Chapter I
The Social Requirements of Technical Systems

Brian Whitworth
Massey University–Auckland, New Zealand

ABSTRACT

A socio-technical system (STS) is a social system built upon a technical base. An STS adds social requirements to human-computer interaction (HCI) requirements, which already add to technical (hardware and software) requirements. Socio-technical systems use technology to connect people socially, for example through e-mail, electronic markets, social network systems, knowledge exchange systems, blogs, chat rooms, and so forth. Yet while the technology is often new, the social principles of people interacting with people may not be. The requirements of successful social communities, whether mediated by computers or the physical world, may be similar. If so, socio-technical systems must close the gap between social needs and technical performance, between what communities want and what the technology does. If online society is essentially a social system, of people interacting with people, social principles rather than the mediating technology should drive its design. Societies create value through social synergy, which is lost for example when people steal from others, whether time (spam), money (scams), credibility (lying), reputation (libel) or anything else of value. The success of today's global information society depends upon designing the architecture of online interaction to support social goals. This chapter briefly reviews some of the emerging requirements of STS design.

Man is a social animal

—Seneca

INTRODUCTION

A *socio-technical system* (STS) is a social system sitting upon a technical base, with email a simple example of social communication by technology means. Whether a community is electronically or physically mediated a socio-technical system is people communicating with people through tech-

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nology rather than the physical world (which is a "socio-physical system"). The term *socio-technical* was introduced in the 1950's by the Tavistock Institute as the manufacturing needs of industry confronted the social needs of local communities, e.g. longwall mining in English coalmines (see http://www.strategosinc.com/socio-technical.htm). It opposed Taylorism which broke down assembly line jobs into "most efficient units", suggesting that technical systems needed to respect social needs, e.g. a nuclear plant near a village had to balance its technical needs against social needs. The socio-technical view later developed into a call for more ethical computing by supporters such as Mumford (Porra & Hirscheim, 2007).

General Systems Theory

In general systems theory (Bertalanffy, 1968) systems form when autonomous (self-directing) parts *mutually interact to create equally autonomous wholes*. Such systems do not reduce entirely to their parts as their creation involves not just those parts *but also complex feed-back and feed-forward interactions*. Just as a person is a system of autonomous cells, so a society is a "system" of autonomous citizens. Such holistic systems, whether simple cells or complex people, can *self-organize* and *self-maintain* (Maturana & Varela, 1998).

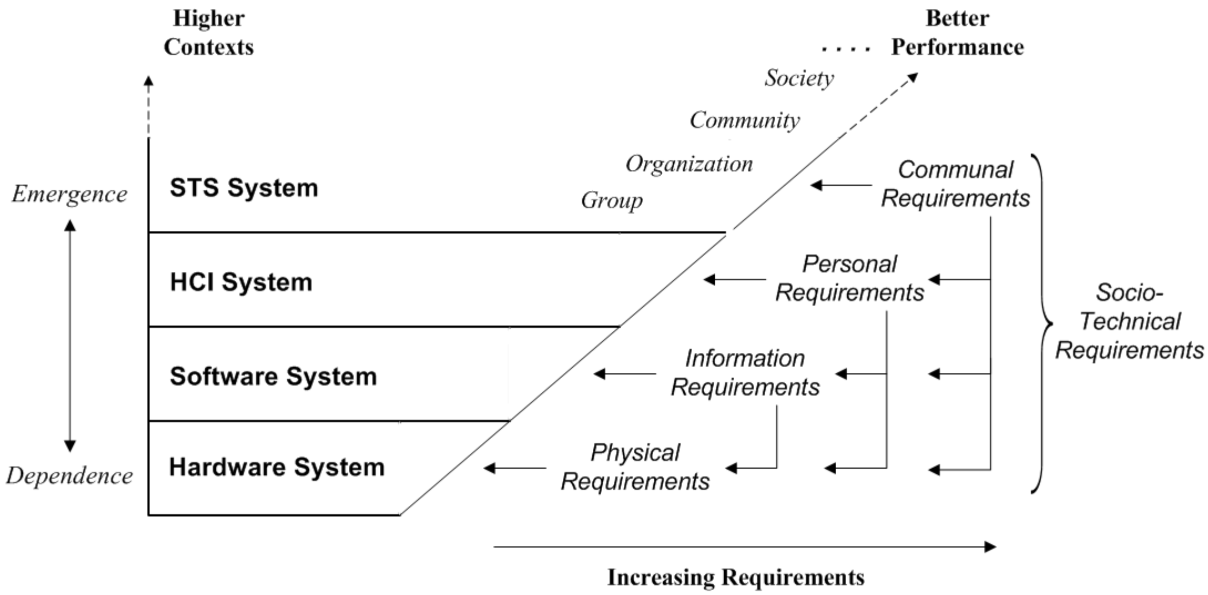
The socio-technical system (STS) is not just social and technical systems side-by-side but the whole unit. For example, a pilot flying a plane is two side by side systems with different needs, one mechanical (the plane) and one human (the pilot). In human computer interaction (HCI) these systems must work together–pilots must understand the plane's controls, which must be understandable by its crew. The STS is the plane plus crew as a *single system* with human and mechanical levels. On the mechanical level the human body is just as physical as the plane, with weight, volume etc. However the "crew + plane" system can now strategize and predict, say in an aerial dogfight. The perspective change seems minor, but has major ramifications. If a human system sits *next to* a technical one it is usually secondary, as ethics is an afterthought in engineering, but if social systems *include* technical ones, as physical societies have architectures, then the social *contextualizes* the technical even as it is created by it. Hence STS research is not just applying sociological principles to technical effects (Coiera, 2007), but how social and technical aspects integrate into a higher level system with emergent properties.

Socio-Technical Levels

Are physical systems the only possible systems? The term "information system" suggests not, and philosophers propose idea systems in logical worlds, sociologists propose social systems, psychologists propose cognitive systems, economists have economic systems, programmers have software systems, and engineers have hardware systems. Which of these approaches is "real"? Paradoxically, none are… and all are. None are, because they are all just ways of conceptualizing systems, like views in a database, not the system itself. All are, because one can without contradiction describe a system from many perspectives, namely from that of the engineer, computer scientist, psychologist and sociologist.

