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Pervasive Computing and Urban Development
Issues for the individual and society

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"You had to live--did live, from habit that became instinct--in the assumption that every sound you made was overheard, and … every movement scrutinized" -George Orwell 1984

Abstract:
Pervasive computing is the third wave in IT, after the PC and the Internet and is based on the use of numerous "invisible", omni-present, always-on, communicating computers embedded into everyday environments which gather personal information from people and deliver services to them.

Whilst this technology promises great benefits, being invisible and autonomous and with its access to the most personal human behaviours, it raises significant new dangers for individuals, city dwellers, cultures and society as a whole.

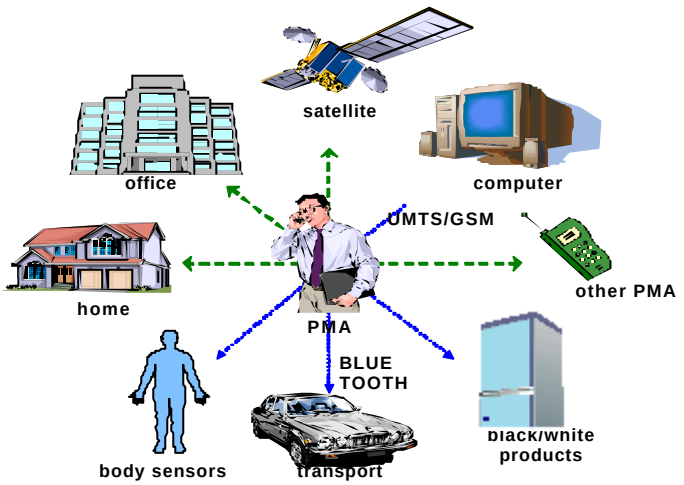
Perhaps the most significant issue is privacy - an individual's right to control the collection and use of personal information - especially by external agencies such as companies, political, other institutions and other individuals.

The ongoing theme of this paper is who should control access to personal information on the individual in their role as home occupant, worker, consumer and citizen?, How should such control be regulated at local, regional, national international and multi-national levels since it is likely that commercial interests will often outweigh national interests in the future. Is there room for a truly international form of regulation under the auspices of the UN comparable to a bill of rights and responsibilities.

This paper seeks to discuss the issues so that the population at large can begin to think about the personal or regulatory needs involved.

1.0 Introduction
Imagine a world in which every artefact in our environment, ranging from domestic appliances through clothing to dust-like particles (e.g. in the pigment of paint) contains a small networked computer, each transmitting information about its sensory state and receiving the sensory states of other artefacts. Imagine further that such computers contain autonomous intelligent agents which sense the world and can program and organise themselves into collaborating groups with a minimum of human intervention to manage the environments we inhabit. Now imagine that there are

companies, governments and individuals that wish to control these resources to further their own ends. Many lay-people might be surprised to learn this scenario is not a plot for science fiction book, nor a vision of a distant time but rather a technology that is already beginning to work its way from research labs into our everyday environment and is the vision for pervasive computing (alternatively known as ambient intelligence or ubiquitous computing) often known generically as Pervasive Intelligent Computer Technology (PICT) [Lyons 02]. Perhaps the most obvious manifestation of this can be found by looking at the development of the world's most famous data network the Internet. Its growth is breathtaking having grown from nothing to over 200 million users in a little over 10 years [Facts 03]. Perhaps an even more remarkable and all pervasive data network is the digital mobile phone. In a similar period, this has grown from nothing to a truly massive 680 million mobile phone users [GSM 01]. However dwarfing all these developments is a somewhat quieter but just as significant revolution, the spread of small cheap processors into everyday products, so-called embedded computers [Chin 03a]. Metcalfe estimated that in 2001 a staggering 7840 million microprocessors were used to build embedded-computers (in contrast to some 160 million being used in conventional computers) [Metcalfe 01]. These technologies are the forerunners of a massive, omni-present, always-on pervasive networking technology that promises to connect not just every citizen of this planet, but ultimately every artefact in the world. Clearly, placing such all-pervasive systems in personal political and commercially sensitive areas of society, which gather information and control the environments people live in, would have significant consequences for society. The forces propelling this technology forward are massive. Not only are there large commercial interests, and in the age of terrorism significant political pressures too, but this technology is also the key to mankind's long term habitation of deep space, which will almost certainly depend on wholly technological environments such as spaceships and "urban" planetary habitats controlled by such technology [Clarke 00].



Technology View #1 *The person of the future will be able to communicate with millions of devices worldwide. Locally through the use of wearables and locally defined communities of devices they will be able to invent new functions for their homes, cars and places of work.*

Thus, this new computing paradigm suggests a new, massive and lucrative market that is drawing in the world's major companies such as British Telecommunications plc (henceforth referred to as BT), Philips, IBM, Siemens, Hewlett-Packard and Microsoft etc. [Bruno 02]. These organizations are investing heavily in related research in the belief that PICT will become a major market. In the

following pages, we will seek to explain what this technology is together with its ramifications for the individual and society at large.

2.0 Pervasive Computing

PICT is a new computing paradigm that was described by the Lou Gerstner, CEO of IBM, as a vision where " *…. a billion people will interact with a million e-businesses via a trillion interconnected devices"* [Gerstner 99], an intriguing description which captures that the enormity of the potential for this technology. This potential has not gone unnoticed by governments and various national programmes such as the UK's DTI Next Wave Technology programme [DTI 03] and international programs such as the EU's Disappearing Computing programme [ISTAG 01] (the authors have been funded for research into PICT by both initiatives). Research to generate the technology to support this vision is now well under way. Perhaps the most influential benchmark for this vision is a report entitled "Scenarios for Ambient Intelligence in 2010" produced by the European Community Information Society Technologies Advisory Group (ISTAG) in 2001 [ISTAG 01]. The ISTAG report envisioned a world in which everyday environments were built from numerous artefacts containing tiny (sometimes physically invisible) omni-present, always–on computers with attached sensors and actuators, communicating and collaborating with each other, and people, to control and offer information relating to the environments we live in [Chin 03b]. From a global perspective there could be a billion people interacting with a trillion devices, with homeowners interacting with hundreds of devices (many of which might be highly dynamic in terms of their mobility, failure etc). Intrinsic to this technology is the use of intelligent agents which will be integrated into the machines making up the environment. These agents remove the cognitive load from people by assuming some of the decision making in particular the technical aspects. They filter the information to be provided to their human users based upon sensing and reasoning about what the user is seeking to achieve. This frees the user to get on with more productive and useful tasks [Callaghan 00]. Clearly whatever the particular technology employed, such systems requires the existence of vast numbers of sensors and monitoring devices to acquire and interpret information on what the users of such systems are doing at any given time. Whilst this technology is advertised as offering benefits e.g. improving the quality of life of homeowners, increasing the profitability of companies etc, the presence of sensors and intelligent agents gathering information about us is an issue that needs very serious consideration.

