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BOUNDARIES/NETWORKS

Consider, if you will, Me++.

I consist of a biological core surrounded by extended, constructed systems of boundaries and networks. These boundary and network structures are topological and functional duals of each other.[1] The boundaries define a space of containers and places (the traditional domain of architecture), while the networks establish a space of links and flows. Walls, fences, and skins divide; paths, pipes, and wires connect.

BOUNDARIES

My natural skin is just layer zero of a nested boundary structure. When I shave, I coat my face with lather. When I'm nearly naked in the open air, I wear—at the very least—a second skin of spf 15 sunblock.

My clothing is a layer of soft architecture, shrinkwrapped around the contours of my body. Beds, rugs, and curtains are looser assemblages of surrounding fabric—somewhere between underwear and walls. My room is a sloughed-off carapace, cast into a more rigorous geometry, fixed in place, and enlarged in scale so that it encloses me at a comfortable distance. The building that contains it has a weatherproof exterior shell. Before modern mobile artillery, fortified city walls would have provided a final, hardened, outermost crust; these sorts of urban-scale skins remained reasonably effective at least until the 1871 siege of Paris, during the Franco-Prussian War.[2]

In the early years of the Cold War, outer defensive encasements reemerged, in extreme form, as domestic nuclear bunkers. The

destruction of the Berlin Wall in 1989 marked the end of that edgy era. But still, if I end up in jail, an internment camp, or a walled retirement community, the distinction between intramural and extramural remains brutally literal. If I retire to a farm, a boundary fence stops my stock from straying. And if I locate myself within the homeland of a major military power, I take refuge behind a dubious high-tech bulwark that extends across thousands of kilometers; our extradermal armored layers have coevolved, with increasingly fearsome weapons systems, into invisible radar curtains and missile shields that create vast electronic enceintes. I surround myself with successive artificial skins that continually vary in number and character according to my changing needs and circumstances.[3]

All of my boundaries depend, for their effectiveness, upon combining sufficient capacity to attenuate flow with sufficient thickness. If I want to keep warm, for example, I can use a thin layer of highly insulating material or a thicker layer of a less effective insulator. If I want acoustic privacy, I can retreat behind a closed door, or I can simply rely on the attenuation of sound waves in air and move out of earshot. If I want to create a jail, I can construct escape-proof walls, or I can remove the prisoners to a sufficiently distant place—like the eighteenth-century British convicts transported to Australia. In sparsely populated territories, distance creates many natural barriers, while in buildings and cities, efficient artificial barriers subdivide closely packed spaces.

CONNECTIONS

But I am, as Georg Simmel observed, a "connecting creature who must always separate and who cannot connect without separating."[4] My enclosures are leaky. Crossing the various boundaries that surround me there are paths, pipes, wires, and other channels that spatially concentrate inflows and outflows of people, other living creatures, discrete goods, gases and fluids, energy, information, and money. I am inextricably entangled in the networks of my air, water, waste disposal, energy, transportation, and Internet service providers.

To create and maintain differences between the interiors and exteriors of enclosures—and there is no point to boundaries and enclo-

sures if there are no differences—I seek to control these networked flows. So the crossing points are sites where I can survey what's coming and going, make access decisions, filter out what I don't want to admit or release, express desire, exercise power, and define otherness. Directly and indirectly, I employ doors, windows, bug screens, gates, cattle grids, adjustable apertures, valves, filters, prophylactics, diapers, face masks, receptionists, security checkpoints, customs and immigration checkpoints, traffic signals, routers and switches to determine who or what can go where, and when they can go there. So do you, of course, and so do others with the capacity to do so in particular contexts.

Through the interaction of our efforts to effect and control transfers among enclosures and our competition for network resources, we mutually construct and constrain one another's realms of daily action. Within the relatively stable framework of our interconnecting, overlapping, sometimes shared transfer networks, our intricately interwoven demands and responses create fluctuating conditions of freedom and constraint. And as networks become faster, more pervasive, and more essential, these dynamics become increasingly crucial to the conduct of our lives; we have all discovered that a traffic jam, a check-in line, a power outage, a server overwhelmed by a denial-of-service attack, or a market crash can create as effective a barrier as a locked door. The more we depend upon networks, the more tightly and dynamically interwoven our destinies become.