As system complexity increases higher system views seem to apply. For example, in the 1950s/60s computing was primarily about hardware, while in the 1970's it became about business information processing, and in the 1980s about "personal computing". With the 1990s and email computers became a social medium, and in this decade social computing has flourished with chat rooms, bulletin boards, e-markets, social networks, wikis and blogs. Computing "reinvented itself" each decade or so, from hardware to software, from software to HCI, and now from HCI to social computing. To explain this, Grudin suggested three IT "levels" (hardware, software and cognitive) (Grudin, 1990) and Kuutti later added an organizational level (Kuutti, 1996). These *physical, informational, personal* and *communal* levels suggest hardware, software, HCI and STS systems (Figure 1):

Figure 1. Socio-technical system levels



1. **Hardware systems** based on *physical level* exchanges of energy, and face problems like overheating.
2. **Software systems** emerge from hardware systems, are based on *information level* exchanges of data and code, and face problems like infinite processing loops.
3. **HCI systems** emerge from software systems, are based on *personal level* exchanges of meaning, and face problems like misunderstanding or information overload.
4. **Socio-technical systems** emerge from HCI systems, are based on *communal level* normative exchanges, and face problems like mistrust, unfairness and injustice.

Here "technology" is the hardware-software combination, so an organization's technology is both IT infrastructure (hardware) and IT services/applications (software). Equally "social" includes both people and their relations and company policies and norms. A *socio-technical system is one that involves all four socio-technical levels and their interactions.* STS research describes the connections between hardware and software technologies and people and communities.

How system levels emerge raises interesting questions:

1. **Information derives from mechanics*:*** How can physical voltage changes in a wire create bits and bytes that make computing distinct from engineering and physics?
2. **Personal cognitions derive from neural information exchanges:** How can neuronal mini-processors combine on/off Boolean states to create human awareness (Whitworth, 2008)?
3. **Social unity derives from personal cognitions:** How can a "society" emerge from autonomous yet interdependent individuals interacting?

Note that a "society" is more than buildings, information or people, being a *general form of human interaction that persists* despite changes in individuals, communications or architecture (Whitworth & deMoor, 2003).

The levels of Figure 1 are suitable for IT purposes, but biologists might want a biological level between information and human processing. Stamper's semiotic ladder splits the information level into empiric and syntactic, and distinguishes semantics (meanings) from pragmatics (intentions) (Stamper, 1996). The top of Figure 1 is open-ended, as social groups can coalesce into bigger ones, e.g. in social evolution people first formed villages, then city-states, then nations, super-nations and perhaps today a global humanity (Diamond, 1998).

System Performance

Higher levels are not just more efficient ways to *describe* a system but also more efficient ways to *operate* it. A group is just any set of individuals who see themselves as a group (DeSanctis & Gallupe, 1987), yet this perception increases performance. *Seeing* something at a higher level lets one *organize* it in a better way, just as software is a better way to operate computers than manipulating circuit voltages. Software functions are in turn giving way to user task concepts like "affordance" and task analysis methods, e.g. for users to backup a "document" currently takes three functional steps: 1. *Save As*, 2. *Select backup file name* (unlike previous backups), 3. *Load original file* (else further work changes the backup not the "master"). A "Backup Document" button that does this task in one click would be popular, reduce problems and improve productivity.

In general, as systems evolve the "performance" focus rises to higher levels. Hence *lower level performance is disregarded if higher levels fail,* e.g. computers "crash" when the software goes into an infinite loop, and users have to re-boot the machine. Yet the hardware is working perfectly. We say the system "failed" when software ignores user demands, even though the hardware is responding to software demands. In general:

System performance is defined at the highest productive level.

If a level fails, the levels above it automatically fail, as hardware failure means software failure, etc. Yet system success depends on the highest level, e.g. a web site with working hardware, software and interface "fails" if no-one visits it. Just as one can have hardware failures, software failures and usability failures, socio-technical systems can be social failures, as if one calls a party and no-one comes it doesn't matter how nice the food was. While hardware failures, software failures, usability failures and social failures seem different, they have one thing in common—in the *end the failed system does not run,* which can cause "extinction."

At each level higher performance incurs higher requirement "costs". Physical systems have physical requirements, like the stress requirements for a bridge, which designs must satisfy. Equally higher level systems have information requirements, semantic requirements and community requirements. These cumulate, each adding to the previous, just as software requirements add to hardware requirements. The requirements of a level affect not only that level but all those below it, i.e. new requirements impact the whole system. For example, the needs of database and network software led to new hard-wired CPU commands, and Web 2.0 semantic demands require code systems like UML to better transmit meaning. Socio-technical requirements like accountability, privacy and ownership can be expected to change interfaces, software and hardware. Socializing the Internet will change the whole socio-technical system, not just add social "icing" to the existing technical "cake".

Combining Reductionism and Constructivism

Software systems presume a hardware base, HCI systems presume a software base, and STSs presume an HCI base. This can be seen as higher levels emerging, or as higher levels being derived. The conflict between *constructivism* and *reductionism* seems essentially whether one sees the levels in Figure 1 as derived from the bottom-up (the parts define the whole), or as being a top-down re-definition of the system (the whole defines the parts). Psychology constructivists like Piaget, Chomsky and Maturana suggest that people "construct" the world and so see *a* world not *the* world (Maturana

& Varela, 1998), while determinists like Watson, Hull and Skinner hold that the objective world creates real sensations which define behavior (Skinner, 1948). The latter describes behavior from the bottom up, while the former takes a top-down approach. Sociology generally sees individuals as conduits of meaning for external social structures, and rejects psychological, biological and physical explanations as faulty reductionism (Bone, 2005). Yet top-down approaches cannot stand alone, as if somehow (magically) all thoughts about a culture were erased from its members, it would cease to exist, just as it would if all its members suddenly vanished physically. Indeed sociology is reconnecting to its psychology roots, e.g. Bourdieu's "habitus" concept based on the individual's perception of the social environment, and Gidden's discussion of the mental frames that underlie social life (Bone, 2005). It is being realized that the emergence of sociology from psychology does not imply that sociology reduces to psychology.

Conversely, reductionist views on any level tend to deny choice, e.g. psychological determinists would define all behaviour by physical stimulus contingencies, while social determinists hold that society writes cultural agendas like communism or capitalism upon individual *tabula rasae*[1]. Swapping behavioural engineering for social engineering seems hardly progress, as in both the world is a machine. Even in physics *one cannot take the observer out of the world equation,* so attempts to reduce systems to one level is to deny the emergent nature of the world.

The ongoing constructivist-reductionist debate assumes a single right view, but emergence allows both derivation and "new rules", e.g. chemical events must derive from quantum events, but this does not make the discipline of chemistry a sub-set of physics. If chemistry can co-exist with physics, then sociology, psychology, computing and engineering can also work together. Attempts to fit all reality to one view are doomed to fail, as any view is inherently incomplete. Rather than trying to reduce all disciplines to one "reality", let them superimpose, with the researcher or designer free to choose their viewpoint. Taking multiple perspectives *in turn* is like walking around an object to view it from all sides[2]. This approach re-introduces choice and abandons determinism, the belief we can specify an absolute order. Constructivism and reductionism remain as relative not absolute views which complement each other. Hence a "person" can be at once a physical object, an information processor, a cognitive source, and a social unit. These are not different systems but *overlapping views of the same system,* corresponding to engineering, computing, psychological, and sociological perspectives respectively (Whitworth, Fjermestad, & Mahinda, 2006). The "real" person is the interaction of all these things and perhaps more.

