in biology, manufacturing, and, of course, services, including the creation and management of appropriate information for intelligent decision making in connection with service co-production and customization.

Index/Pointer Schemes are foremost an efficiency tool for identifying (through an index) and locating (through a pointer) files; in this way, a massive storage server is not required – and the files can remain distributed and reside in local servers which belong to the creators of the files. Although similar to a search engine, the schemes are, of course, more efficient because of the index/pointer approach. In addition to being efficient in regard to the management and sharing of information, the schemes are actually an ideal vehicle for safeguarding sensitive information on, as examples, criminals and terrorists. Indeed, the U.S. Federal Bureau of Investigation (FBI) maintains an Interstate Identification Index (III) database that contains personal identifiers of offenders, as well as pointers to states which maintain criminal history records on those offenders. If such a scheme were in place for known terrorists, perhaps the September 11, 2001, tragedy might have been averted.

Demand Management includes a number of methods that are particularly effective in the services area, especially given the customer-centricness of services. Since, as noted in Section 2, a customer's satisfaction with a service is a function of the customer's expectation of how well the service might be rendered (i.e., greatly satisfied if the service is considerably above expectation and greatly dissatisfied if the service is considerably below expectation), satisfaction can therefore be enhanced through the effective management of expectation. In addition to recognizing this somewhat intuitive phenomenon, Tien and Cahn (1981) applied expectation management to significantly increase citizen satisfaction by having the police department tell every non-emergency caller the likely response time (i.e., at the 95 percent confidence level) rather than the standard, “we'll be right there” response – which, of course, tended to raise expectation and thereby decrease satisfaction. Expectation management has since been employed to optimally locate baggage claim areas at airports and to make waiting lines bearable at amusement parks, checkout counters and banks. In one example at the Bank of Boston (Larson 1988), customers waiting in line for tellers did not mind the wait when they were being entertained by a moving message board which displayed sports and weather information along with some advertisements of the bank's various services; in fact, some people became so engrossed in the board that tellers had to remind them that they were next to be served. In sum, the object of expectation management is to align a customer's expectation with service performance so that satisfaction can be assured.

Yield Management is another powerful

demand management method. Also known as revenue management or dynamic pricing, yield management is best applied to a limited capacity and perishable product; it seeks to allocate the right type of capacity, to the right kind of customer, at the right price, in order to maximize revenue or yield. Yield management has been applied to a number of industries, including airlines, hotels, trains, cruise lines, utilities, trucking, amusement parks, and rental cars. For example, Cassaigne and Singh (2001) employ a yield management approach to oil pricing. Yet, other demand management methods exist; they all seek in some way to minimize the variance in demand. Whereas yield management accomplishes this through optimal pricing, other approaches include curtailing the supply (e.g., electrical “brown outs”) and letting demand exceed supply (e.g., reservation “overbooking”).

Adaptive Techniques, including neural networks and genetic algorithms, are especially appropriate for dealing with co-production and customization issues. As an example, in deciding on novel candidate pharmaceuticals, Embrechts et al. (2000) analyzed molecular data and obtained information concerning some 1000 descriptors for each molecule; based on various neural network and genetic algorithm models, the quantitative structural activity relationships (QSARs) were determined to help screen and decide on those molecules which could be candidate drugs due to their interesting or improved bioactivities. Also, consistent with the decision informatics approach, the entire process was automated, employing a systems engineering framework that includes returning the non-selected molecules to the information base for further QSAR analysis, screening and selection.

The ultimate in adaptive techniques is, of course, Artificial Intelligence or, as Buttazzo (2001) calls it, “artificial consciousness.” Although in 1997 IBM's Deep Blue computer beat Garry Kasparov, the then reigning world chess champion, it was accomplished through computing speed and a sophisticated search algorithm – and not through artificial intelligence, as defined by the Turing test. (In 1950, computer science pioneer Alan Turing suggested that a machine could be considered intelligent if its answers to a series of questions were statistically indistinguishable from those provided by a human.) Interestingly, with increased speed, the advent of molecular computing (that more reflects the human brain), and quick access to all known facts, perceptions, and past activities and actions of an individual, the computer of tomorrow may well pass the Turing test, while not being able to display the range of human emotions. Nevertheless, despite a premature focus, artificial intelligence – as defined by Turing – may finally be within reach.

