The Reconfiguration of the Personal Environment

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INTRODUCTION

The rapid proliferation of building environmental systems over the course of the twentieth century eventually prompted two responses from the architectural community during the 1960's and early 1970's. The first was the inevitable aesthetization of the mechanical componentry, given that this service equipment often usurped up to a third of a building's volume. From Louis Kahn's service towers in the seminal Richards Medical building to Richard Roger's service envelope for Lloyd's of London, the functionality of the systems had been progressively backgrounded as the iconography of their componentry had been fetishized. The second response was the intellectual critique of this willful exploitation of the architectonic features of equipment which possessed neither an architectural lineage nor any requisite relationship with the building form. Visionary projects from the Situationalists—Superstudio and Archigram—portrayed a future in which human environments would no longer require static enclosures, and Reyner Banham suggested "that if dirty old Nature could be kept under the proper degree of control by other means, the United States would be happy to dispense with architecture and buildings altogether."[1] Anathematic to both responses was the concept of the discrete or personal environment. This was a thermal environment that was intended to be centered around an individual, and ultimately transportable, ideally cloaking each person in his/her desired and possibly unique conditions. The inherent discretization of the personal environment precluded the use of systematically distributed, universal components, necessary for the production of a coherent language to facilitate the former response. For the proponents of the latter response, the personal environment represented not only the demise of architecture but the portent of societal disintegration. Cedric Price, in describing what he called "ECHOES" or "Environment Controlled Human Operational Enclosed Spaces" warned that they "must not become yet another post-justificational reason for anti-social congregation."[2]

The rise of the personal environment, however, was unchecked by the internal discourse occurring within the architectural community. Commensurate with the relegation of mechanical equipment to iconographic building elements was the industry's transition to less effective environmental systems. The Arab oil embargo of 1973, with its resulting energy shortages, changed virtually overnight the attitude towards environmental control, as, suddenly, every building seemed to have an oversized system. The generous quantities of conditioned air supplied continuously by the previous standard—the Constant Air Volume (CAV) system with its redundant secondary systems—were summarily replaced by the penurious meting out of the Variable Air Volume (VAV) system. Many of the load variations that had been compensated easily for in constant volume operations, such as thermal mass swings and transient occupant dependent loads, became nearly insurmountable obstacles. Joining the widespread implementation of VAV systems were a host of other energy conservation measures which further exacerbated thermal load variability: peak demand scheduling, duty cycling, economizer operation, occupancy determined lighting and night time shutdowns. As a result, the environmental system of the mid-to-late 1970's was providing interior conditions that were much less comfortable than systems of the previous decades, at precisely the time when the extravagant exposure of these systems by architects was reaching its pinnacle. The energy crisis eventually subsided, interest in the architectonic expression of the componentry waned (along with its accompanying criticism), but the degraded interior environment remained. The personal environment emerged as the most plausible solution to controlling energy while providing comfortable interior conditions.

ZONAL PERSONAL ENVIRONMENTS

The initial conceptual approach to the personal environment simply conceived it as analogous to and subordinate to the overall building environment. In the typical perfectly mixed homogeneous environmental system, conditions at any one location within a space can only be maintained if the entire space is conditioned to the same specifications. When energy conservation objectives dictated a reduction in air exchange, the personal environment emerged as a strategy to compensate for poor air quality in certain locations. Discretization takes place through zoning, and although discrete zones may have different setpoints and responses, all of the mechanical equipment is nevertheless integrated into an overarching system. This type of personal zone within a custodial environment is exemplified by the image of the TRON project: "from the moment that an employee arrives at work, the building's distributed systems will recognize him, open doors for him, serve him refreshments and make sure that both temperature and humidity in the workplace are just the way he likes them."[3] Manifesting such a personal response, however, requires the installation of subordinate equipment, which in turn necessitates restricting individual movement. The most popular of the commercially produced "zones" is the workstation based personal environment. From the most basic provision of supplementary desktop air supplies to fully contained office cells with their own controls, these workstation environments share the primary objective of compensating for the diminished air exchange resulting from overall system cutbacks for energy savings, and the secondary objective of enabling some local temperature adjustment. The inherent problematic with these systems is that they are both mated with and modeled after large scale distribution systems, but they lack the volume and distances necessary for proper distribution and mixing. As a result, even though workstation systems can improve local air quality, they often require constant adjustment by the occupant to maintain comfort. And of course, the air quality is only acceptable as long as the individual remains within a confined zone. More recent zonal environments have begun to move away from fixed individual spaces to more generic occupied zones in which individual control is sacrificed for freedom of movement. Nevertheless, both ends of the zonal spectrum significantly increase the integrational complexity of the overall building environmental system, and both still require additional energy in order to improve local conditions.