> ***Story #1****: "Ama, Bubba and Collo live in a gated community on the island of Java. This purpose built complex for wealthy participants in the knowledge culture provides them with all of the comforts of a wealthy lifestyle and none of the drawbacks. The independent state of Java has a number of such communities and each offers highly secure environments in several senses. Java's citizens have benefited greatly from the development of these super-wired communities so the level of local resentment is at a minimum and Java has negotiated a completely surveillance free relationship to the rest of the 'noosphere' – the virtual world that is the dominant economic feature of the global economy. Amma works on developing augmented and virtual reality training programmes for space shuttle staff taking holidaymakers to the space hotels that are an increasing feature of the travel industry. Bubba trades in ontology futures, the building blocks of the wired world while Collo gets the very best of eduction via VR and can play freely and safely with the other kids in Java-7's spacious, secure and superbly appointed grounds ."*

We believe that the significant issue is privacy - an individual's right to control the collection and use of personal information by third parties. The ongoing theme in this paper is that of who should exercise this control, the individual, government, commercial organizations or combinations of all; how should that be effected, what regulation is required and how should it be policed.

2.1 Pervasive Technology and Urban Environments

An urban environment is a highly complex system or system of systems. In the extreme it consist of millions of people, hundreds of thousands of buildings, similar numbers of vehicles, extraordinarily complex infrastructures of power, water, transportation etc, vast numbers of relationships both business and personal, countless transactions all of which combine to make the incredibly diverse social-nexus we call cities and towns. At first sight it might be thought that it is in this cauldron of human activity that pervasive computing systems are likely to be developed first. However unlike government, which is frequently top-down and centralised in nature, pervasive computing is "bottom-up" and highly decentralised. It functions in a similar way to society by symbiotically attaching itself to people (or their living places), forming synergetic relationships to other pervasive devices, communities or environments which in an increasingly virtual world could be anywhere on the planet. What are the longer-term consequences for existing urban systems as a consequence of the development of PICT? Currently there are places where there are 'friendly' tax regimes or where you can guarantee the privacy of your financial holdings. As the major economic forces become more etherealised (virtual) – the knowledge industry for instance and the fact that trading in and pursuing such operations no longer needs specific locations and institutions but like trading in stocks and shares today can be carried out almost anywhere in the world, so via this technology location becomes less important. Consequently the forces that led to the development of urban centres are being undermined by the development of cyberspace and Marshall McLuhan's vision of the 'global village' is reflected in the virtual trading floors and institutions of learning etc that will become the (virtual) reality of the future. This raises an in interesting question for any futurist; how will people balance the need for physical versus virtual interaction in their lives? One possibility is that the pressures that led to the building of urban areas will be reduced and there may well be the migration of the rich out of cities, where they might have to live cheek by jowl with the poor, into gated communities and into (protected) areas a long way from conurbations. There may even develop places where privacy laws etc encourage big players to settle free from interference from the state and safe from the poor and the dispossessed. After all the virtual market for knowledge could be physically anchored in enclaves for the rich widely distributed around the globe and away from urban areas as easily as it could be anchored in cities that currently have some dominance in the money markets e.g. London, Tokyo, New York. In this way of thinking, the appeal of the city, and urban developments like cities, may well diminish with the development of PICT. Should coordination be a significant factor for the growth of PICT, it is certainly going to be more tractable to the vision to co-ordinate a village-like structure than a city. Consequently the city as an agglomeration of relatively self-contained communities would be a far more tractable proposition for the extensive use of the technologies being discussed. Another view is that cities do remain the major gathering places for wet-ware (people) and as such afford the variety of human experiences that will remain difficult to reproduce virtually for longer than the development of PICT based communities. If such physical contact predominates over virtual contact then urban areas might remain much as they are now, perhaps dispersed simply as a consequence of more efficient travel systems. However, if virtual contact takes on a dominate role in human interaction, then urban

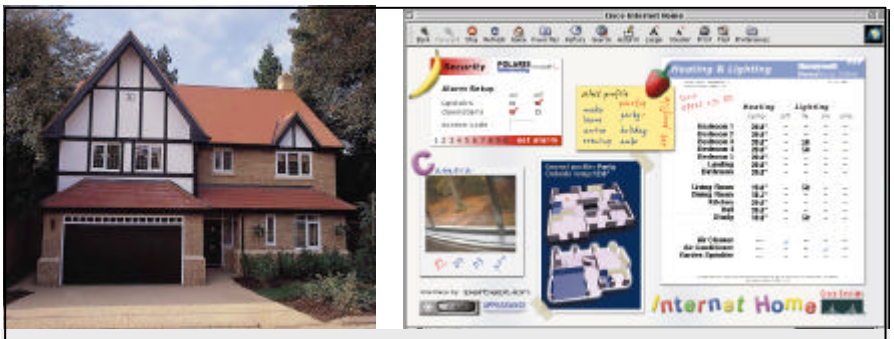
areas, depleted of the more educated tier of the population, could become more impoverished and more brutal places to live and will remain underdeveloped relatively speaking in their use of the virtual world. There may in fact be a virtual and a real world that to some extent mirror the contemporary distinctions between the rich and the poor, or the ruling class and the working class, or the first and the third world. Thus urban life might actually become more 'nasty brutish and short' as it was in 19th century London and is on the periphery of many of the major conurbations of the world today.