GENERAL SYSTEM PERFORMANCE REQUIREMENTS

While performance seems a simple concept, the variety of animals that have evolved to "fitness" suggests it is not (David, McCarthy, & Sommer, 2003). The variety of successful information technologies today suggests the same, as an IT system is not "high performance" if it:

1. Cannot get results (ineffectual).
2. Cannot be made to work (unusable).
3. Breaks down often (unreliable).
4. Succumbs to viruses (insecure).
5. Fails when things change (inflexible).
6. Cannot work with standard plug-ins or data (incompatible).
7. Cannot download or upload (not connected).
8. Reveals private information (indiscreet).

The web of system performance (WOSP) model proposes that systems have four elements: a boundary, an internal structure, effectors and receptors. Designing each element to either reduce risk or increase opportunity gives eight basic goals, (Whitworth et al., 2006):

A. The boundary element separates "system" from "not system":
   1. **Risk focus:** Protect against unauthorized entry, misuse or takeover *(security)*.
   2. **Opportunity focus:** Use outside elements as system "tools" *(extendibility)*.
B. The structure element defines how the system operates internally:
   3. **Risk focus:** Continue operating despite internal failure *(reliability)*.
   4. **Opportunity focus:** Adapt the system to environment changes *(flexibility)*.
C. *The effectors element changes the outside world directly*:
   5. **Risk focus:** Minimize the relative resource costs of action *(usability)*.
   6. **Opportunity focus:** Act directly on the environment to produce a desired change *(functionality)*.
D. *The receptors element records the outside world and receives signals*:
   7. **Risk focus:** Manage the release of self information *(privacy)*.
   8. **Opportunity focus:** Open and use channels to communicate meaning to other systems *(connectivity)*.

These eight requirements are well known in the literature, but their combination into one framework is new. Criteria priorities vary with environment, e.g. low threat environments make security less important, while turbulent environments make flexibility more important, etc. The four "active" goals (functionality, flexibility, extendibility, connectivity) increase *opportunities*, while the four "passive" goals (security, reliability, privacy, usability) reduce *risks*. Both active and passive goals are equally important in system performance.

One might imagine that functionality (what the system does) is always top priority. Yet while "non-functional" requirements (NFRs) may be second-rate needs in IT design, many systems have more lines of error or interface code than functional code, and many fail for "unexpected" non-functional reasons (Cysneiros & Leita, 2002, p699). Indeed in nature the strongest claws, teeth or muscles are not always the "fittest", perhaps why tigers are now an endangered species. Some animals like turtles are slow but have strong defensive shells (security), while others like viruses specialize in parasitism (extendibility). Some have almost no "functionality" but are very reliable (plants), while others like bacteria are flexible enough to alter their DNA within hours. Claims that privacy is "dead" by technology's hand are premature, as the animal kingdom equivalent of privacy, camouflage, is alive and well in the animal kingdom, and the military spends billions on the physical equivalent (stealth technology). Overall, there is support for the view that IT system performance involves many goals (Chung, Nixon, Yu, & Mylopoulos, 1999).

Many criteria on many levels gives in practice what IT developers call the "requirements mess", the struggle to define "what people want" in complex socio-technical systems (Lindquist, 2005). This struggle has destroyed many a software project, and the complexity of modern IT requirements has led to agile development methods, which don't assume we know much at all.

