The Non-Standard, Un-Automatic Prehistory of Standardization and Automation in Architecture

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"Change or Perish"

At the 2006 AIA National Convention, Pritzker Prize winner Thom Mayne put a mouse to the head of his audience and said, "If you want to survive, you're going to change; if you don't, you're going to perish."[1] He was referring to the increasing momentum of two technologies that will purportedly and automatically change everything in architecture: Building Information Modeling (BIM) and digital fabrication. In doing so, Mayne succinctly perpetuated what is perhaps architecture's most blatant fiduciary *irresponsibility*: despite the fact that technology dominates our buildings, our practices, and our lives, architects know relatively little about it. This condition is a product a persistent fallacy: architecture teaches and practices technology as technologically determined rather than socially constructed. In the history of technology in architecture, the discipline views social relations as a variable of technology. In our adjacent disciplines, however, technology is understood as a variable of social practice and progress.[2] This recurrent fallacy is a fundamental problem of knowledge and practice for architecture in the twenty-first century.

The implementation of the BIM and digital fabrication provide an apt illustration of the uses and abuses of architecture's approach to technology. On one side of these approaches are the euphoric pronouncements and promises of the *capabilities* of technology. These arguments view technology as decidedly deterministic: the technologies themselves will engender categorical, if not merely seductive, changes, revolutions, or even paradigm shifts in the practice of architecture.[3] On the other side of these approaches are the grossly unstated *culpabilities* of such technology. The history of the technologies that precede digital fabrication and BIM—a history of standardization and automation technologies—presents a recurrent pattern of euphoric promises in the marketing rhetoric of a technology that rarely aligns with the actual effects of the technology. In all cases, these technologies inevitably bear unexpected consequences for the host industries. The aim of this paper is to address this recurrent pattern: the techniques and technologies that prepare the way for the deployment of BIM and digital fabrication technologies as well as the unexpected consequences of implementation. In doing so, the paper will necessarily address our discipline's historical approach to technology and the desperate need for revised, deeper, and more studied approaches to technology in architecture. In our perpetual rush towards novelty, it is more important that ever that architects know more than ever about the operations, functions, and substrate of technology.

This paper thus departs from a few basic principles about technology in architecture that derive from the history and philosophy of technology:

The first is that every technology is social before it is technical or physical.[4] Technical development is first an expression of an immaterial need or desire, and only later becomes material and technical.

Secondly, when a technology does become physical, it is not a benign reserve of technical solutions to social, ecological, material, management or fabrication problems but rather produces its own risks and problems as a constitutive artifact of that technology. All technologies contain some form of risk.[5]

Third, every technology is principally undetermined until it situated within the broader economic, social, and cultural assembly that presupposes and engenders that technology.[6] We will know very little about the capabilities and culpabilities of technology if we only study a technology in terms of its technical promises and performances in building production.

Finally, any technology is anything but new. If we will understand technology at all, we will begin to see it as an uninterrupted and ubiquitous practice.[7] All technologies have a long period of social, cultural, technical, and practical preparation. The habits of mind that underwrite one technology often influence successive technologies. In our mythical paradigm of progress, technical mastery, and paradigms shifts, terms such as “new” are merely rhetorical escalations.

The Prehistory of Contemporary Technologies: Recurrent Patterns

Buried within this last principle are intimations of a nearly eternal recurrence pattern in technical practices. In the case of technology, history does not repeat itself but it often does rhyme. The prehistory of a technology includes a long period of preparation which inevitably is a social history of the decisions and habits of mind that underwrite the need, desire, ‘invention,’ development and deployment of any technology. In the case of digital fabrication and BIM approaches, nothing sobers the euphoric claims about the ‘new’ technologies that will allegedly shape tomorrow than familiarity with the recurrent patterns in the histories of the technologies that have precede them, prepare the conditions for their adaptation, and haunt their implementation and effects. The technologies that overtly prepare and condition the contemporary implementation of BIM and digital fabrication are technologies that engaged the standardization and automation of industrial production and communications, transferred from adjacent modes of production. It is not in the scope of this paper to fully account fro these histories, but in abbreviated form this history includes:

-The Army Ordnance Department: After the War of 1812, the Army Ordnance department developed the first broad application of standardization for the manufacture for weapons with interoperable components with systemized jig production and interstate communications. The implementation met great resistance and experienced several social and economic failures.[8]