Technology View #2 *The iDorm is a PICT test-bed based on a student bed-sitting room where experiments on capturing the behaviour of the occupant and allowing them to define communities of devices are being carried out.*

The mutual effects and interdependence of real and virtual life, and their effects on society, arising from new technology was rather dramatically illustrated in an analysis of UK statistics on increasing divorce rates which attributed part of the cause to be affairs arising or supported by Internet technology [BBC 04]. In particular the discussion centred on a phenomena of "old flames" being put back in contact through the web-site "Friends Reunited" which has 12 million UK subscribers. From this, it can be postulated that the impact of a broader set of pervasive computing technologies on personal relationships will have an impact on society. However, it should also be noted that internet technology can be supportive of relationships by using virtual presence technologies (e.g. instant messaging, internet telephony, video conferencing etc) to enable geographically distributed families (e.g. students studying abroad) to maintain close relationships.

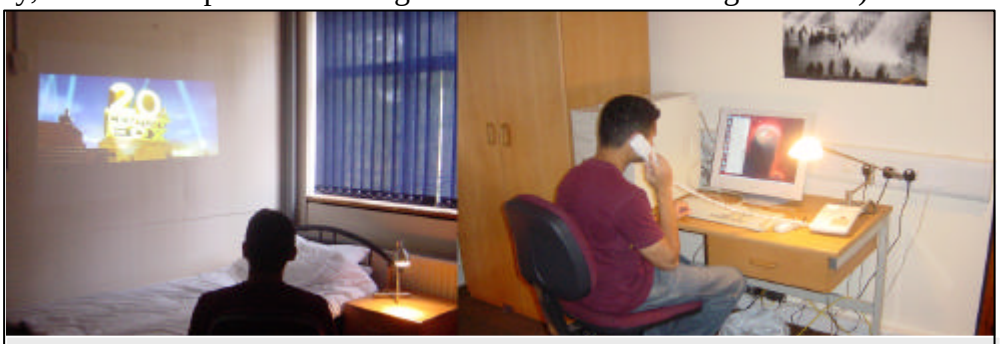
2.1.1 Pervasive Technology in Domestic Environments

One of the most important areas of an urban environment is the home. The home is our most private and personal space in any urban environment. Most people are protective of their privacy, and technology that has sensors and records activity is likely to find it hard to be accepted unless there are overriding reasons and advantages.



Technology View #3 *The Internet Home was built in the London commuter belt town of Watford as a partnership between Cisco Systems and the construction company Laing Homes to form a showcase for technologies that are already available and will soon become the norm.*

Pervasive technology in home environments started with the idea of smart homes, or intelligent buildings. In such homes, computers are connected via a network (often a power line network) to major appliances such as heating and lighting systems to make them more responsive to people's needs. Such system can help reduce energy consumption and increase our comfort, health and security, keeping us entertained and in touch. Such behaviour is generally accomplished by writing programs which include conditional statements such as "if the room is unoccupied, set the heating to minimum and lights to off". More sophisticated programs with some "intelligence" are able to learn a user's habits and potentially increase the efficiency of the system by pre-empting user actions based on habitual patterns of behaviour (e.g. on Tuesday night the occupant comes home from work early, therefore adapt the control algorithm to switch the heating on earlier).



Technology View #4 *Rules based upon previous experience of the user's preferences provide behaviours appropriate to particular circumstances. If a film is being displayed the blinds and the lights are set appropriately. When the phone rings the film is paused and the desk lamp illuminated in case the user needs to write* anything down

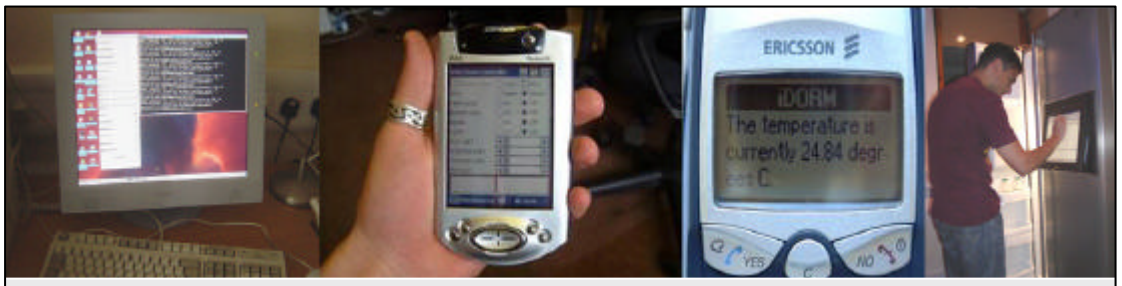
Savings can be considerable, for instance, [Davidsson] estimates up to 40% of energy consumption in the home could be saved by the use of this technology. Such homes are available on the market, currently Cisco Systems is involved with several, including two, in the UK and France, which have been sold, after a period of demonstration, to private buyers.

Advances in microelectronics and network technology is resulting in ever cheaper and more functional appliances being developed. Such cheap and compact microelectronics means non-electronic artefacts e.g. shoes, cups, chairs, floors beds, clothing fibres, paint pigments etc. are now potential targets of embedded-computers (or stand-alone sensors) [Hollar 00]. In addition, such systems can also be implanted into our own bodies. Indeed, there is no reason why, as domestic animals increasingly are, we could not be 'chipped' at birth with a unique identity that could be used throughout our lives. This is clearly also the stuff of nightmares of control by political systems and needs to be discussed widely. At this moment it isn't clear that the advantages of this sort of 'tagging' are anywhere near outweighing the potential disadvantages.

The key difference between pervasive computing environment and other environments is that appliances can collaborate together to produce meta-functions (virtual appliances) formed from communities of coordinating devices (or functions.). One key question for individuals and society is, how these systems are programmed. Intelligent agents could be used to autonomously program the system with only implicit involvement from the user. Alternatively, people could be intimately and

explicitly involved in the programming of collectives of devices, which they may also have defined themselves. These are hotly debated issues amongst some researchers with passionate views being held on either side.

When faced with the task of setting up and programming any computer system an end-user is faced with a significant cognitive load as he seeks to understand and configure the system appropriately. The underlying principle in the use of embedded-agents is to transfer some of this cognitive loading from people into computers, so that they can take over some of these configuration and programming chores, freeing the user from the need to understand the technology. Such systems work by sensing the user as he goes about his habitual routine in the house, and learning from this behaviour (i.e. self-programming) so as to autonomously make the pervasive system perform is a manner the user seems to require.