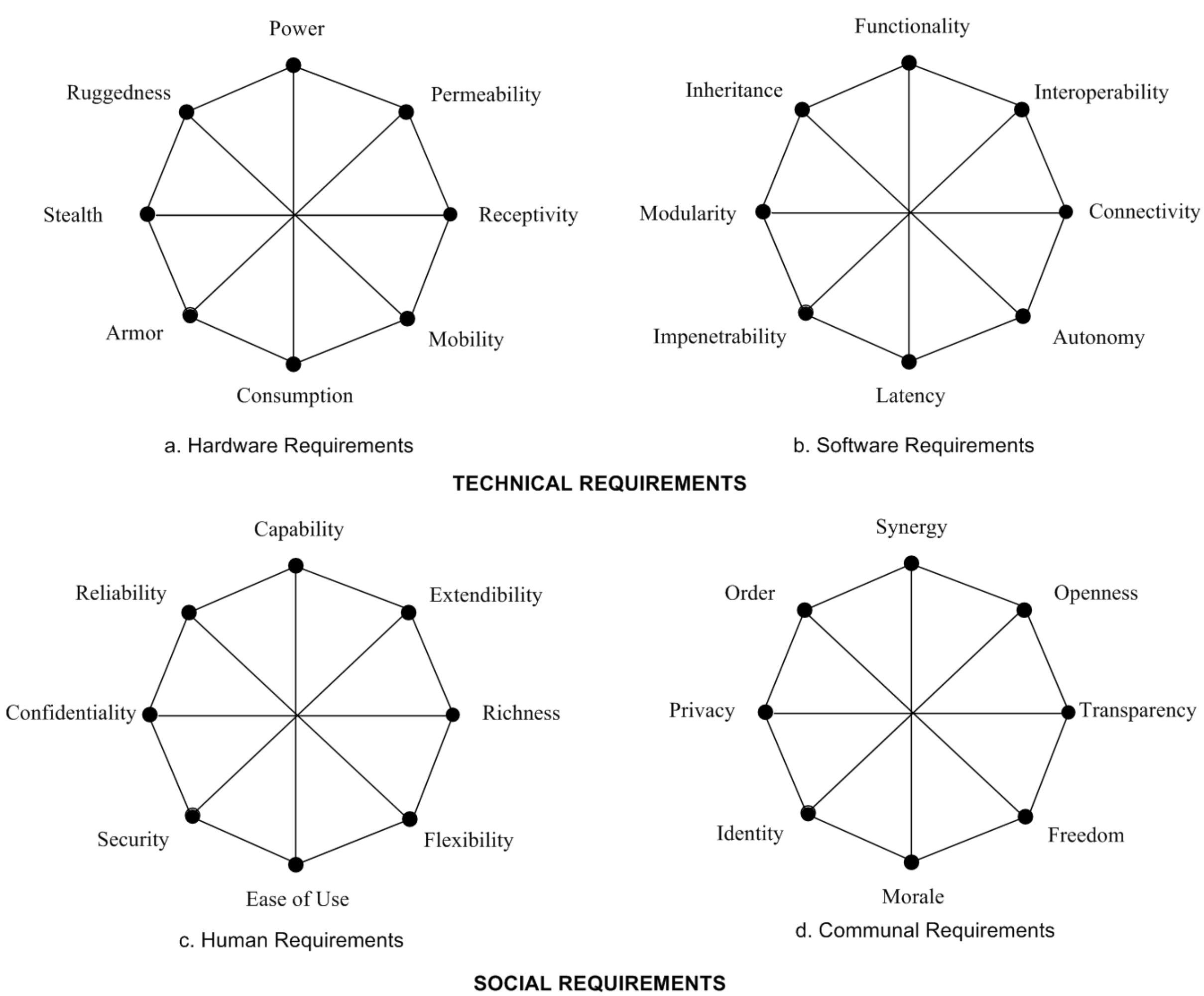
Socio-Technical Performance

Design complexity, it is proposed, arises when multiple system performance aspects vary by multiple levels, e.g. reliability varies by level, as a system can be hardware reliable but software unreliable, or both hardware and software reliable but unreliable for operator data entry (Sommerville, 2004, p. 24). Each level raises different problems. Likewise usability (the relative cost of action) means less cognitive "effort" in an HCI system, less memory/processing for a "light" software utility, or less power use for a hardware laptop. Again these are different design problems, so reconciling reliability and usability must occur on each level, not just one.

Figure 2 shows the WOSP model broken down by system levels. The details are outlined elsewhere, but in simple terms the web *area* is the overall performance, the web *shape* is the performance profile, and the web *lines* are performance tensions where improving one aspect of performance reduces another, e.g. improving flexibility can reduce reliability. As the levels change so does what the system exchanges: hardware exchanges energy, software exchanges information, people exchange meaning and communities exchange norms, ideas and beliefs. The WOSP performance criteria apply at each level, but with different names:

1. **At the hardware level** (Figure 2a) the system output is *power,* but equally important is *consumption*, as a car's miles-per-gallon is important as well as its speed. In the military a computer that worked even if soldiers dropped it was *rugged*, but it also had to be *mobile* to move it if the environment changed. A physical system that doesn't "leak" compromising emanations has *stealth*, while one that can pick up distant communications like radar is *receptive*. The boundary between system and not system must be *permeable,* as cell walls accept nutrients, yet also *protect* against attacks, like the walls and moat of a castle.
2. **At the software level** (Figure 2b) a system's *functionality* is the information processing it can provide, but equally important is *latency,*

Figure 2. WOSP Requirements by system level



or how long the processing takes. *Inheritance* ensures that each sub-routine carries forward reliable code, while *autonomy* (local freedom) lets systems respond flexibly to environment changes, as in plug-n-play. Object orientated design is an internal structure that combines inheritance and autonomy. Software must be *connected* to download or upload information, yet *modularity* lets subroutines keep private information. It must be *interoperable* by agreed standards to allow plug-ins and applets, yet remain *impenetrable* to attacks by virus or hacker hijackers.

3. **At the human level** (Figure 2c) meaning not information is exchanged, so functionality is replaced by user task *capability*, and ease of processing replaced by cognitive *ease of use*. The human terms *flexibility* and *reliability* describe the ability to change and not change given outer changes and inner changes respectively. *Richness* represents how much human meaning is communicated, and *confidentiality* lets one control one's "image" to others. Also part of human success is tool use, which in IT is *extendibility,* yet we also need *security* to defend against hijack attempts.
4. **The communal level** (Figure 2d) exchanges group, community, organization or society norms, beliefs, memes and culture. People in social groups have *synergy* if a social unit produces more than its members would alone. Equally social participation uses up *morale* or social capital*,* as does online conflict, rudeness and abuse. If the effort to participate becomes too high citizens rebel or leave. A society's ability to endure requires predictability or *order*, while its ability to innovate and reinvent itself in new times requires *freedom*. A society needs *privacy* rules to shield members from each other, and has *transparency* if services like "the media" let people see what is going on. *Openness* means the society lets other people and ideas enter to make value, while *identity* draws the conceptual boundary between "us" (the in-group) and "them" (the out-group), which written or unwritten "constitution" can prevent foreign mores from taking over the group and defines who can join.

In STS design one must first address appropriate system levels, as technical designs that ignore social factors often get "unintended" consequences. Secondly the principle that performance is not one-sided excellence applies equally to the social level. The WOSP social level (Figure 2d) suggests that STS designers and users ask if the system technology supports properties that improve community performance:

1. **Synergy:** Does the community creat extra benefits by social interaction, whether physical, informational or human outputs like enjoyment or understanding?
2. **Morale:** Does the online community have goodwill, is it socially an enjoyable place to be, without social conflict, and do members help others?
3. **Order:** Are the rules or norms of social interaction supported, giving social predictability?
4. **Freedom:** Are valid "rights" granted broadly, to allow bottom-up participation?
5. **Privacy:** Does the community respect the right not to communicate?
6. **Openness:** Does the community let new ideas in or out?
7. **Transparency:** Can people easily see what is going on?
8. **Identity:** How is the community identity maintained against ideological hijack, e.g. by online constitution, by membership rules, by community logo, slogans or symbols?

For example, in the tension between order and freedom, the order of a police state tends to stifle innovation, while anarchic freedom tends to be unstable. Democracy in its various forms is a social invention that reconciles freedom and order (somewhat).

In sum, there is no single magic "bullet" strong enough, nor any magic "pill" pure enough, to kill all the devils of system performance. One-sided "excellence" always tends to "bite back" both in design and use (Tenner, 1997), with a common example being network security "improvements" that reduce usability so much that overall performance goes down. Myopic single focus performance concerns like security (OECD, 1996), extendibility (De Simone & Kazman, 1995), privacy (Regan, 1995), usability (Gediga, Hamborg, & Duntsch, 1999) and flexibility (Knoll & Jarvenpaa, 1994, p6) tend to produce diminishing returns. The problem facing designers, researchers, managers and policy makers alike is that a blinkered focus on one system part causes problems to pop-up elsewhere. Good design inevitably requires the *innovative synthesis of conflicting goals in the total design space* (Alexander, 1964), as progress is not a simple one-track ladder "upwards".