NETWORKS

The archetypal structure of the network, with its accumulation and habitation sites, links, dynamic flow patterns, interdependencies, and control points, is now repeated at every scale from that of neural networks (neurons, axons, synapses) and digital circuitry (registers, electron pathways, switches) to that of global transportation networks (warehouses, shipping and air routes, ports of entry).[5] And networks of different types and scales are integrated into larger network complexes serving multiple functions. Depending upon our relationships to the associated social and political structures, each of us can potentially play many different roles (some strong, some weak) at nodes within these complexes—owner, authorized user, operator,

occupant, occupier, tenant, customer, guest, sojourner, tourist, immigrant, alien, interloper, infiltrator, trespasser, snooper, besieger, cracker, hijacker, invader, gatekeeper, jailer, or prisoner. Power and political identity have become inseparable from these roles.

With the proliferation of networks and our increasing dependence upon them, there has been a gradual inversion of the relationship between barriers and links. As the ancient use of a circle of walls to serve as the ideogram for a city illustrates, the enclosing, dividing, and sometimes-defended *boundary* was once the decisive mechanism of political geography. Joshua got access the old-fashioned way; when he blew his righteous trumpet, the walls of Jericho came tumbling down. By the mid-twentieth century, though, the most memorable ideogram of London was its underground network, and that of Los Angeles was its freeway map; riding the networks, not dwelling within walls, was what made you a Londoner or an Angeleno. And the story of recent urban growth has not been one of successive encircling walls, as it mostly would have been for ancient, medieval, and Renaissance cities, but of network-induced sprawl at the fringes.

More recently, the unbelievably intricate diagram of Internet interconnectivity has become the most vivid icon of globalization. Now you get access by typing in your password, and IT managers dissolve the perimeters between organizations by merging their network access authorization lists. Today the *network*, rather than the enclosure, is emerging as the desired and contested object: the dual now dominates.[6] Extension and entanglement trump enclosure and autonomy. Control of territory means little unless you also control the channel capacity and access points that service it.

A year after the September 11 attacks on New York and Washington, the implications of this were sinking in. The President's Critical Infrastructure Protection Board bluntly reported (to nobody's very great surprise),

> Our economy and national security are fully dependent upon information technology and the information infrastructure. A network of networks directly supports the operation of all sectors of our economy—energy (electric power, oil and gas), transportation (rail, air, merchant marine), finance and banking, information and telecom-

munications, public health, emergency services, water, chemical, defense industrial base, food, agriculture, and postal and shipping. The reach of these computer networks exceeds the bounds of cyberspace. They also control physical objects such as electrical transformers, trains, pipeline pumps, chemical vats, radars, and stock markets.[7]

Connectivity had become the defining characteristic of our twenty-first-century urban condition.

CLOCKS

All networks have their particular paces and rhythms. Within the nested layers and recursively embedded networks of my world, my pulse—the sound of an intermediate-scale, low-speed vascular network—has been mechanized, regularized, externalized, and endlessly echoed back to me. Just as boundary, flow, and control systems subdivide my space into specialized, manageable zones, these constructed rhythms partition my time into discrete, identifiable, assignable, sometimes chargeable chunks. Bean counters are also minute counters; measurable, accountable time is money.

The miraculously monotone beat of the pendulum first established this possibility.[8] Ancient sundials and water clocks had marked the flow of time, and Benedictine monastery bells had formalized its approximate mechanical subdivision. Clock towers had provided European towns with faster communal heartbeats—essential, as Lewis Mumford pointed out, to the regulation and coordination of social and economic life, and eventually to the industrial organization of production.[9] Then, in the seventeenth century, Christiaan Huygens devised a pendulum clock that ticked precisely.

This innovation also initiated a shift in scale. Furniture-sized towers (grandfather clocks, standing in domestic hallways) soon began to associate timekeeping with the dwelling and the family rather than with the town and the larger community. Substituting spring-driven mechanisms for pendulums allowed clocks to become even smaller, more portable, and eventually wearable—now associating timekeeping with the individual.[10] Timepieces moved to pockets, then to

wrists—provocatively, the organic pulse's most obvious point of presence. Clinging tightly to flesh, they have enabled the large-scale scheduling and coordination of individual activities; during the American Civil War, for example, the Union forces depended upon them to synchronize operations.

As artificial pulse rates have accelerated, timekeeping mechanisms have continued to shrink. Today, the gigahertz, crystal oscillator hearts of tiny computer chips are embedded everywhere. (Chips without clocks are possible, and may turn out to have some important advantages, but they are not yet in widespread use.)[11] Electronic vibrations subdivide seconds into billions of parts, pace the execution of computational tasks, discipline our interactions with computational devices, calibrate GPS navigation systems, regulate power distribution and telephone systems, measure and commodify both human and machine work, and precisely construct the accelerating tempos and rhythms of the digital era—coordinated, where necessary, by a central atomic clock.[12] They not only *mark* time, they *trigger* the execution of instructions and programs. Seconds, milliseconds, microseconds, nanoseconds, picoseconds: the electronic global heartbeat keeps quickening and gathering power—so much so that, when its coordinated microrhythms threatened to falter at Y2K, there was bug-eyed panic in the technochattering classes.[13] There was talk of "spectacular explosions, nuclear meltdowns, power blackouts, toxic leaks, plane crashes, and bank failures."[14]

PROCESSES

But there is, of course, more to the construction of time than the increasingly precise subdivision of the day. As clocks multiply and distribute themselves spatially, the relationships among them begin to matter.