Technology View #5 *Various forms of user interface have been developed to provide tools for the user. These interfaces can allow the user to define a community of devices and also provide the means for explicit programming and/or the amendment of implicit programming of such communities. They can also be used directly to control devices.*

Whilst autonomous agents may appeal to many people, their acceptance is not universal. Some people distrust autonomous agents and prefer to exercise direct control over what is being learnt and when. Moreover, there are other reasons advanced in support of a more human driven involvement, such as enabling the creative talents of people by providing them with the means to become designers of their own systems. So-called people-centric approaches are being developed to enable people to direct the operation of pervasive computers in a way that gives them full control, but avoids any need for them to have technical knowledge of the systems. One example of explicit end-user control and programming is the UK DTI funded PHEN (Pervasive Home Environment Networking) research consortium's user interaction paradigm called Task Oriented Programming (TOP); an approach that puts the *user at the centre of the system programming experience* by exchanging autonomous learning for *explicit user-driven supervision*. In this approach, a user defines a community of coordinating pervasive devices and "programs by example" the system usage rules and coordinating actions for groups of pervasive devices by just using the devices in the way s/he wants the system to learn. This work builds on the metaphor of people "decorating" their homes by enabling people to create an electronic space built from a variety of network ready computer-based appliances such as TVs, DVD players, cookers, washing machines and mobile phones etc. However, the model goes further than simply connecting existing appliances as TOP uses the notion of decomposition of appliances into basic functionalities, which users can recombine, to form soft, or virtual, appliances. A key aspect of this new end-user empowerment is that lay-users have the power to associate together devices (and functions) in both familiar and novel arrangements to make highly personalised systems. A significant aspect of this paradigm is that it allows the coordination of numerous devices to provide new "meta functions" or

virtual appliances opens up the possibility of the lay-user creating novel meta functions that were not foreseen by individual appliance manufacturers. In short, lay-users could become the designers of the potentially unique functionality of their own home systems. This work transfers the focus of design from the manufacturer to the end-user, a paradigm that could greatly empower the lay-user, and challenges the nature of current appliances, all of which might contribute towards profound changes in social activity in the home and urban environment.

> ***Story #2*** *: Hu Sin had become the most successful and famous of the new wave of Chinese directors with his third interactive film/game 'Intelligent Clouds', the most downloaded film/game of 2020 with over a billion hits. This was a science fiction film/game based loosely on the work of Stanilaw Lem about communities of robotic creatures that melded to become one in much the same way that the slime mold acts in concert to produce a mushroom like entity necessary for its self-reproduction. What was remarkable about Hu Sin's film/game was that there was not one human actor in it and yet the human characters were totally believable at every level and could be developed and invented by the user. Everyone marvelled at the way that Hu Sin's Beijing studio had produced the first totally convincing digital people. In future the actor would be redundant in cinema and gaming. Actors would become anachronistic, consigned to side-shows in local markets. Now too the imagination was free since it could be truly claimed that 'no humans or animals have been harmed in the making of this film/game.' Everything was possible and only limited by the user's imagination.*

2.2 Pervasive Technology in Commercial Environments

The workplace has features in common with the home in that there will be heating, lighting, communication and computing systems. However, the variety and types of device are likely to be greatly different, as are the behaviours of the users. For instance for many office workers most of their daily activity can be characterised by sitting in front of computer screens which differs greatly from the typical behaviour of a home based pervasive computing system user. In addition the typical worker is not the principal stakeholders of his environment in that he does not own the environment, nor is he master of his own time; rather he is often following a highly structure daily routine designed and supervised by other people. This managerial (and supervisory) style of life leads to the natural inclination for the stakeholders to utilise pervasive technology in a very different way to a domestic home. For instance, the manager or owner of a business may be more interested in the amount and quality of his employees work than their being allowed to design novel arrangements of appliances to entertain themselves. A manager might be interested in the employees' time keeping, or whether there is misuse of resources such as surfing the internet for private ends. Similarly, he may be interested in employing technology to make working practices more efficient, or perhaps rewarding employees based on their ability to rapidly complete certain tasks. Such practices are already common as many employers monitor e-mail, telephone calls or breaks. Pervasive computing enhances the employers ability to monitor employees as it brings cheaper, more numerous and more varied sensors with more intelligent capabilities. For example, existing number-plate recognition technology is being ported from enforcing congestion charges in inner cities to applications such as controlling and charging employee parking facilities (with clear potential to be extended on providing information on attendance that could be used in other ways). Also, looking more forward in time, embedded agent techniques can allow agents to learn and characterise habitual patterns of behaviour (allowing one employee to be compared to another),

and to detect and flag "abnormal" behaviour by comparison to a template or ideal, whilst conventional networking technology gives the employer the ability to have a virtual presence with the employee, whenever he chooses.

Whilst it can be argued that the employer is acting within his rights by using this technology to make the supervision of his staff more efficient and less costly, it clearly has the potential to appear as extremely threatening to employees as few of us like to have someone standing over our shoulder as we work. Also, in some jobs initiative and independence, encouraging responsiveness and flexibility, are valuable human characteristics which such close monitoring might undermine. It would seem that for employees to accept such monitoring then the technology has to appear not just beneficial to the manager, but also to the employee, and not be used as a tool to enforce a rigid working ethic but rather to support and reward employee creativity or make their job less of a chore in other ways. In Lyons' excellent paper on the use of pervasive computing to monitor consumers and employees [Lyons 02], he makes the point that technology that seeks to enforce working practices according to well defined rules, is equivalent to the "work-to-rule" weapon that employees have traditionally used against employers. Thus, he argues it would seem counter productive for employers to turn this "weapon" on themselves.

3.0 Social Implications

3.1 Introduction

The development of the sort of pervasive technology already described has several implications for the citizens of the future. Although this technology is directed towards being helpful and enabling by the scientist involved, it clearly can be used to develop and sustain a surveillance society. Without careful planning and regulation to control the systems and software of the pervasive computing environments of the future we could be creating a modern equivalent of Bentham's Panopticon [Panopticon] with some variety of "Big Brother" [Orwell] being able to monitor your every move and find out about all of your personal preferences [Clarke 00].