MEANING EXCHANGE REQUIREMENTS

The HCI connectivity-privacy line (Figure 2c) introduces a social dimension to applications based on meaning exchange. Most *computer-mediated meaning exchange* theories postulate underlying psychological processes. Early theories proposed a single rational analysis process (Huber, 1984; Winograd & Flores, 1986), yet communication seemed more than just factual information exchange. Several theorized process dichotomies were suggested, including 1. *task vs. socio-emotional* (Bales, 1950), 2. *informational vs. normative* (Deutsch & Gerard, 1965), 3. *task vs. social* (Sproull & Kiesler, 1986), and 4. *social vs. interpersonal* (Spears & Lea, 1992). A three process model (Whitworth, Gallupe, & McQueen, 2000) combines these competing dichotomies into a single model of online communication with three meaning exchange processes:

1. **Resolving information:** the intellectual exchange of literal *message content* meanings about the world.
2. **Relating to others:** the emotional exchange of *sender context* meanings about sender state.
3. **Representing the group:** the intuitive exchange of *group position* meanings about group movement.

The first process intellectually gathers and analyses "facts", but information sources can give disinformation (lie), incomplete information, or information that is too late to be of use (Whitworth, Van de Walle, & Turoff, 2000). Hence in communication the source is as important as the message, as the judgement of *who* is communicating affects the meaning of *what* is said (Hovland, Janis, & Kelley 1953). If we do not trust a sender then *all* their communications are in doubt, and the better they sound the more they may be lying. It pays to build relationships because friends tend to be honest, to disclose the whole situation, and to volunteer timely messages, giving distinct relationship dimensions to communication (Devito, 1997) (p24). Finally, for a group to act it must "cohese" into an acting entity. Groups that cannot agree do not even have a decision to be right or wrong about, so groups need agreement as much as decision quality (Whitworth & Felton, 1999). This process differs from interpersonal relating as it involves individuals identifying the group "position" and adjusting their behaviour accordingly, as proposed by social identity theory (Hogg, 1990).

Each process reflects a practical human concern, namely the world, other people, and the community one is within. All are important, as sometimes what you know counts, sometimes who you know counts and sometimes, as on which side of the road to drive on, all that counts is that you do what everyone else does.

Group cohesion has in the past been seen negatively as "conformity" (Asch, 1952) or mindless "groupthink" (Janis, 1972), but the value of this process must be assessed in its combination with other processes (as that is how it normally works). When normative influence causes many minds to blindly follow a laid down group decision the problem is not that group process #3 above is working, but that the individual process #1 is not. If group members contribute by thinking, then the normative process contributes by pulling the group in behind the majority. Communal interactions serve to create unity, not to create thought, as the latter is the job of the individuals within it[3]. Normative influence works *best* when people think for themselves.

The three goals of rational understanding, emotional intimacy and group belonging can work simultaneously because one communication can have multiple semantic "threads" (McGrath 1984), e.g. one can say "I AM NOT UPSET!" in an upset voice. In this semantic conflict most people prioritize the sender state analysis, i.e. assume the person really is upset. As well as factual content and sender context, messages also contain a core of implied action, e.g. saying *"This is good, lets buy it"* gives *content* information (the item is good), *sender state* information (tone of voice), and the sender's intended action *position* (to buy the item). Figure 3 summarizes how the three meaning exchange processes tend to interact, with representing the group identity first, keeping up relationships second, and resolving world tasks by analyzing message content a distant third priority. This suggests three cumulative stages in Internet development:

- Stage 1. **A global knowledge exchange system:** This seems established, with the Internet a huge library of the world's knowledge, served by search tools like Google and knowledge harvesters like Wikipedia.
- Stage 2. **A global interpersonal network:** This stage seems underway, as people relate to people across the world by email, chat and social networks, with increasingly few degrees of separation.
- Stage 3. **A global communal identity:** This stage is still inchoate, as current online communities struggle with social features like leadership, democracy and justice, are not yet proven stable over time, and as yet have few common social structures or mores.

COMMUNICATION SETTING REQUIREMENTS

Media properties

An early attempt to classify communication media defined media "richness" as the "*capacity of the media to facilitate shared meaning*" (Daft et al. 1987 p358), suggesting the order: face-to-face, audio-visual, telephone, letters and posters. However studies found no performance quality differences between email, telephone, audio-visual and face-to-face (Masoodian, Apperley, & Frederickson 1995), and audio not face-to-face (FTF) gave better task times (Suh 1996). Email studies also broke the richness sequence, as subjects chose e-mail over telephone for social tasks (Lea 1991; Sproull & Kiesler 1986). Richness was clearly not the only new media factor.

Terms like "distributed" and "asynchronous" arose to contrast email with FTF conversations, but they assume that physical space-time concepts apply to online settings. Yet if two "distributed" e-mail correspondents were magically "co-located" to the same room, in email communication terms *nothing has changed at all*. Calling email "distributed applies the physical concept of space to an electronic setting where it doesn't apply. Likewise media synchronicity, defined as "… *the extent to which individuals work together on the same activity at the same time*" (Dennis & Valacich 1999) uses physical time to define an electronic media property. If email technology developed to allow virtually instant communication, would email then become synchronous? If so, at what transmission speed would asynchronous email become synchronous? Conversely, imagine two people talking "synchronously" by telephone when one boards a rocket to Mars. As the rocket leaves the earth the transmission delay increases to minutes then hours. Is the telephone still a "synchronous" medium? If not, when does it become asynchronous as the rocket speeds to Mars? That the same medium changes its type depending on use is undesirable, as true properties should change only when the thing described changes. Rather than using physical space-time properties like distributed or asynchronous, the classification below uses the interface property of *continuity*, defined as the degree of continuous communication.