-Warship Assembly Line Production: During WWI, the US Navy attempted assembly line production for warships headed by Henry Ford in Detroit. Unforeseen complications and difficulties in a seemingly simple transfer of technology resulted in massive delays and cost overruns that threatened national security.[9]

-the US Air Force Numerical Control program: A massive post WWII program intended to yield an automated system of production for weaponry. Untenable for the market, the dream of the fully automated factory floor is funded and developed with massive subsidies. This approach to the market is central to the ‘Permanent War Economy.’[10,11]

-the automobile industry’s adoption of automated processes: US versus foreign approaches: A new form of organized irresponsibility is transferred along with automation technology transfer from the Numerical Control program. Here, the concept of structural unemployment emerges as the industrial glacier recedes over the Rust Belt. Elsewhere the benefits of the German, Japanese, and Scandinavian approaches to partial, more strategic automation technologies bear fruition.[12]

-the aerospace industry’s development of parametric modeling: The birth of solid modeling and parametric design in the French/British development of the Concorde aircraft. By design, the process yields and expensive and elaborate plane that amongst things, leads to the development CATIA software.

-the AEC industry’s adoption of CADD technologies in the 1980’s and 90’s: The more familiar history of the implementation of an

automation technique within architecture. Amongst other promises such as productivity gains and more time for design, the promise of the paperless office somehow yields ever more paper, less time for design, and a loss in productivity due to interoperability issues. [13]

Each of these instances of standardization and automation are rehearsals of the implementation of successive technologies, such as BIM and digital fabrication. In each case, the habits of mind and processes that engendered the previous technology extend into the next and share a pattern of thoughts and decisions as well as promotion, marketing, argumentation, and implementation. They also share similar outcomes. Throughout each of these applications of standardization and automation, several recurrent problems routinely compromised the jubilant expectations of its promoters and designers. All shared massive inefficiencies where massive efficiencies were promised; in each, massive capital was required to develop, adopt the technology, and manage the interoperability issues discovered after implementation–this often required large government subsidies for economic feasibility; unemployment if not structural unemployment; and an associated deskilling and atrophy of knowledge of the respective disciplines. In all cases, the asymmetry between the *capabilities* of technology and the *culpabilities* of technology engendered the irrational outcomes of what is purportedly a most rational of endeavors: technology. At the core of this asymmetry is a view of history as technologically determined rather than socially constructed. The history of these standardizing and automating techniques do not prescribe an automatic and standardized future, but rather a series of social decisions and habits that determine the course of these techniques. Historian of technology and labor David Noble has commented on this recurrent pattern, "At every point the technological developments are mediated by social power and domination, by irrational fantasies of omnipotence, by legitimating notions of progress and by the contradictions rooted in the technological projects themselves and the social relations of production."[14]

While a 'Change or Perish' approach to technology is euphorically embraced by software manufacturers, contractors, and subsequently the American Institute of Architects, the future history of BIM and digital fabrication is anything but automatically determined by the adoption of these automating technologies. Just as all technology is social before it is technical, all technology is social after it is technical as well: "If the social changes now upon us seem necessary, it is because they follow not from disembodied technological logic but from a social logic—to which we all conform."[15] The capabilities and culpabilities of these technologies will ultimately be determined in the social field. While a range of issues emerge from the proposed implementation of new technologies and the recurrent patterns of the previous technologies of these technologies, two issues—interoperability and economics, for instance—illustrate the social basis and outcomes of these technologies.

1. Integration and Interoperability:

Amongst the claims made for the implementation of BIM and digital fabrication technologies are productivity efficiencies in the coordination and management of drawings sets, coordinated databases, communication, more time on design, better rendering capabilities, fewer errors, new services with additional fees; all aimed at benefits for the architect.[16] Given the foibles of the briefly mentioned history of CADD implementation, there seems to be near unanimous agreement on the inefficiencies of the current model of CAD enabled practices amongst building owners, architects, and builders: "Inadequate interoperability increases the cost burden of construction industry stakeholders and results in missed opportunities that could create significant benefits for the construction industry and the public at large."[17] In many ways, it seems natural in our culture to implement another technology to amend the shortcomings of a previous technology. This is what David Noble describes as a 'machine mentality' which is the "understandable perhaps but nevertheless self-serving belief that whatever the problem, a machine is the solution. This manifests itself in a preference for, and tireless promotion of, capital–intensive methods and in the widespread but mistaken belief that the more capital intensive the process of production, the higher the productivity."[18] In architecture, the escalating technologies of this machine mentality inevitably engage the problematics of interoperability.