We are caught in the paradox that in order to help, the system has to know but once it knows others can know too. However, the developmental trajectory of these systems is towards greater and greater distribution and local autonomy of both knowledge and activity – so technically the model is much more of a highly distributed form of control. These systems are intrinsically anti-hierarchical in their design and operation and as such they might well present greater and greater difficulties for any centralised monitoring and control. They might thus be used as a metaphor or guiding model for a political reality in which control is more widely distributed.

3.2 Citizenship and Pervasive Computing

Knowledge is power, and the level of distribution or centralisation of those exercising control over pervasive systems may be key to moulding of political systems (and vice-versa). Thus, for example, the sort of technology that has been described opens up the possibility of the plebiscite as a major form of democratic process. This puts the education and development of responsible individuals at a premium, an aim that is very much at the heart of the mission of the International Research Foundation for Developments [http://irfd.org/] which operates within its special category of

consultative status with the Economic and Social Council of the United Nations (as specified in the UN Charter Article 71) . This opens up the possibility that the preferences of the population as a whole would be more visible to the population as a whole, with this technology acting as a form of real-time market research. Rather than confining itself to indirect implicit data to government, the power of pervasive computing could be used to allow the population to give explicit and direct feedback to government which would put the education of the population at a premium. A closed society may well still hang on to a command structure which is supported by PICT. However, technology itself can become a force for grass-roots driven political reform that even the most powerful command structures would find hard to suppress.

3.3 Privacy and Security

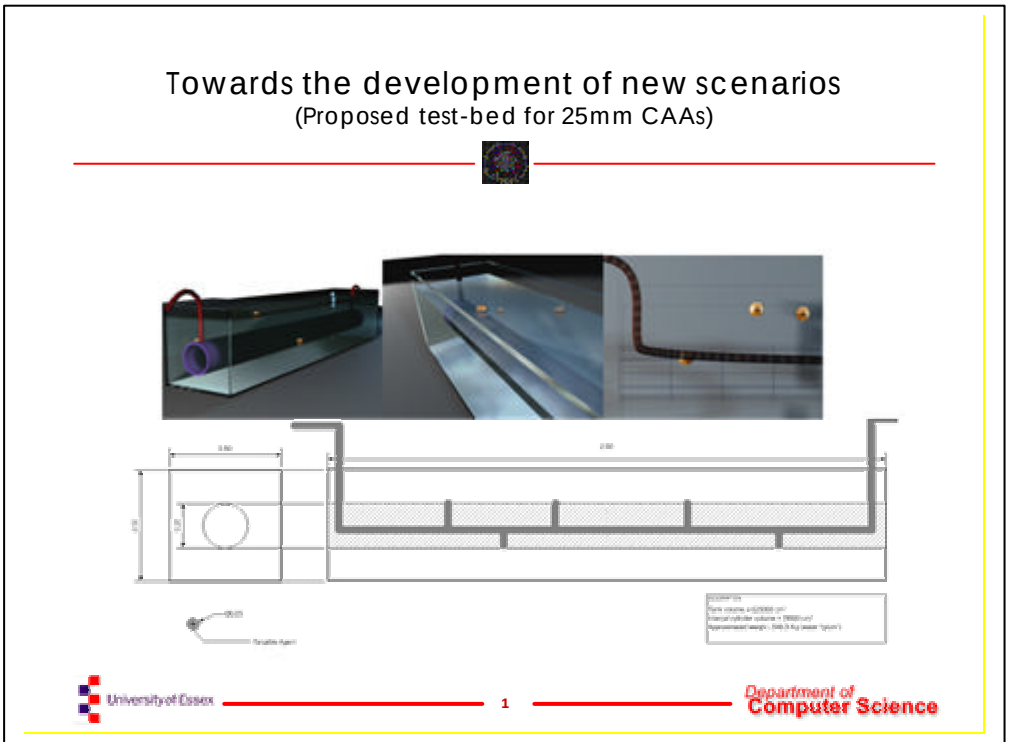
Whilst wanting to be able to control your own domestic environment, you would want to be able to ensure that no one else has the same level of access.

> ***Story #3****: "Mala felt as if she was being observed, which she was, but she knew about that and had purchased a home control model that left her in command, anything she didn't like she could remove. Furthermore the local gateway came with a guarantee that information gathered on her behaviour could never be accessed by a third party. She had had to pay a small premium for this but it was worth it. Perhaps it was her medicine that was causing this mild paranoia she wondered and took a pill to increase her serotonin levels. She had been put on a course of agentX "programmable" pills funded by her health care policy a few weeks ago. AgentX pills were the ultimate in silicoan designer pills; they were in fact nano-scale agents that were injected into the body to repair problems (in her case to seek and destroy fatty deposits clogging her arteries). The much advertised advantage was that the agents provided feedback on what they found, and could either reprogam themselves, or be reprogrammed by specialists Avoiding an opertion was something Mala liked. What she didn't know was that the agents also recorded other (wider) biological data from within her body primarily aimed at providing better analysis to improve the treatment she was receiving, together with helping the scientist improve their technique. This was all perfectly legal as the small print of the agreement, which Mala hadn't read, detailed such possibilities preparatory to major (expensive) surgery. Unfortunately for Mala this wasn't the end of it. If during the period she was on the course of agentX pills she ignored the strict regime the doctors had spelt out for her – and provided written confirmation of – she could be required to pay for the treatment herself because of her flagrant abuse of the contract between her and the health firm. There was work afoot to try to stamp out such arrangement but there was little success now that the cost of nationally provided health care had reached such exorbitant levels that cheap health care alternatives were flourishing and firms needed such data to counter litigation claims where patient themselves were liable for not following faithfully the direction they were given.*