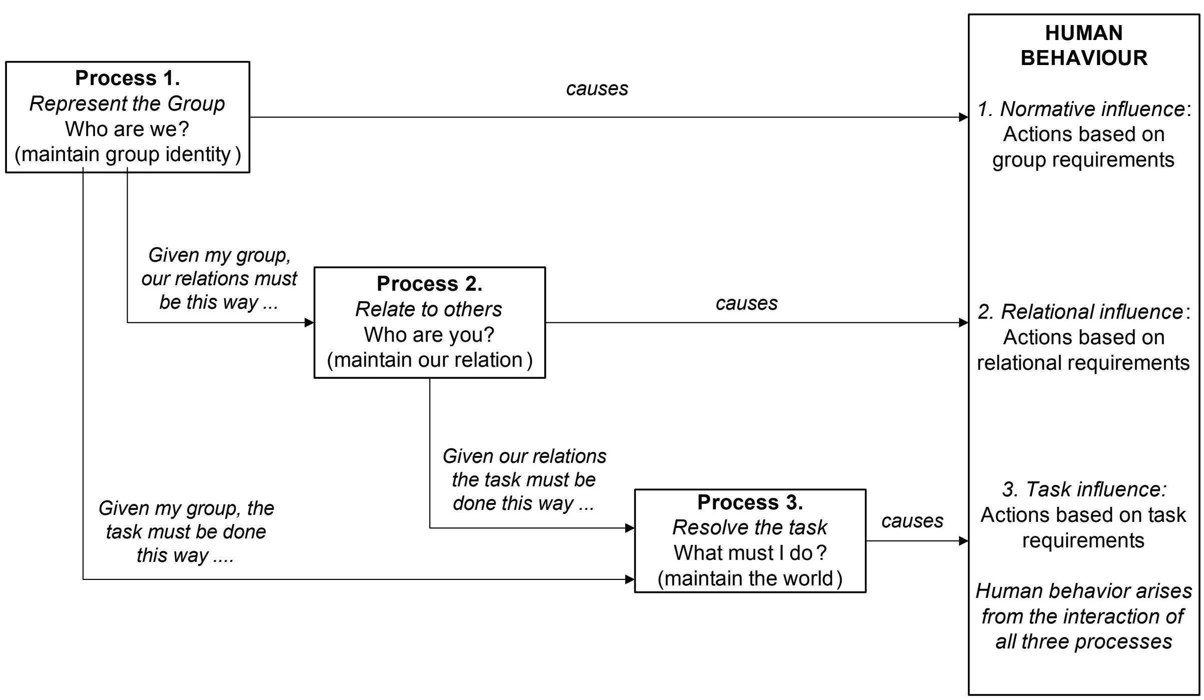
Another interface property is sender-receiver patterns like one-to-many (DeSanctis, Poole, Dickson & Jackson, 1993) which when combined with communication interactivity (Kraut, Galegher, Fish, & Chalfonte, 1992) gives communication *linkage* (B. Whitworth et al., 2000), see Figure 4. Increasing the linkage of one-to-one, one-way communication (Figure 4a) gives a two-way dyad (Figure 4b) or one-to-many broadcast (Figure 4c). A medium that supports many-to-one merging (Figure 4d) can support many-to-many, two-way signals (Figure 4e). For example, people in a choir sing (transmit voice signals) which by Fourier transforms the air "merges" in to one group sound broadcasted to all. In this communication form the group "communicates" with the group, as when a group applauds a performer. This allows a normative process whereby people match what the group is doing, so when choirs move off-key they usually do so together. The same process can occur in face-to-face discussions, where the group "valence index" (average position) on an issue effectively predicts the discussion outcome (Hoffman & Maier, 1964). Here position information can come from body language, facial expression, behaviours (like drumming fingers) and non-language sounds like groans. Computers achieve this communal communication by adding and displaying online votes, allowing electronic teams to generate online agreement using anonymous, lean messages only (Whitworth, Gallupe, & McQueen, 2001).

A Communication Setting Framework

The following communication setting properties contribute to semantic richness, defined as the total meaning exchanged:

1. **Expressiveness:** The total meaning transmitted at a moment in time based on channel number and richness:
   a. **Position** (symbolic). A discrete single symbol, say agree or disagree, that is not a language. An audience that raises their hands to vote is single-symbol communication.
   b. **Document** (structured symbols, static). *Text* language is alphabetic symbols connected by syntax into sentence forms which have meaning. *Graphics* also has "texton" elements that form by gestalt principles into meaningful "objects",

Figure 3. Human meaning exchange processes



with color and texture as attributes. Text/graphic "documents" fill most of the web today.

c. **Dynamic-audio** (dynamic, structured, single-channel). Dynamic-audio communication allows *speech* where phonemes create word and sentence sequences, *music* where notes create melody sequences, and emotive sounds. In dynamic-audio timing, tones and timbre more expressively convey feelings.

d. **Multi-media** (multi-channel, dynamic). Audio-visual communications open multiple dynamic channels to be more expressive. Face-to-face interaction maximizes richness and channels.

On a physical level expressiveness is like total network capacity (number of cables times bandwidth).

2. **Continuity:** The degree communication is a continuous flow, without pauses:

a. **Streaming.** Streaming communications flow continuously when transmitted or received, so senders cannot edit nor can receivers recall. Streaming at the sender interface is *unedited, spontaneous* and *genuine,* while received streaming is *ephemeral. Live* communication streams both when sent and received.

b. **Recorded.** In recorded communications the receiver interface stores the communication on arrival until the receiver is free to view it.

On a physical level continuity equates to the total time the network is communicating.

3. **Linkage:** The number of people sending and/or receiving meaning in a single transmission:

a. **Broadcast** (one-to-many, one-way): Communication goes from one sender to many receivers.

b. **Interpersonal** (one-to-one, two-way): Interactive communication between sender and receiver.

c. **Communal** (many-to-many, two-way). Communication goes from many to many, from the group to the group. It can occur by repeating interpersonal or broadcast communications, but pure communal communication is many-to-many in one transmission.

On a physical level linkage is like a network's communication type, e.g. line vs. wireless.

4. **Cost.** The Psychological cost to send a message is the "messaging threshold" (Reid, Malinek, Stott & Evans, 1996), e.g. e-mail has a lower threshold than letters, so sends more messages.

Figure 4. Linkage values, where S = Sender and R = Receiver

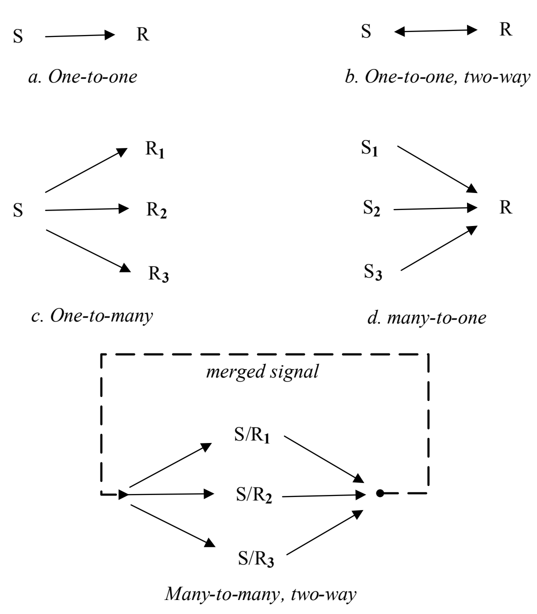


Table 1 shows this framework for physical and electronic communication settings, with the cell order informally by communication cost, e.g. email comes before letter as it takes less effort. Using this framework, telephone communication is streaming no matter how slow the transmission is, as senders cannot edit nor can receivers replay messages. Likewise email is recorded no matter how fast transmissions are, as receivers need not be present when the signal arrives.