BIM standardizes communication with expanded compunications and automates aspects of production. Interoperability is central to all these BIM techniques. While there is clear and perhaps obvious potential to revise the shortcomings of current CAD approaches, it is not exactly clear, however, how BIM will resolve this issue in actuality rather than rhetorically. With BIM, certain 'integrating' ambitions undermine the means of integration. For instance, BIM claims to interchange cost, energy, and material calculations in a single model. However, certain modeling ambitions, such as energy modeling, require not only their own software, codes, and file types but fundamentally different modeling approaches. Computational fluid dynamic models require radically entities and parameters than what is contained in a BIM. This is not an issue of interoperability or exchange but rather fundamental differences in the approach to various modeling ambitions. It prompts the fact that multiple models will exist of a single project—with all the corollary implications for integration and coordination that multiple models presuppose. This is essentially a more complicated and information-dense expansion of the interoperability issues in CAD approaches: consultants working on outmoded or incorrect drawings and models of a project and the source of the errors and omissions in the CAD model. Other forms of integration, too, proposed for BIM assume vast databases of accurate material data, cost information and even code information. It is equally unclear at the moment who will validate and verify such information much less insure that a range of options exist, thereby excluding as much as it integrates. The term "Integrated Practice" implies that these databases, software protocols and interoperability technologies are integrated if not now, then in the very near future. However, even with the relatively simple translation of the 2-D CADD programs presented irresolvable translation problems in the past two decades, leading to the default adoption of AutoCAD as more or less the industry standard. As an order of magnitude greater than CAD, the increasing complexity of model intentions, softwares, and file types of BIM suggests that the problem of interoperability does not tend towards integration but rather grows as exponential function of the exponential growth of technology, prompting questions about whether or not translation and/or interoperability protocols can be developed.[19]

It is an open issue if these interoperability problems can be resolved and provide the operational efficiencies promised by the arguments for this technology or whether this is merely Noble's 'machine mentality' made manifest. Given that the ultimately compromised ambitions of CADD in practice rehearsed these very arguments a decade ago and that the range of interoperability issues is increasing geometrically, it difficult imagine an efficient resolution of the issue. Simply stating that the IFC is working on standards explains nothing about a solution to interoperability. In the very least, such interoperability makes 'integrated practice' only available to those who choose to practice in this capital-intensive mode.

2. Economics: "If the primary motivations behind capital-intensive production methods were not necessarily economic, neither were the results." [20]

Given the patterns of implementation in the previous histories outlined briefly above, it is apparent that the technologies will optimize two sets of practices in architecture: couture boutiques and capitalist-driven builders. Cunning, top tier practices such as SHOP, Morphosis, and Gehry Partners will undoubtedly yield novel results with new forms of practice in standardization and automation techniques and be set forth as a model for such practices.

However, it is important to note the social basis of this optimization. For instance, nothing transformed Frank Gehry's practice more than his contracts, a social rather than technical implement.[21] Gehry's contracts with clients and builders are perhaps the most revolutionary aspect of his practice. Due to social value of star architects, Gehry requires near inculpability with his contracts and simultaneously demands a fee structure that enables the technologies and practices often exemplified in BIM and digital fabrication. The social 'technologies' of contracts and fee structures precede any implementation of the capital-intensive methods of production that shifted Frank Gehry Architects as a design consultant that eschewed the liabilities of anything beyond schematic design in the eighties to a full-service Gehry Partners, replete with its own research and development entity, Gehry Technologies.