The nature of risks and concerns may differ between situations and are not always obvious (e.g. whilst access to a refrigerator might not seem like a security issue, the secondary information it projects about whether the occupant is at home might pose a significant risk of burglary). Thus, in general, strong security measures are necessary because in a society where computer hacking and spam are such a widespread nuisance and danger to the continued development of such systems we need to be able to guarantee levels of privacy and security for this technology to be accepted and effective. One major security problem since all these systems will be dependent upon electrical power of some sort is the failsafe setting for the systems should there be a widespread power outage. Clearly, the desired failsafe would be the return to whatever mechanical normal operation

was in place before PICT. Otherwise people could become trapped in their own homes and unable to get out. However this also goes to illustrate that in the future the importance of infrastructural provision of power will be at a premium and reinforces the notion of the interconnectedness of all these systems. Novel autonomous ways of producing power will be at a premium with the development of autonomous PICT based systems. Technology is not just limited to PICT we can physically see, but also those PICT systems physically so small they are invisible to the human eye - nano technology. The EU Future and Emerging Technologies programme's SOCIAL project illustrates this issue well. It is addressing the development of free-moving nano-scale agents that can carry out tasks such as floating in kidney dialysis fluids cleaning filters. It is possible to imagine such nano-agents being injected into the body to fix defects without the need for traditional operations. Whilst there are persuasive arguments in favour of human centric control of pervasive computing technology, there clearly are areas of it, such as this, where it is both necessary and beneficial to deploy autonomous agents. This leads to the hybrid notion of "adjustable autonomy"; altering the balance of human versus agent control to suit the situation. Later in this paper we discuss the issue of self and political regulation of this technology.

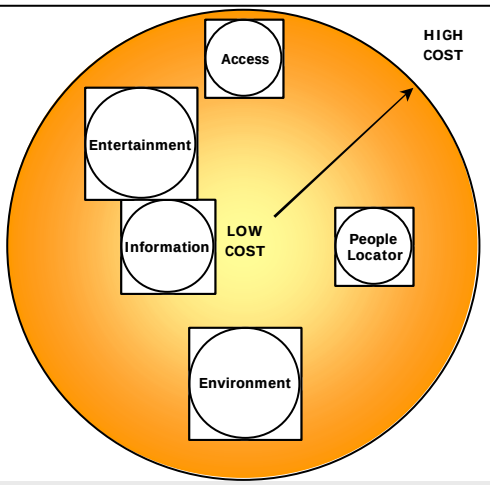
In the same way that the Internet contains its own security measures, there is no doubt that a system such as the one described here would require robust security. The doubt that is left is who is to be trusted with such security? It is hoped that with the open consumer market that the service based approach provides, it will be up to the consumer to decide on whom they trust and with what. However, the opportunities to commercial and governmental interests to underwrite security would also potentially open up these systems to data mining for these vested interests so there is little doubt that security will be a number one priority if privacy is to be achieved, and the technology is to be accepted by society.



Technology View #6 *Development testbed for micro robots for identification and repair of breeches in pipelines as part of planned development of nano scale robots for kidney dialysis repair.*

3.4 Cost

Pervasive computing systems generally require the sharing of information across a wide area. This area may transcend geographical and personal boundaries such as state, county and national borders. It may be that the mechanisms for providing services and indeed some level of servicing itself will become as much a part of the infrastructure of an advanced society as the provision of health care, education, roads, railways and clean water in today's society. However the social cost of these basic infrastructures is not being met totally out of the public purse in most countries now but depends upon their commercial exploitation to supplement governmental support. With this in mind, how could the system of providing services across networks be made financially manageable? Initially it would seem that with so many different financial interests included in the scope of an individual's movement, (from home to office, local town and different state or country) the problem of creating a fair system of billing seems very difficult. However, there are examples where a similar situation exists cf. the Internet and mobile phone networks. In ways similar to satellite television, different "packages" might be offered at different prices. These enable the user to access a subset of services in the same way that different satellite packages enable access to different channels (Sky, MTV, etc.). These packages would be charged at a fixed cost at regular intervals (similar to line rental with a phone company) and the range of costs within the different services is represented in the diagram by the diameter of the service sphere. Different companies can offer different packages to suit the needs of an individual or group and can charge for these services individually. The example packages in the diagram include "environment" which could involve the ability to control the environmental conditions in the user's home or office. It also includes "entertainment" which could mean access to certain entertainment media such as television, cinema or certain restaurants, depending on the level of service that is purchased. There is a problem of difference in income leading to difference in education, privacy, level of service etc, if ability to pay determines everything. Which in the context of current health and education systems becoming increasingly privatised the fear is that this will reinforce the already two (or more) tiered system and will lead to the rich having access to everything they want and the poor having nothing.



Technology View #7 *Increasingly in the future services provided across the internet or similar will be of crucial importance to the well being of everyone. Some of these services might be provided as of right but others will be subject to a charge of some sort. Who pays for these services, how much they pay and the wider consequences for ordinary citizens will be of sianificance in the future.*

4.0 Regulation of Pervasive Computing

If we are to live in pervasive computing environments, then questions like "who has control?", "what is the extent of their control?", "who has access to sensory data from our home, what use are they making of it?" etc. In short how are people going to be protected from the potential ravages of commercial or governmental powers based upon technology of this power? Whatever the official answers to these questions, how can lay people be sure that any assurances they are given on access and use of data gathered in the home is being complied with, and that there is no misuse by subversive organisations, individuals or perverts? Various fictional works ranging from the building orientated "The Tower" and "Demon Seed" (the latter involving Julie Christie being terrorised and forcibly inseminated by a rogue computer!) to the more wide ranging tale "2001" (describing in part how the advanced computer HAL in control of a spaceship decides that people are a danger and must be eliminated) [Clarke] raise some of the philosophical and moral dilemmas faced by designers of such systems and, in particular, the need for citizens to have a hand in framing the rules that govern their operation.

Undoubtedly the highly specialised and technical nature of pervasive computing makes it hard for the individual to understand the entirety of the vulnerabilities he faces, and makes it difficult for him to have confidence in any technical tools that supposedly protect his privacy. Whilst government legislation and self-regulating computers might go part of the way to providing assurance to the individual, the ultimate assurance to an individual relies upon his understanding of the issues, and the provision of tools he can understand, use and trust to protect him. In our mind there is much work to be done in relation to educating the population on the issues (both good and bad) relating to emerging technology and even more work to be done to provide trustworthy and transparent tools for the user to help himself. We suggest that the scientist who are busy developing this new technology should put some effort into developing such tools, as without trust by the general public, the full market potential of such technologies will not be realised. Thus it is in the best interest of companies seeking to build these market places to address these concerns by funding work on all aspects of the issues that give rise to public concern about the dangers of pervasive computing. In the following sections we discuss some of the issues relating to regulation.