TRANSPORTABLE ENVIRONMENTS

Counter to the zonal approach is the transportable environment. In this approach, there is no overarching system for the ambient environment. The transportable environment eveloped directly from the space program's environmentally contained suits for astronauts, and it has veered little from its precedent's conceptual basis as a "wearable" environment intended to protect the wearer from a hostile surrounding environment. Phase change systems were originally considered to have great promise as they do not require electromechanical equipment and they can often be easily recharged in the field. The least sophisticated of these systems consists of garments constructed of water absorption materials; these garments are simply soaked in water and worn, cooling the body as heat is extracted for evaporating the water. More common application has been for direct body cooling by enveloping part of the body with a chilled substance, which may or may not be recharged. In its simplest form, pockets in garments surrounding the chest cavity are filled with ice or gel packs. The life of these packs is proportional to their weight, such that a reasonably weighted garment will provide cooling for no more than two hours before requiring replacement or recharging of the packs. In contrast, highly sophisticated "umbilical" systems developed for the military do not require recharging as they include local compressors or chillers. The garments for these systems are constructed of layers of channels through which chilled air or fluid is continuously circulated. True portability requires a battery pack, thus still adding substantial weight and restricting deployment time. Convinced that this transportable environment will be *de rigueur* equipment for future military personnel, the US Defense Department is concentrating on the development of microgenerators to replace the battery packs.[4] Although many of these strategies are finding application outside of hostile environments, particularly for medical needs, all of the transportable environments are limited by the requirement that the individual must carry, wear *and* maintain them.

TWENTIETH CENTURY DEVELOPMENTS IN HEAT TRANSFER THEORY AND TECHNOLOGIES

These two modes of the personal environment, the zonal and the transportable, have been unable to transcend their positioning as integration intensive secondary systems or idiosyncratic responses and move into a primary role in environmental conditioning. The concepts behind the existing personal environments, as for the standard systems, are based on both old technology and old theory. The prototypical environmental system is use today was born from experiments conducted in the nineteenth century and is based on a strategy that was last substantially modified in 1904. Heat transfer and fluid mechanics—two of the primary disciplines comprising mechanical engineering—were the last branches of classical mechanics to develop theoretical structures that could adequately explain empirical behavior. These theories were not in place until 1920, and not readily applicable until the 1960's. Although one more commonly associates supersonic flight and nuclear power generation with these new theories, the characterization of air behavior has also undergone a significant reformation from anecdotal descriptions to specific predictions that can track the movement of single molecules. The microelectronics industry was among the first to take advantage of new analytical methods for describing air behavior, using them to reconceptualize the heat exchange between a computer chip and its surrounding air. Further miniaturization of computer chips has been constrained not by silicon manufacturing technology, but by the inability of the assembly surrounding the chip to effectively shed its heat. Similar to the personal environments that developed for humans, numerous discrete environments were developed for microelectronics assemblies including cryogenic coolers and high velocity air nozzles. The breakthrough occurred at the beginning of this decade when it was demonstrated that heat transfer coefficients were readily manipulable, allowing control not only of *how much* heat an entity transferred, but *where* that transfer takes place. Although the human body within an architectural environment is clearly of a much larger scale than a microelectronics assembly, current research investigating thermal behaviors in rooms demonstrates similar results.[5]

Commensurate with the unprecedented development of the theoretical structure, the applicable technologies have transformed as microelectronics have supplanted mechantronics. In place now is the understanding that the thermal environment is better conceptualized and *controlled* as an ensemble of discrete thermal behaviors rather than coerced into homogeneity through high velocity mixing systems. Indeed, displacement ventilation strategies, in which cool air is delivered at floor level, depend upon thermal discontinuities to enhance air quality. Rapidly developing are a host of mini and micro energy conversion devices building upon already feasible mini-heat pipes, micro-evaporators, microcondensers and micro-compressors, many sized from under two centimeters to 100 microns (compare with a human hair which has a diameter of around 70 microns). In 1994, MEMS (microelectromechanical systems) researchers throughout the country were scrambling to produce the first commercially viable micro-heat pumps for environmental system air conditioning. The micro heat pumps were clearly feasible, as early prototypes were capable of transferring heat flux up to 1 watt/sqcm, and projections were that, by 1997, the capacity would reach 100 watts/sqcm.[6] During 1997, however, micro-heat pump development programs all but disappeared. Researchers had far exceeded their objectives in the capacity of the heat pump, but had concluded that application for building environmental control was impractical. The primary concern was that the heat pump was too small physically to overcome the viscous effects of air in order to provide homogeneous conditions in large volumes.[7] Regardless of the extraordinary possibilities afforded by discrete and direct manipulation of thermal behavior, the application of this new technology has been constrained by the "requirement" that the interior environment must maintain its current configuration.

THE PROBLEM OF THE PERSISTENT PRECEDENT

Discrete systems are becoming available that will allow discrete control. Yet, environmental systems designers have chosen to bypass the theoretical and technological underpinnings of the mechanical engineering profession's twentieth century redefinition in deference to a hegemonic precedent of the interior environment that was established in 1904. An appropriate analogy might be to consider that the attempt to homogeneously control large volumes of air in order to manage the thermal comfort of a human body as being similar to attempting to make an airplane fly by controlling all of the conditions of the surrounding atmosphere rather than of its boundary layer (and, indeed, even airplanes have been adopting MEMS: micro-flaps, sized under 50 microns, on the skin of aircraft reshape the boundary layer to inhibit eddy formation, thereby significantly reducing drag[8]). The theoretical, analytical and technological impediments to establishing direct thermal mitigation of the human body are being lifted. Why, then, has a near-century old precedent maintained a hegemonic dominion so pervasive that it has quelled any substantial research into new paradigms?