In Gehry's case, his practice is largely indemnified from errors, omissions, cost overruns and delays to the extant his builders are not allowed to bemoan aspects of his building design. This social situation expressed itself recently in lawsuits between General contractor M.A. Mortenson Co and Gehry's office over the construction the BIM-heralded Walt Disney Concert hall.[22] Even if most architectural offices could approach the audacity of such contracts and fee structure, they cannot, the basis for the lawsuit mentioned above is telling enough: despite the rhetoric of productivity efficiencies, the lawsuit was based upon a 174 million dollar cost overrun on a $100 million dollar budget and the fact the building finished six years late. Such failures, cost overruns, inefficiencies, and social fallout echo the previous deployments of automated technologies in our industry and our adjacent disciplines. As David Noble noted on these implementation woes, the "investigation of the actual design and use of capital-intensive, labor saving, skill-reducing technology has begun to indicate that cost reduction was not a prime motivation, nor was it achieved."[23] Other sources of impetus must be behind these 'technical innovations' besides profit, time-saving, or integration—none of which clearly meet the promises of their promoters. Interestingly, much like the technologies that prepared them, the success stories of BIM and digital fabrication tend to be "based upon high not low prices and innovations not in production but in organizational management and, especially, marketing."[24] In the history of these technologies, the spin of marketing and the reorganization of social relations are at the core of these technologies. Economic progress (cost savings, time reduction, profit) has rarely been an outcome of implementing technologies of standardization and automation, especially for most architects who operate in a economic milieu that is fundamentally distinct from that of the padded fee structure of couture architects, much less the heavily subsidized organization of the military, aerospace and automobile industries. The fallacy of technological transcendence in the 'machine mentality' is at the core of these histories of technology and is at the core of the problem that issue from architecture's technologically determined approach. It is a self-fulfilling, if not vicious, cycle of technological recurrence in which the failures and the flaws of the previous technical system warrant yet another technical system to amend production. We have to see that is not primarily the technology in these practices that enables the practices but rather a series of social constructs. Within the perceived advantages in these practices, BIM and digital fabrication are the consequence, not the what, of change. If there is to be paradigm shift in architecture, it will occur in the complexity of the social rather than the technical field.

The other entities that are most prepared to capitalize on the operative principles of standardization and automation are large scale developers and builders: the 97% of construction that does not involve architects.[25] If the efficiencies yielded by BIM technologies allow us to build for less yet, it begs the question why this 97% will not grow to an even larger number once BIM is fully automated to include everything from material and methods to codes, as is being pursued currently by Gehry Technologies. In short, a technology such as BIM will undoubtedly produce more big box stores, cheap hotels, and suburban houses faster for less and less yet again. The effect for what lies in between the event buildings of couture architects and the bemoaned standardization and automation of the middle landscape—the Stim and the Dross of American Cities— is an open and unanswered question.[26] As Michael Benedikt has remarked on the perceived benefits of incorporating (2-D) CADD into practice in the past two decades:

"The efficiencies that computers afford raise a critical question: who benefits from the increased productivity? I would venture that it is not the architect. I would venture that intense market competition between architects, focused on service for fee and the ability to control costs, has passed the these productivity-won savings cleanly along to clients, and that architects have not, with these savings bought one minute more of their own time to spend on the design or refinement of their buildings. Indeed, so seductive is the computer's capacity to copy files hither and thither and to render 'spaces' in no time at all, that I would venture that less time is being spent in design, profession-wide, than ever before...And so the economizing continues, round after round, the average architect delivering less and so being asked to deliver less yet for less yet."

In all cases, the entities and industries that have benefited the most from the techniques of standardization and automation are large corporations with large capital reserves and subsidized market structures. Standardization and automation works for a Boeing jet but less so for less for a Piper Cub. What works for Gehry Partners may not work for other architectural practices with fundamentally different fee structures and social value. Capital-intensive enterprises and economies of scale are fundamental economic principles of standardization and automation and these principles are fundamentally at odds with aspects of architectural practice: the customization of building types for particular codes, sites, budgets, performances, and preferences. Architecture most often lacks the economies of scale, massive capital and government subsidies that optimize these technologies in our adjacent disciplines, no matter how much we compare our industry to theirs.[27] In the histories of technology mentioned above, the adoption of new technologies inevitably shifted social bonds, responsibilities and benefits. They also yielded social problems for the host industries that claimed to benefit so much from the implementation of the technologies. The discourse on BIM and digital fabrication has yet to address these culpabilities alongside the capabilities of the technologies.

Conclusion:

As noted, ironically, in the 2005 AIA Technology Practice BIM Design Awards program case study on the Morphosis San Francisco Office building, “At this stage, accurate quantification of benefits remains highly elusive as new relationships are forged between designers and fabricators. We encourage the construction industry to begin detailed analysis of the cost benefits that may accrue to the process: estimating, detailing, and scheduling. Open dialogue between all parties can move the discussion to a more sophisticated level and allow a predictive framework to emerge.”[28] That is, the actual benefits of implementation remain rather elusive and the *fait accompli* of the technology resides in social relations.