4.1 Self-Regulating Technology – Beyond Asimov's Laws

Isaac Asimov explicitly addressed the problem of self regulating technology in his "I Robot" book series [Asimov] (recently released as a movie by 20th Century Fox) in which he proposed a set of three rules designed to protect humans from the robotic technology they created. These rules can be summarized as "1) Protect Humans, 2) Obey Humans and 3) Protect Yourself". Although not without flaws these have since become widely accepted within mainstream science as providing a well founded moral framework for a society of robots and humans [Clark]. What should be the equivalent laws for pervasive computing, which arguably involves a more intimate relationship between the individual and machine world? Would Asimov's Laws of Robotics suffice for pervasive computing controlled buildings and vehicles?

Technology View #8 *The 20th Century Fox movie inspired by the short story collection by Isaac Asimov. In the year 2035, robots have become everyday household items, trusted by everyone, except one person (Will Smith)*

In previous work, we have argued that pervasive computing controlled buildings (so called Intelligent-Buildings) can be regarded as robots we live inside [Callaghan]. From this, one may draw a parallel that the role of a robot is likened to that of pervasive computing devices. The particular nature of pervasive computing supported buildings is that they are often expensive and multi-occupant dwellings. This raises moral issues such as the rights of individuals versus a society of occupants or indeed an owner. For instance, should an individual member of an urban dwelling be allowed to take an action such as reducing the temperature below freezing point, which may have some benefit to him, but severely damages the building or put a company (i.e. not a person) and all its human dependents out of business? Clearly the relationship between a person, a dependent community of people, a 'robotic building' or a robot is of a different order, the former being *self-reflexive* rather than hierarchical or separable in simple terms. This raises many difficult issues that are not explicitly addressed by Asimov's Laws of Robotics.

Story #4*: "Xavier works as a porter in the first of the orbiting hotels – the Space Hilton. He works for three weeks on with relatively short periods off during any one day – if you aren't on holiday space can be very boring. He then has a weeks 'shore' leave when he comes back to his hometown of San Diego. Here he lives in one of the greatest conurbations of predominantly Hispanic peoples known to man - Los Angeles Mayor. Since the rich started to withdraw from normal urban life these areas have become even more dangerous than they used to be fuelled as they are by drugs and local rivalries in a megalopolis of over 200 million people – a loose confederation of thousands of gangs and small time crooks who have some purchase in their own areas but little power or influence outside of that. Hi-tech surveillance of these communities is at a minimum though they are savagely policed by a heavily armed militia style police with hi-tech equipment. Attempts to have all citizens tagged earlier on in the century failed so only people like Xavier who work in prestigious areas of great delicacy are visible to the constant sweep of the detectors over the dark and threatening city/state. Xavier doesn't care that he is being monitored, he is no threat and he is used to having everything he does night or day monitored. There is no alternative in the Space Hilton, there is too much at stake! You get used to knowing that everything you are doing is being observed explicitly or implicitly by someone or something. So far there have been no terrorist attacks on the orbiting hotels thanks to the high levels of security and the total absence of privacy, but no one is complaining."*

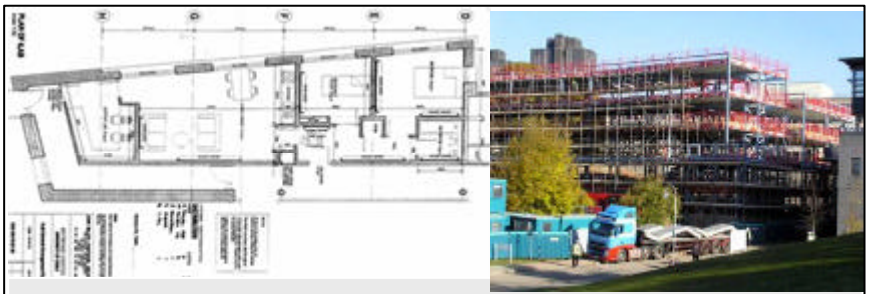
We argue that Asimov's Laws refer to an ideal world where machines have the ability to interpret and execute such rules or laws. However, this is clearly impossible as present - machines (or pervasive computing devices) are simply not advanced enough. For instance, they cannot adequately mediate differences of opinion amongst occupants, or make judgments on flimsy

evidence part-human, part physical science (e.g. an individual making a destructive adjustment to the building that he claimed would be to some greater good of the stakeholders). Such judgments are difficult even for us and would necessitate highly advanced knowledge and artificial intelligence techniques not currently available. However, whilst engineers do not have sufficiently sophisticated technology to fully implement Asimov's Laws, each time they build an agent they implicitly implement a set of rules that determine its operation; these can be explicitly compared with these Laws.

The pervasive computing devices we are developing at Essex University [Chin03] [Callaghan], [Hagras], [Doctor] are rule based systems. In these, there are rules implicit to the design of the rule mechanism that are the equivalent of Asimov's laws. Looking at our current work in this light we can derive the following set of (implicit) Essex pervasive computing laws:

1. *Do not violate any safety constraints set by law or the manufacturer*
2. *Do not violate any privacy constraints set by user of the environment or community (providing safety constraints are not violated)*
3. *Accept instructions (including configuration and training) immediately from the stakeholders of the environment) (providing safety and privacy constraints are not violated)*
4. *Preserve the pervasive community (providing all the above are not been violated)*

The first law is aimed at ensuring user safety is paramount. Rule two aims at ensuring that access to the system is safeguarded so as to rigidly adhere to the user's wishes. The third law aims at allowing the user to particularise the pervasive environment to satisfy his individual need. Commonly this is undertaken in either a teaching or learning mode. The forth law aims at making the pervasive system as robust and reliable as possible. For example if a member device fails, the community of devices immediately seeks to find a replacement device, and thereby maintain the operation of the overall system. Far from regarding these as ideal long term laws, we see them just as a short term pragmatic approach to allow us to build pervasive computing environments from today's technologies whilst we are awaiting the arrival of more advanced processes and better established 'laws' based in widespread use.