Supply Management is also a set of service-related methods; it includes strategic, tactical and operational approaches to dealing with issues associated with planning, scheduling, tracking, production, packaging, transportation, warehousing, distribution, delivery, replenishment, recycling, and disposal. Because of its early focus on manufacturing and goods, supply management methods are better developed than demand management methods which, as stated earlier, are more applicable to service issues. Nevertheless, most of the supply management methods are also applicable to services, although some like tracking and warehousing, require a redefinition within the services context.

Economic Value Added (EVA) analysis is a system-oriented approach which has helped managers run their businesses better and executives make the right decisions. Simply stated, an operation's EVA is its after-tax operating profit minus its total annual cost of capital (which includes such assets as cash, inventories, receivables, heavy equipment, computers and real estate). Taking the total cost of capital into account is what makes EVA a more holistic measure. EVA, for example, prompted Quaker Oats to focus on the long-term, instead of trying to increase quarterly earnings that used to consume precious capital. Additionally, Quinn (1992) attributes the growth of out-sourcing to this systems-oriented, EVA approach. Thus, if a) one were to consider an enterprise as a processor of inputs to economically add value, b) a part of this value-added chain can be better processed externally, and c) the part is not strategically critical for the enterprise to control, then the part is an obvious candidate for outsourcing.

Data Envelope Analysis (DEA) can compare the efficiency of multiple service entities that provide similar services by explicitly considering their use of multiple inputs (i.e., resources) to produce multiple outputs (i.e., services), without resorting to mapping all inputs and outputs on a single attribute (e.g., dollars). Known as the Charnes, Cooper, and Rhodes model (1978), DEA is a linear program that attempts to maximize a service entity's efficiency, expressed as a ratio of outputs to inputs, by comparing a particular entity's efficiency with the performance of similar service entities – but of differing characteristics (e.g., size, location, management, etc.) – that are delivering the same set of services. Through this analysis, some entities are determined to be highly efficient and are referred to as the “relatively efficient entities” (which together constitute the “efficient frontier”), whereas other entities with lower ratings are deemed “inefficient.” By comparing the operating procedures of those on the efficient frontier with those less efficient entities, appropriate procedures can be identified for improving efficiency.

Reengineering has also helped to increase the efficiency of service organizations. A central observation behind reengineering is that most of the work in companies is organized inefficiently, around specialists employed in what Hammer and Champy (1992) call “functional slots,” such as accounting, engineering or marketing. For example, at the IBM Credit Corporation, it used to take six full days to approve a loan application, even though the actual work consumed only 90 minutes. The loan documents used to move from one specialist to another. Now, through reengineering, a single person handles the request from beginning to end; the turnaround time has been reduced to four hours, and the number of workers involved in the various loan-processing activities has likewise been reduced. It should, however, be stated that the investment in information technology is one key reason why reengineering is achieving efficiencies in the service industries.

Life-Cycle Analysis is, as noted in Table 8, part of the traditional systems engineering approach; it includes the steps of needs assessment, design/development, production/ construction, and phase-out/disposal. Through such a life-cycle perspective, service systems can be better or more productively designed and operated.

For the purpose of this paper, a more relevant approach to considering the range of emerging services is to characterize them from a service systems engineering perspective, as is done in Table 12. For each identified emerging service example or problem, Table 12 indicates its potential for being amenable to the service systems engineering methods that address the information-driven, customer-centric, e-oriented and productivity-focused issues that are pertinent to services. As specific examples, Amazon.com fuses data from several presumably non-homogeneous data sources to develop customer profiles and to customize their recommended "buy" for an active customer. The Ford Motor Company could have forestalled the onslaught of Explorer/Firestone tire law suits if their "early warning" system had a real-time data analysis capability that could have noticed the increasing number of Explorer/Firestone tire mishaps in the more recent sequence of automobile incidents. In the future, it is critical that education, especially of working professionals, be carried out at any time and from any where – through the Internet. The nation's law enforcement agencies need effective data processors to cull appropriate information from their various data sources (i.e., call-for-service data, patrol notes, detective reports, etc.) in order to anticipate or decide on the intensity and movement of crime "hot spots." Medical doctors require computationally-intensive information to triage or diagnose problems, including information concerning the possible adverse interactions of two or more drugs. Although e-Bay has demonstrated the viability of Internet-based auctions, it is constantly endeavoring to facilitate and improve their customer decision making process. The September 11, 2001 terrorist attack might have been thwarted if a more robust and system-oriented passenger screening system were in place instead of the 1998 initiated CAPPS program (which employs a computer-based formula to identify potential terrorists); it had already experienced a drastic cutback, and moreover, had not been uniformly used by the airlines. In the routing of telephone calls, a real-time algorithm is required that is sensitive to system-wide conditions.