Rather than an indictment of BIM technologies or digital fabrication, the aim here has been to draw attention to the role of technology in architecture, not as a technically determined practice but rather one that should grasp the social construction, histories and futures of technology. Historically, architects are unabashedly susceptible to the capabilities of technologies while euphorically ignoring the culpabilities of technologies. With each successive wave of new technologies, architects seem to lose more ground than they gain. In our hasty rush towards perpetual novelty we neglect to study the technologies that we collectively grant such great momentum in this receding horizon of practice. If there is an indictment in this paper, it is the way that architects study, teach and practice technology. This presents a significant problem of knowledge for contemporary architects in which our practices and lives are dominated by technology. In a context of increasing, if not misplaced or superfluous, complexity in the production of architecture, the most cogent approaches in the twenty-first century understand technology as a variable of social progress. So often the complexity and required capital of practices escalates as we try to amend the unexpected and inexplicable complexity of the previous wave of technology. Perhaps it is time to relocate the scene of complexity into more potent understandings and practices of technology itself rather than pursue perpetual technical novelty for the sake of perpetual technical novelty—and perpetually deal with its associated social, economic, ecological and political digressions. As Sanford Kwinter has noted,

> “Our task today I would argue, is to resist these pathways of thought, and wherever possible to expand the concept of the concrete and to extend the play of intuition into new domains. To do this effectively I believe, it must remain within our power (conceptual and political) actually to refuse the advent, not so much of the specific machines and techniques of contemporary development, but of the broader systems of rationality in which they come packaged or for which they serve as Trojan horses. Communications networks, computers, microprocessor control systems are socially toxic entities primarily when used “correctly,” that is, in their capacity to routinize interactions with people and processes in increasingly engineered, confined and deterministic spaces. It is our duty and mandate to refuse this new, pseudo-

material space entirely, and to follow the "minor," *archaic* path through the microchip, that is, to make the electronic world work *for us* to reimpart the rich indeterminacy and magic of matter out of the arid, cruel, and numericalized world of the reductionist-mechanical and the disciplinary-electronic.[29]"

Exactly when technologies come to dominate our lives and practices, architecture must deepen its engagement with technology as mindful participants in our technics. As David Noble stated, "There are no technological promises, only human ones, and social progress must not be reduced to, or confused with, mere technological progress."[30]

Endnotes

[1] Thom Mayne, "Change or Perish: Remarks on building information modeling." *AIA Report on Integrated Practice*. (Washington D.C., American Institute of Architects, 2006).

[2] Thomas P. Hughes, "The Evolution of Large Technological Systems." in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Eds Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch. (Cambridge, Mass.: The MIT Press, 1987). , Merritt Roe Smith and Leo Marx, eds. *Does Technology Drive History? The Dilemma of Technological Determinism.* (Cambridge, Mass.: The MIT Press, 1994). Langdon Winner, Autonomous *Technology: Technics-out-of-control as a Theme in Political Thought*. (Cambridge, MA, The MIT Press, 1977).

[3] As a pertinent example, the AIA Report on Integrated Practice is replete with examples in which the report's authors forecast changes in practices, brought about by changes in technology. Michael Broshner, Norman Strong, and Daniel Friedman, "Report on Integrated Practice." (Washington D.C. American Institute of Architects, 2006)

[4] 'Tools always presuppose a machine, and the machine is always social before it is technical. There is always a social machine which selects or assigns the technical elements used.' Deleuze, Gilles and Claire Parnet. *Dialogues II.* Columbia University Press, New York. 1987. p. 70.

[5] Beck, Ulrich. *Risk Society: Towards a New Modernity.* (London, SAGE Publications, 1992).

[6] Deleuze, Gilles. 'Treatise on Nomadology.' A *Thousand Plateaus.* University of Minnesota Press, Minneapolis. 1987.

[7] Lewis Mumford. *Technics and Civilization*. (Harcourt Brace & Company: New York, 1963).