Technology View #9 *A new apartment-based intelligent inhabited environment is being built at the University of Essex to allow for experiments based upon the sorts of approaches to PICT described above. This should provide an international test-bed for research into the areas of PICT discussed in this paper.*

5.0 Government Regulation

What then are the issues for today's society and law makers to consider? Clearly, unless society takes a hand in framing such laws it will be left to small vested interest groups and commercial

companies to construct rules to their own ends. Thus, at a minimum, such issues should be widely known and debated within society. Such a discussion would be interesting as investors may argue that any fundamental rules of machines should reflect the need to protect them (as investors, as companies etc) whilst individuals and various social political groups would surely make very different arguments.

> ***Story #5****: In Europe the take up of PICT was much slower than in the developing world. There was a built-in inertia in terms of the existing investment in technology which the developing countries didn't have. They had no need to consider the cost of replacing a technology they had already invested heavily in since they were leaping from a mainly pre-industrial to an advanced industrial technical civilisation within a generation. Furthermore, the complex legal and cultural traditions of Europe, developed over millennia, were proving to be an impediment to the development of PICT technology and the European Court of Human Rights was bogged down in a backlog of sensitive cases on the issue of privacy. Old fashioned ideas about privacy and ownership and 'civilised' values were acting as a brake on the full development of PICT within Europe. By the end of the first quarter of the 21st century the really dynamic economies were all in Africa and Asia. With their massive built-in markets they had no need for 'the West' and without the encumbrance of a deeply established technical infrastructure they were free to take up the PICT vision enthusiastically. Not being burdened by the 'advanced' notions of individuality that were also symptomatic of 'the West' these cultures had less internal opposition to, and paranoia about, a technology that asked little but gave much. It was the community, not the individual, that was the fundamental unit within these cultures.*

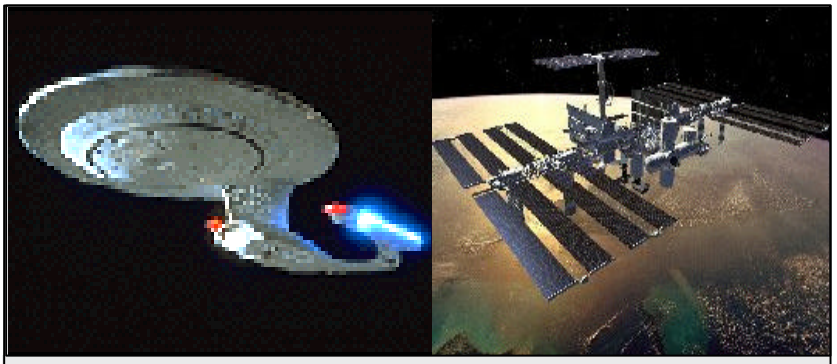
It is possible in the future that much of the Health and Safety legislation will be actively embodied within the bounds of allowable operation of a building rather than sitting in a statute books gathering dust. If there is no regulation then there are immense dangers that the technology will get misused by various groups with their own agendas. For instance, individuals might tap into sensed home data to find out information on home owners such as whether people are at home, what valuables they have etc. Detective agencies might gather evidence for marital disputes and this technology might enable a new and more sinister form of stalking to develop. Companies might seek to gather information on people's behaviours to enhance their products, or to sell the data to third parties to mitigate the costs of their services (and increase their profits), and government agencies might gather evidence of fraudulent tax or disability claims etc. It is also only to possible to imagine extremist organisations, or governments, using the technology to develop terrorism or create a police state. The opportunities for misuse of this technology are almost endless. Likewise, whilst most of this discussion focuses on the dangers of abuse of this technology, it should not be overlooked that it offers immense political and commercial opportunities to enhance our quality of life and government, providing the dangers discussed are avoided.

Of course, there are parallels to other technologies such as the internet and mobile phones. Experiences with these have revealed that there are additional problems such as the distributed and international nature of the services and providers which means it is difficult to frame laws that work as the violators may be operating out of countries, using network connections, where there are different laws and which make it almost impossible to enforce. In this respect, as with climate change, international organisations such as the UN would seem to be perfectly placed (and maybe the only organisation with the capability) to frame and enforce such legislation.

The development of international institutions run under the auspices of the UN may turn out to be the only alternative to the potential chaos of individual states and corporations finding loopholes in national laws.

6.0 Future Urban Habitats - Communities in Space

As we move into the longer term future (beyond 2020) we will become even more dependent on technologically supported environments. For example, as mankind ventures outwards, towards habitation of other planets, people will need to live in permanent space stations, planetary colonies or in spacecraft engaged on inter-planetary journeys. In these the social and other constraints are simplified as the absolute dependency upon each other and the environment is highlighted.



Technology View #10 *The International space station is the forerunner of mankind's ambition to inhabit deep space as is portrayed by may sci-fi stories such as the NBC production of Star-trek (created by Gene Roddenberry) which contains many interesting visualisations of future inhabited intelligent environments*

We are all of course dependent, to some degree or another, upon others in our daily lives and many of us experience the pleasures and support of working within relatively close functional communities, many of which overlap e.g. family and work communities.

With the space colony, in some form or another, we will be moving into an experimental community of an entirely different order of magnitude in that it will need to be reliably autonomous and self governing at all the levels of critical safety, although individuals will probably still retain a strong desire to personalise aspects of their habitat. Functional authority rather than rigid hierarchy, a sense of community that is both practical and durable, a means of resolving conflict and reaching agreement without schism and so on are going to be of the highest priority in off earth urban habitat. This interdependence and local autonomy are qualities that will be shared by both the social and the technological organisation of the community.

The need to be able to see things for what they are and not transfer deep pathologies into space with us means that the selection of personnel and their continual support within the communal practice of the vessel, colony or space station is going to have to be addressed. Although, currently, space habitation is managed via a clear line of hierarchical control, for the longer term the metaphor of a community of distributed co-operating pervasive devices and agents, without any obvious hierarchy is precisely the sort of model that these new and demanding circumstances might require. Space is an interesting example where inhabitants of an urban planetary habitat might

realise that mutual dependence, tolerance and respect is much more likely to engender a robust and flexible community separated, as they will be from immediate help from Earth and dependent upon their own communal resources for survival [Clarke]. It is certainly true that the exploration of space will require us to look at ourselves and the ways in which we can work together in groups to achieve our common aims. We will be required to do this in a way that has rarely been asked of us before and with a range of tools and theories as to the social nature of human beings that are still being developed. This might enable us not just go to other planets and found new colonies but in a genuine sense, to found new societies.

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