Table 1. A simple communication settings framework

	Linkage					
	Broadcast		Interpersonal		Communal	
Expressiveness	**Streaming**	**Recorded**	**Streaming**	**Recorded**	**Streaming**	**Recorded**
Position	Flares	Footprint, Track	Body posture, Gesture	Acknowledge	Show of hands, Applause	Web counter, Karma system, Tag clouds Online voting, Reputation system, Social bookmarks,
Document	Blackboard, PowerPoint	Web site, Blog, Poster, Photo, Notice board, Book	Sign language	Texting, E-mail, Letter	Chat, Instant message	Social network Wikipedia, Emarket, Online com-munity, Bulletin board, News feeds Online reviews Media sharing ListServ
Dynamic-audio	Radio, Loudspeaker, Soapbox	Podcast, Music down-load Record/ CD	Telephone, Skype	Answer-phone	Radio talk-back, Conference call Choir,	Online talk-back? Online choirs/music groups?
Multi-media	Television, Movie, FTF speech, Show,	Online video, Videotape, DVD	FTF conversa-tion	Video-phone	FTF meeting, Cocktail party, TV interviews	MMORPG, Simulated worlds, Video-confer-ence

Examples and Implications

Some examples may clarify the issues. A telephone is a streamed, dynamic-audio, interpersonal communication, while an answer-phone is the same but recorded. A letter is also interpersonal and recorded, but in document form. A book is a one-to-one recorded document that is "broadcast" to readers by publishing duplication. Radio is a streaming dynamic-audio broadcast, ephemeral to the receiver (unless they record it on tape or CD). It is "live" if the sending interface is also streaming. TV is like radio except multi-media (has a visual channel). A movie is recorded and edited when sent, but streaming when viewed by movie patrons.

Web sites let people "publish" documents, talks (podcasts), music to download and online videos. Blogs broadcast text opinions, while email is two-way recorded text communication, as people send and receive. Chat is a few-to-few text broadcast stream for small groups, where no permanent record is kept. Instant messaging is similar, except that instant messages go to known people while chat rooms can be open. Repeating interpersonal communications like email gives a broadcast effect, as ListServs repeat point-to-point emails to "broadcast" to many people. Repeated broadcast communications in comment boards like Slashdot allow communal communication, but many "lurkers" are shy of public broadcasts. Social networks like Facebook let people limit broadcasts to friends only, which increases participation. Media sharing systems like Flickr (photos) and UTube (videos) are document systems that exchange multi-media files. True multi-media systems like video-conferencing struggle, but simulated worlds like Second Life and social games like World of Warcraft are popular.

Table 1 implies some interesting conclusions. Firstly, electronic interaction was expected to evolve to "richer" audio-visual multi-media like video-conferencing (Row 4), but instead it moved to more linkage (Column 3). The success of systems based on many-to-many position exchange is interesting, as eBay's reputation system, Amazon's book rating system, Slashdot's karma system and bulletin board "tag clouds" are not multi-media at all. They succeed by involving more people not by richer message content. *Indeed, expressivity, continuity and linkage seem all part of total communicative "power", the total meaning exchanged.*

It follows that maximizing all communication aspects is "expensive" in interface terms, as rich, continuous communal communication creates overload. For example, an electronic audio-visual meeting of twenty people would need twenty video streams to be represented on the computer screen. The physical world not only combines these streams into a common "space", it resolves real time contentions like two people speaking at once, and gives each individual view choices, including the ability to see where others are looking. This capability goes well beyond currently technology, but even the physical world interface cannot support this communication for large groups of thousands or millions.

Table 1 is interesting for the gaps it suggests. For example, the video-phone, shown as the future in shows like Star Trek is now technically possible with many mobile phones, but is still not widely used, despite marketing efforts. Perhaps video adds little to interpersonal relating above what sound already gives, or perhaps vision induces extra costs like having to look good. In some countries the movement is from mobile phone speech to texting, i.e. to less richness not more! Also interesting is the lack of dynamic-audio equivalents of text based online communal systems like Wikipedia. Are "online choirs", where people sing together via the Internet, or "online jamming" where they make music as a group, a likely future possibility? What does seem clear is that groups are critical to the Internet's future. Even the simplest online activities could be enhanced by group support, e.g. a "Group Browser" where people browse the Internet together, commenting as they go, and taking turns to choose the next site. Experts could offer online "tours" with such a tool.

Fitting Processes to Settings

The human meaning exchange processes of the last section each favour different communication settings:

1. **Literal meaning exchange** suits broadcast document communication (web site), as though message preparation cost is higher for typing text than speaking, message reception cost is equivalently less, as reading is faster than listening (Chafe, 1982) by a factor of up to four (Weeks & Chapanis, 1976).
2. **Interpersonal meaning exchange** suits two-way dyadic settings that require identification like email, or are rich enough to convey emotional feelings, like the telephone.
3. **Communal meaning exchange** in contrast needs high linkage but not richness, and can be anonymous.

For example, maximizing linkage is easiest when expressivity is lowest, as in reputation and karma systems where only position information is exchanged. This improves download and processing speeds making such systems fast. Also merging many contributions anonymizes them, which lowers the risks of participation. The "weak ties" (Granovetter, 1985) of group position exchange are a *highly condensed form of human communication* (Hiltz & Turoff, 1985) quite apart from richness.

While transmission duplication allows many-to-many interaction, in "true" many-to-many linkage groups send and receive in a single communicative act. For example, a manager could request feedback on an issue from 20 staff by email. If all replied to everyone including themselves this would create 400 emails. If each of these 400 replies also was responded to by all staff to all staff, after two rounds the discussion would create almost 1,600 emails. Hence group discussions via one-to-one communication settings like email tend to create information overload. In contrast an online vote on an issue like what software to purchase lets the question be put and responded to in a single operation that is relatively insensitive to group size. While exchanging opinions requires users to type, exchanging position information in social bookmark systems like Digg requires just a mouse click. Tag clouds go a step further, as users merely view or download as they normally do, and the system adds up their actions to create the online equivalent of "tracks" in a forest of information.

SOCIAL REQUIREMENTS

Figure 2 suggests that not only must different community needs be reconciled but also the needs of society must be reconciled with the needs of individuals. One discovery of game theory was that individual needs need not support social needs, as the "equilibrium point" of the prisoner's dilemma for example is that both cheat each other (Poundstone, 1992). While mutually beneficial synergistic interactions like fair trade create enormous benefits, synergy is just one possible human interaction outcome (Table 2). Since game theory cases like social loafing and the volunteer dilemma are common in social interaction, social systems should, like the atom before quantum theory, collapse in on themselves. Based on the Darwinian principle that individuals tend to do what benefits them, social communities should be unstable (collapse) under the pressure of anti-social acts like stealing.