Finally, to a large extent and as discussed in Section 1 (Introduction), a critical goal of service systems engineering is to enhance service customization; thus, as depicted in Table 13, the goal is to move services to the top right quadrant where there is a high degree of customization at low labor intensity. As examples, if genomics, proteomics and glycomics were successfully carried out, then the holy grail of customized medicine would be within reach; on the other hand, Tien (2000) suggests that individual-centered or customized education is within reach through Internet-based courses and curricula. It should also be noted that there are other approaches – especially e-technologies – for enhancing service customization, including, as indicated in Table 11, software agents, synchronization software and peer-to-peer networking.

Table 12 Service Systems Engineering: Characteristics of Example Emerging Services

Example Emerging Services	Service Systems Engineering Characteristics			
	Information-Driven	**Customer-Centric**	**E-Oriented**	**Productivity-Focused**
Wholesale & Retail: Mass Customization	✔	✔	✔	✔
Business & Professional: "Early Warning" System	✔			✔
Education: Internet-Based Distance Learning	✔	✔	✔	✔
Government: Crime "Hot Spots"	✔			✔
Health Care: Medical Triaging	✔	✔	✔	✔
Finance, Insurance & Real Estate: Internet-Based Auctions	✔	✔	✔	✔
Transportation: Airline Passenger Screening	✔	✔		✔
Communications: Real-Time Routing	✔	✔		✔

Table 13 Service Systems Engineering: Toward Service Customization

Current Degree of Labor Intensity	Current Degree of Customization	
	Low	**High**
Low	Produced Services: – Computing – Medication	Customized Services: – Maintenance – Banking
High	Mass Services: – Education – Retail	Professional Services: – Legal – Consulting

Source: Adapted from Fitzsimmons and Fitzsimmons (2001, p23)

5. Concluding Remarks

In conclusion, several remarks should be made. First, while a number of service systems engineering methods have been highlighted in the paper, there remains a host of other considerations that is critical to the design and production/delivery of services. For example, given the customer-centricness of services, the privacy, security and safety of the customers must be safeguarded; for the most part, such safeguards remain to be developed, especially in regard to emerging, Internet-based services.

Second, as with safeguards, service systems engineering methods are evolving as the underlying information/communications and decision making technologies evolve and as computing becomes faster and cheaper. As a consequence, this multidiscipline represents an exciting area for research and development. Moreover, the multidiscipline should benefit from ongoing research in other fields, including cognition or understanding how people process input.

Third, since services are real-time in nature and are consumed at the time it is co-produced, the human decision maker or service provider will increasingly become a bottleneck; indeed, in many situations, the human must make way for a smart robot or software agent. For example, everyone could use a smart alter ego or agent which could analyze, and perhaps fuse, all the existing and incoming e-mails, phone calls, Web pages, news clips, and stock quotes, and assigns every item a priority based on the person's preferences and observed behavior. The software agent should be able to perform a linguistic analysis of a message text, judge the sender-recipient relationship by examining an organizational chart, and recall the urgency of the recipient's responses to previous messages from the same sender. To this it might add information gathered by watching the user, either by video camera or by scrutinizing the user’s calendar, so that it could determine when the user can safely be interrupted, with what kind of message, and via which device. Perhaps the same agent could serve as a travel agent by searching the Internet and gathering all the relevant information about airline schedules and hotel prices, and, with the user's consent, returning with the electronic tickets.

Finally, as stressed throughout this paper, services constitute a critical and growing economic sector; systems engineering is an effective, efficient and evolving multidiscipline; and service systems engineering is a powerful and productive combination. The combination reflects a “sweet spot” for research, application and education. In short, service systems engineering's time has come.

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