Different places may simply run on their own clocks, or their timekeeping systems may be standardized and synchronized. When there was little communication between spatially separated settlements, local time sufficed, and there was no need for such coordination, but linkage by long-distance railroad and telegraph networks eventually made it imperative. In 1851 the Harvard College

Observatory began to distribute clock ticks, by telegraph, to the railroad companies. As transportation and telecommunication capacities have increased, we have entered the era of globalized network time—of GMT, time zones, and sleep cycles decoupled from the solar day.[15] Once, villagers rose with the roosters to work until sunset in nearby fields; now, jet-lagged business travelers do their email at three a.m. in hotel rooms far from home.

Computers have added additional layers of complexity to the construction of time. The first computers—constructed according to the elegant principles of Turing and von Neumann—were strictly sequential machines, executing one operation at a time; programming was a matter of specifying these operations in precise order. Everything was rigorously governed by clock increments and finite (though small) durations. But as interactive computing developed, a distinction emerged between tasks that could be performed in "real" time and those that could not. For example, computer animations of three-dimensional environments could be computed and stored for later playback, or (as in today's video games) they could be computed and presented on the fly, with no perceptible time lag. In other words, if you take advantage of fast machines to compress processes, you can elide the distinction between simultaneity and sequence. "Virtual reality" would be impossible without this.

The practice of timesharing has produced a further elision. If a processor is fast enough, it can be programmed to divide its time among multiple simultaneous processes—providing the illusion that it is devoting itself exclusively to each one. In effect, a single, sequential processor divides itself into multiple "virtual machines" that seem to occupy the same space and time. The ancient, seemingly unproblematic concept of *hic et nunc*—what's here and now—begins to frazzle.

As processors have become smaller and cheaper, and as they have been integrated into networks, it has become increasingly feasible to program parallel rather than strictly sequential processes; tasks are divided up among multiple processors, which simultaneously contribute to producing the desired result. It is even possible to imagine organizing the entire Internet as a parallel computation device.[16] At this point—particularly as network speeds approach the internal bus

speeds of computers—it no longer makes sense to think of a computer as a compact, discrete object, or to distinguish between computers and networks. Eventually, we will approach the physical speed limit, and its associated paradox; information cannot travel faster than light, so spatially distributed events that seem simultaneous from one node in a lightspeed network may seem sequential from another, and vice versa.

The logical endpoint of this shift to networked parallelism is the emerging possibility of quantum computing—in which every atom stores a bit, vast numbers of atomic-scale processing elements are harnessed to execute computations at unprecedented speed, and the notoriously strange spatial and temporal logic of quantum mechanics (rather than the familiar logic of our everyday world) takes over.[17] (It isn't easy to wrap your mind around the fact of quantum systems occupying several places at once, quantum bits registering 0 and 1 at the same time, and quantum computers performing large numbers of computations simultaneously.) And, maybe, the ultimate network will operate by the quantum-magical means of quantum entanglement and teleportation of quantum states from one site to another.[18]

So we have gone from local habitation and mechanical subdivision of time to a far more dynamic, electronically based, network-mediated, global system of sequencing and coordination. The early moderns measured out their lives in clock ticks (and sometimes, as Prufrock lamented, coffee spoons); now, our webs of extension and interconnection run on nanosecond-paced machine cycles that are edging into the domain of quantum logic. The more we interrelate events and processes across space, the more simultaneity dominates succession; time no longer presents itself as one damn thing after another, but as a structure of multiple, parallel, sometimes cross-connected and interwoven, spatially distributed processes that cascade around the world through networks. Once there was a time and a place for everything; today, things are increasingly smeared across multiple sites and moments in complex and often indeterminate ways.

DISCONTINUITIES

In the fast-paced, digitally mediated world that we have constructed for ourselves, what exists between 0 and 1, a pixel and its neighbor,

or a discrete time interval and the next? The answer, of course, is nothing—profoundly nothing; there's no there there. The digital world is logically, spatially, and temporally discontinuous.