[8] Merrit Roe Smith. Harpers Ferry Armory and the New Technology (Cornell University Press, Ithaca, 1977)

[9] David A. Hounshell. "Ford Eagle Boats and Mass Production during World War I." in *Military Enterprise and Technological Change: Perspectives in the American Experience*. Ed. Merrit Roe Smith. (The MIT Press, Cambridge, MA, 1985).

[10] Retijles, J. Francis. *Numerical Control: making a New Technology.* (Oxford University Press, New York. 1991).

[11] Seymour Melman, Permanent War Economy. *The Permanent War Economy: American Capitalism in Decline* (NY: Simon & Schuster, 1985).

[12] David F. Noble, *Forces of Production: A Social History of industrial Automation*. Alfred A. Knopf: New York, 1984.

[13] Mike Colley, *Architect or Bee?: The Human/Technology Relationship.* (South End Press, 1982)

[14] Noble, 324.

[15] Noble, *Forces of Production,* p. 324

[16] While the examples and sources of these claims pervasive in advertising and literature, two examples provide good summaries of the claimed benefits of the proposed technologies: AIA report on Integrated Practice mentioned above and Stephen Kieran and James Timberlake, *Refabricating Architecture: How Manufacturing Methodologies are Poised to Transform Building Construction.* (New York: McGraw-Hill, 2004).

[17] Michael P. Gallaher, Alan C. O'Connor, John L. Dettbarn, Jr., and Linda T. Gilday *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*. U.S. Department of Commerce, August 2004

[18] David F. Noble. "Statement of David F. Noble at Hearings on Industrial Sub-Committee of the 98th U.S. Congress" in David F. Noble, Progress Without People. (Charles H. Kerr Publishing, Chicago, 1993.) p. 100.

[19] Integration of a technical apparatus is a exponential function of the complexity technical apparatus. The exponential growth of Moore's Law or of Ray Kurzweils' Law of Accelerating Returns in the complexity of technology suggests that

integration for BIM will be an exponential function of its own exponential complexity of file types, modeling ambitions, and database sources. This proves obviously untenable in practice, so society will decide on standards to guide growth. What must be understood here is that interoperability at its core will be socially determined if it will be determined at all. Ray Kurzweil, *The Law of Accelerating Returns*. (*KurzweilAI.net March 7, 2001.)*

[20] Noble, *Forces of Production,* p. 335.

[21] Carl Sapers provides a brief history of Gehry's contracts in "Toward Architecture Practice in the 21st Century: the Demise (and Rebirth?) of Professionalism," Harvard Design Magazine, vol 19, Fall 2003/Winter 2004. p 80-85. His professional practice course at Harvard expands upon this discussion of Gehry's contracts through case studies.

[22] Tony Illia, "Settlement Reached in Walt Disney Concert Hall Lawsuit" *Architectural Record*, (New York, McGraw-Hill Publications, August 4, 2006). "A "non-disparagement" clause is among the terms of the settlement; it prohibits Mortenson and its subcontractors from criticizing Gehry's work. Also, Mortenson and three subcontractors are not permitted to use Gehry's name in written advertising or marketing materials touting their work on the concert hall."

[23] Noble, *Forces of Production,* p. 334

[24] Noble, *Forces of Production,* p. 335

[25] James Cramer. Presentation to the AIA Chicago Board Members, 2005; as quoted in Daniel S. Friedman in "Architectural Education and Practice on the Verge," *AIA Report on Integrated Practice*; adapted from the forthcoming article in T. Fisher, J.L. Nasar, and W.F.E. Preiser, eds. Designing for Designers. (New York: Rothchild Books, 2006).

[26] Stim and Dross: Lars Lerup, *After the City*. (Cambridge, MA: The MIT Press, 2001). Alan Berger, *Drosscape: Wasting Land in Urban America*. (New York, Princeton Architectural Press, 2006).

[27] The most broad and popular source for these technologies is Kierian and Timberlake Architects' *Refabricating Architecture*, the outcome of the first $200,000 AIA Latrobe Prize.

[28] "Morphosis, San Francisco Federal Building" *BIM Awards Competition, AIA Technology in Architectural Practice*. (Washington D.C., The American Institute of Architects, April 2005

[29] Sanford Kwinter, "Counterblast (The computational Fallacy)." *ANY 10, Mech in Tecture; Reconsidering the Mechanical in the Electronic Era*, February/March 1995.

[30] Noble, *Forces of Production,* p. 351