DEVELOPING A NEW PRECEDENT FOR THE TWENTY-FIRST CENTURY

Precise control of heat transfer would provide much more than reliable determination of surrounding air temperature and humidity. Local velocity and transport of particles can be manipulated to manage air quality. Much of the energy cost associated with environmental systems can be attributed to the amount of fresh air that must be introduced in order to maintain acceptable levels of carbon dioxide within homogeneous volumes of air. Small interventions can, however, selectively redirect specific gases or particles. Among the first applications being investigated for micro-heat transfer control are in the medical field. Many bacteria, including tuberculosis, respond quite readily to individual redirection, and current simulation efforts are exploring the use of interventions as simple as small halogen lamps to provide the thermal discontinuity necessary for improving the efficacy of contamination control in facilities, such as homeless shelters and halfway houses, which often have substandard ventilation systems.[9] The implications are far-reaching: the ability to directly control air composition and locally control thermal conditions could eliminate the need to condition vast volumes of air, a process which serves only to dilute contaminants and diffuse heat. The gross inefficiency of existing environmental systems stems from the necessity to use a common distribution stream to control both air quality and thermal conditions, which are irreconcilable requirements when coupled with energy conservation goals. The discrete and local control that will be afforded by new technologies operating under new theories will adhere to the underlying, and previously unachievable, objective behind the sustainability initiative: protection of the future while providing a better quality present.

The personal environment may then become the definitive environmental system of the next century. But this will be a very different environment than the monadic shell which critics warned against and which the military has invested in. Rather than isolating the individual from the surrounding environment, or restricting one's movement to locations where the systems have been "beefed up," the microtechnology driven environment will dynamically interact with the occupants and the architecture, cooling the body by enhancing its heat transfer coefficient, shedding loads of walls and roofs before they heat up the ambient air, selectively "freshening" the air in the breathing zone. The personal environment will more accurately become a "local" environment, and the architect may finally have the opportunity to *design* that environment rather than be relegated to integrating the entrails of an archaic system.

NOTES

1 Reyner Banham, "A Home is not a House," in Charles Jencks and George Baird, eds., *Meaning in Architecture* (New York: George Braziller, Inc., 1970), p. 111.

2 Cedric Price, "ECHOES," AD 10/69, p. 552.

3 Robert Patton, "Office romance (TRON Hyper Intelligent Building)," *Scientific American* 270 (1994): p. 110. The article additionally stated that the first TRON Hyper Intelligent Building would be erected in Japan within three to four years from the article's publication date.

4 Cited from a presentation delivered by Alan Epstein of MIT's Gas Turbine group at the monthly meeting of the Boston Area Microelectromechanical Systems Seminar held in Cambridge, MA on 27 February, 1997.

5 Heat transfer coefficients for building components—particularly walls and roofs—have always been assumed to be constants for a given material and constructional cross-section. But boundary layer modification can dramatically effect the heat transfer coefficients. As an example, the R-value of any given window or wall assembly can be reduced by a factor of two if a discontinuity is introduced into the boundary layer. Human bodies, as well, manifest a similar convective boundary layer as vertical surfaces. The key to allowing this control is the elimination of high velcoity mixing systems that actually increase the energy consumption in a space. See Michelle Addington, "Boundary Layer Control by Characteristic Length Manipulation," in *Proceedings of the Third International Thermal Energy and Environment Congress* (Marrakesh, Morocco, 1997).

6 Cited from Robert S. Wegeng and M. Kevin Drost, "Developing new miniature energy systems," *Mechanical Engineering* 116/9 (1994). Conversations with the authors in 1996 confirmed that capacity had reached 25 watts/sqcm, and 100 watts/sqcm is a well-accepted figure.

7 Discussions at meetings and telephone conversations with various researchers, including the Pacific Northwest Laboratory development team for the Department of Energy, all indicated this same concern. When queried as to why they were trying to use these discrete pumps to create the same conditions as large systems, they generally responded that their task was to improve energy conversion for existing environmental systems, not to challenge the strategy of environmental conditioning.

8 Parviz Moin and John Kim, "Tackling Turbulence with Supercomputers," *Scientific American* 276/1 (1997): p. 67.

9 The most effective means for killing tuberculosis is to expose the bacteria to ultraviolet radiation. Many research facilities and hospitals have ultraviolet chambers built into their ventilation systems. But tuberculosis is most on the rise in locations where sophisticated ventilation systems are neither available nor feasible. Currently being tested are ultraviolet kill zones within rooms above eye level. These are 100% effective only if the bacteria reaches this zone. Supplemental fans are being investigated, but among the most promising, and certainly the easiest, intervention may be provided by a distributed grid of lamps. See also Michael Valenti, "Lighting the way to improved disinfection," *Mechanical Engineering* 119/7 (1997): p. 86.