Our networks are similarly discontinuous structures; they have well-defined access points, and between these points things are in a kind of limbo. If you drop a letter into a mailbox, it disappears into the mail network until it shows up at the recipient's box, and if you send an email, it's just packets in the Internet cloud until it is reassembled upon receipt. Obviously it is possible, in principle, to precisely track things through networks, but in practice we rarely care about this. We experience networks at their interfaces, and only worry about the plumbing behind the interfaces when something goes wrong.

If you transfer *yourself* through a network, you directly experience this limbo. It is, perhaps, most dramatic on intercontinental night flights. You have your headphones on, there is darkness all around, and there is no sensation of motion. The video monitor constructs a local reality, and occasionally interrupts it to display current times at origin and destination. It is best not to worry too much about how to set your watch right now, precisely where you are, or whose laws might apply to you.

The discontinuities produced by networks result from the drive for efficiency, safety, and security. Engineers want to limit the number of access points and provide fast, uninterrupted transfers among these points. So you can drink from a stream anywhere along its length, but you can only access piped water at a faucet. You can pause wherever you want when you're strolling along a dirt track, but you must use stations for trains, entry and exit ramps for freeways, and airports for airline networks—and your experience of the terrain between these points is very limited. You experience the architectural transitions between floors of a building when you climb the stairs, but you go into architectural limbo between the opening and closing of the doors when you use the elevator.

HABITATS

Decades ago, at the very dawn of the digital era, Charles Moore (the most thoughtful architect of emerging postmodernity) shrewdly

understood what the simultaneous conditions of extension and discontinuity meant for our daily use of space; our habitats no longer consist of single or contiguous enclosures, but have become increasingly fragmented and dispersed. They are no longer bounded by walls, but by the reach of our networks. They are occupied by spatially dispersed organizations, ranging from multinational corporations and retail chains to terrorist networks. They are controlled and defended not at a continuous perimeter, but at separated and scattered access nodes. They are given order and meaning not by participation in strict spatial sequences and hierarchies, but by their global linkages. Our domains of knowledge and action cannot be defined as fixed neighborhoods, but must now be understood as dynamic, emergent, geographically and temporally fluctuating patterns of presence. In his influential essay "Plug It In, Rameses," he observed:

> The most powerful and effective places that our forebears made for themselves, and left for us, exist in contiguous space. They work on an organized hierarchy of importances, first dividing what is inside from what is outside, then in some way arranging things in order of their importance, so that objects give order to a location, and location gives importance to objects, as at Peking, where an axis penetrates from outside through layer after layer of increasing importance (like the skins of an onion) to the seat of the emperor himself, or as in Hindu towns where caste determined location from clean to dirty along the flow of water which served everyone. . . . Our own places, however, like our lives, are not bound up in one contiguous space. Our order is not made in one discrete inside neatly separated from a hostile outside. . . . We have, as we all know, instant anywhere, as we enjoy our capacity to make immediate electronic contact with people anywhere on the face of the globe. . . . Our new places, that is, are given form with electronic, not visual glue.[19]

COMMUNITIES

Sociologists would use more technical language to make much the same point as Moore's. They would say that I—like most urbanites today—get companionship, aid, support, and social control

from a few strong social ties and many weak ones.[20] These ties, which might manifest themselves, for example, as the entries in my cellphone and email directories, establish social networks. In the past, such networks would mostly have been maintained by face-to-face contact within a contiguous locality—a compact, place-based community.[21] Today, they are maintained through a complex mix of local face-to-face interactions, travel, mail systems, synchronous electronic contact through telephones and video links, and asynchronous electronic contact through email and similar media.[22] They are far less dense, and they extend around the world, coming to earth at multiple, scattered, and unstable locations.[23] As Barry Wellman has crisply summarized, "People in networked societies live and work in multiple sets of overlapping relationships, cycling among different networks. Many of the people and the related social networks they deal with are sparsely knit, or physically dispersed and do not know one another."[24]

In the years since Moore wrote, our physical habitats have grown more fragmented and dispersed as transportation networks have extended further and operated faster. Simultaneously, the electronic glue has grown much stronger; it now includes voice, video, and data channels, broadcast and point-to-point links, place-to-place and person-to-person communication, the fixed infrastructure of the bank ATM system, the sleek portable equipment of the corporate road warrior jetting between global cities, and the cheap phone card of the migrant worker.

Wherever I currently happen to find myself, I can now discover many of the same channels on a nearby television, I can access the same bank account, and I can chat with the same people on my cellphone. I can download my email and send replies almost completely independently of location. And my online world, which once consisted of ephemeral and disconnected fragments, has become increasingly persistent, interconnected, and unified; it's there again, pretty much as I left it, whenever I log in again from a new location. The constants in my world are no longer provided by a contiguous home turf: increasingly, my sense of continuity and belonging derives from being electronically networked to the widely scattered people and places I care about.