Yet human society, in various forms, has not only persisted for thousands of years but evolved. It defends itself against anti-social acts by locked doors, moral norms, religious edicts, revenge traditions or state justice. In the latter case the social invention of "fairness", implemented by both revenge cultures and justice systems (Rawls, 2001), seems to have pushed humanity across what Wright calls the "zero-sum barrier", from tribal competition to cooperative society (Wright, 2001). Fairness here is not simply the equal distribution of outcomes (equity), but *allocating group outcomes according to group contribution*. By this principle society punishes those who hurt it, as thieves are put in jail, and rewards those who help it, as artists and inventors are given copyright benefits. The details are argued elsewhere, but fairness plus public good is the requirement for *legitimate interactions*, which are not just fair to the parties involved but also benefit the social unit (Whitworth & deMoor, 2003). Note that to do what benefits the social is exactly the same principle as to do what benefits the individual unit (i.e. "selfishness"), just applied at a higher level. Legitimacy of interaction is a complex social success requirement for any community (Fukuyama, 1992).

If societies to perform well must support legitimate interactions and oppose anti-social acts, this challenges not just STS design but society itself. Currently the "rights" of physical society are often expressed in ownership terms (Freeden, 1991), so "freedom" is the right to own oneself, and slavery the denial of that right. Likewise analyzing who owns what information online (Rose, 2001) lets designers specify online rights (Whitworth, 2006). Such "legitimacy analysis" of online rights may suggest better ways to run physical as well as electronic communities. Meeting the social requirements of technical systems means not just mapping thousands of years of social history to information models, but also considering what this analysis implies for current physical society. Maybe some of our social traditions are just plain wrong, as if individuals can err then so can cultures.

If usability research translates psychological needs into information designs, then the job of STS research is to do the same for social needs. The new "users" of socio-technical systems are in a very real way the communities that they create (Whitworth & deMoor, 2003). For example, currently nearly 90% of all emails the Internet transmits are spam most of which is deleted by filtering technology (Metrics, 2006). Yet even so, that which gets through is enough to make spam the number one networking complaint. This waste of hardware, software and human resources, conservatively estimated in 2005 at over 50 billion dollars (FerrisResearch, 2005), illustrates what happens when socio-technical systems ignore social requirements. The error in this case is an email communication design that gives all rights to senders and none to receivers (Whitworth & Whitworth, 2004).

SUMMARY

It is difficult to express the potential richness of the socio-technical vision in one chapter. It has considered:

1. System levels from hardware to social.
2. Performance aspects like capability and security.
3. Psychological processes that exchange literal, relational and group meaning.
4. Communication setting features like expressiveness, continuity, linkage and cost.
5. Legitimacy as a general requirement for social synergy and stability.

This research landscape is nothing if not challenging, yet the rewards are equally great, as technology plus society combines the two great driving forces of human progress. To imagine the Internet of the future, imagine a world where everything human is potentially known, where everyone is potentially connected, and where all are potentially one community. In this case, it is difficult to imagine any feasible problem that humanity together cannot solve. Business problems like "What do customers want?" could be simple outputs from socio-technical customer communities. Currently insoluble problems in government, education, health, welfare and defense could be amenable to the power of community participation. For example, in a unified and connected humanity millions of eyes watch millions of places, so someone planning a terrorist attack on humanity is likely to be seen by someone, somewhere, at some time. Tips from ordinary citizens found the U.S. Beltway Sniper, watching New Zealand citizens exposed the Rainbow Warrior attack, and likewise international terrorism is vulnerable to intelligence from a connected global humanity.

Table 2. Social interaction types

Outcome for…		OTHER(S)		
		Gain	**Minor effect**	**Loss**
S E L F	Gain	Synergy	Opportunity	Anti-social
	Minor effect	Service	Null	Malice
	Loss	Sacrifice	Suicide	Conflict

Yet without a common human identity, common action is not possible. Human conflict inevitably occurs when some individuals seek power over others for their own ends. Hence to ask "*How can I use STS*?" is to misunderstand why it succeeds. Consider the apocryphal story of the programmer who stole millions using a program that transferred the fraction-of-a-cent leftovers of all financial transactions to his account. The ability to add fractions of a cent into millions of dollars illustrates the power of the computer. That this is stealing, punishable by prison, illustrates the power of society. The collapse of the dotcom bubble illustrated that people can recognize too greedy businesses, even when they are technologized. Today's socio-technical systems like Wikipedia are based on service not plunder, in this case on the principle that if we each give a little knowledge, then we can all receive a lot of knowledge. The social lesson is less that one shouldn't plunder the community and more that one should give to it. If one *uses* a society, seeing it merely as a resource, then one cannot *belong* to it. Equally, if one *belongs* to a society, then one cannot *use* it. A part that diminishes the whole diminishes itself. Cancer cells illustrate what happens when parts of the physical body enhance themselves at the expense of others—the body dies. Conversely, if the social Internet shows anything, it is that large numbers of ordinary people, when working together freely, will voluntarily help each other. This is an extra-ordinary revelation, that we are inherently good not bad, that the human majority has original goodness not original sin.

Of course life will test us. Last century atomic bomb technology asked nations if they wanted to mutually destruct or not. This century Internet technology is asking us if we want to be a single humanity or not. If we were once "*hunter gatherers of the information age*" (Meyrowitz, 1985), and then "*homesteaders on the electronic frontier*" (Rheingold, 1993), shall we now become *electronic citizens of a global cosmopolitus*? If so, the fresh spirit of socio-technical computing suggests that technology can release the goodness of humanity as well as its selfishness. The idea of freely serving one's fellow humanity, not as directed but as one chooses to do so, is illustrated by the Internet today, where every second people help others in undefined and uncontrolled ways. In this view the evolution not just of technology but of humanity itself will be by service freely rendered, not by forced servitude, however politically correct or well intentioned. While negative forces seek discord for personal gain, the social process unifying humanity has been ongoing for thousands of years. It seems very reasonable that computer technology should help bring it about.

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KEY TERMS

Channel: A single, connected stream of signals, e.g. stereo sound has two channels.

Communication: A single transmission of meaning or information between one or many sender(s) and one or many receiver(s) (Lim & Benbasat, 1991).

Communication Interface: Operates at the boundary between communicating entities and the channel (Lim and Benbasat, 1991) and may also record (store) and process communications.

Communication Environment: Any combination of communication settings available to communicators, for example, a communication environment of telephone plus email.

Communication Setting: That through which communication occurs, which may involve many channels, for example, telephone and loudspeaker are different communication settings.

Group: Any set of people who consider themselves a group (Bales, 1950; De Sanctis and Gallupe, 1987).

ENDNOTES

1. Blank slates.
2. One cannot combine different disciplines into one "view", just as one observer cannot *at once* view an object from many vantage points. As one first chooses a vantage point then views, so in the WOSP model one must first choose a level, then analyze from it.
3. Hence "Groups don't think, people do"