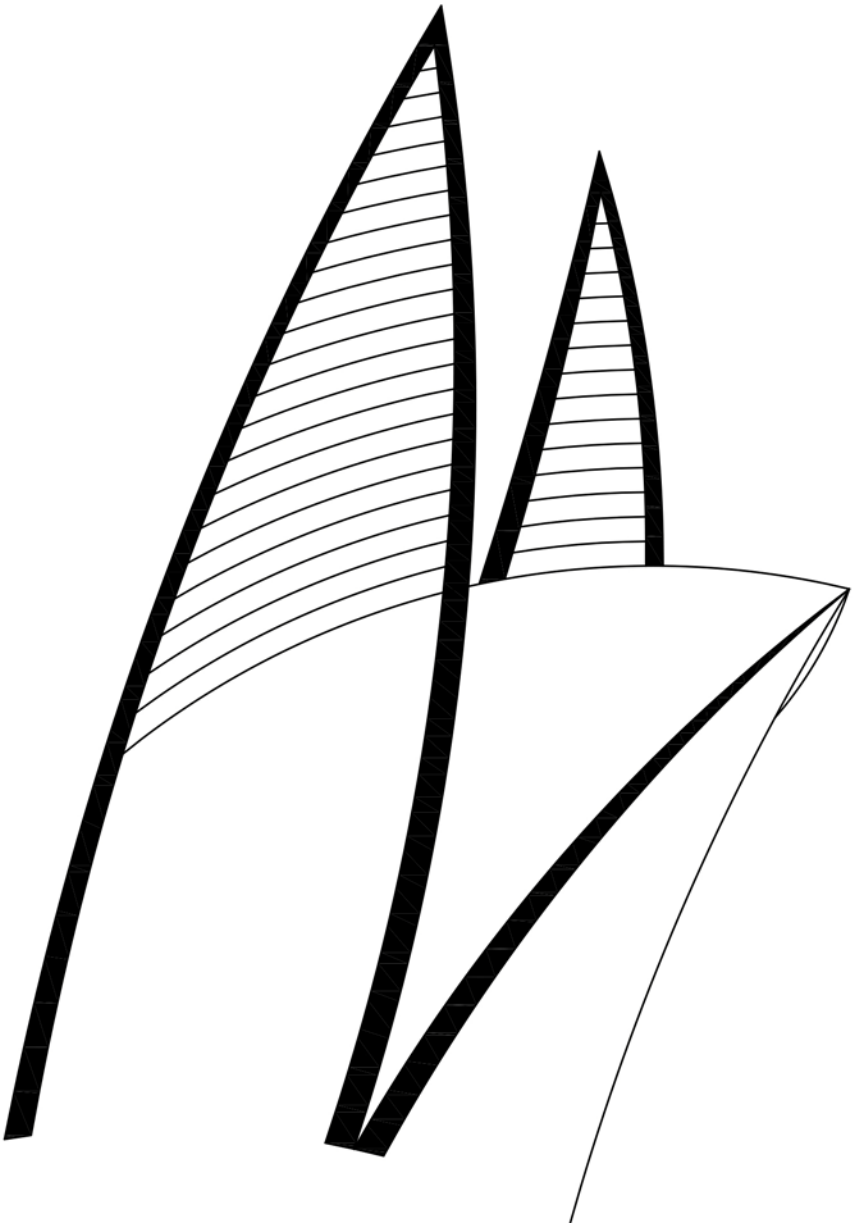

The Silver Tower - A New Paradigm for Tall Building Construction

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Skyscraper, catalytic bigness, eminent domain, air rights, airliner, piezoelectrics, wind turbine, watt, joule, watt-hour, nuclear reactor, molten salt reactor, liquid fluoride thorium reactor

A Selection of Relevant Quotations

"Make no little plans; they have no magic to stir men's blood."
Daniel Burnham

"A monumental proof of hopefulness. It catches up the whole city, with all its diverse elements, yet with common hopes, into its inspiring sweep."
The New York Times

"It was the building that should never have been built, rising in the wrong place at the wrong time. But when it was through, everyone knew it was the purest and most glorious expression of everything the city stood for."
New York: A Documentary Film

"But should one build tall? Yes, I think so. Ever since Biblical times to build tall has been both the arrogance of man and the confidence of man."
Robert A M Stern

"If money and power and ego can create this extraordinary pleasure, this instant landmark, money and power and ego can rescue the city from its ashes."
Gael Greene

"This great structure cannot be confined to the limits of local pride. The glory of it belongs to the race. No one who has been upon it can ever forget it. Not one shall see it and not feel prouder to be a man."
Seth Low

"Build the biggest thing, and you are powerful. Visit the biggest thing, and you partake of this power."
Paul Goldberger

"Sell them what they hoped for, and longed for, and almost despaired of having. Sell them this hope, and you won't have to worry about selling them goods."
Helen Landon Cass

"You need dreams to live. It's as essential as a road to walk on and bread to eat. I would have felt myself dying if this dream had been taken from me by Reason."
Philippe Petit

"When you are in the presence of something marvelous, some little bit of it, like a piece of glitter, falls on you and you've got it. Part of its glory is with you."
Heywood Hale Broun

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ABSTRACT

The events of September 11, 2001, seemed to many to presage the end of the skyscraper as an urban form. Some 15 years later, the skyscraper is more prevalent than ever before, owing to its unique advantages over other building forms in an urban, environmental, and sociological context. Skyscrapers are rising ever higher, pushing the limits of architecture and engineering. In 2001 there were 23 buildings over 1,000 feet in height. As of this writing there are 173 buildings over 1,000 feet completed or under construction, with 300 more in various phases of proposal.[1] Despite their enormous initial cost in both capital and energy, the skyscraper maximizes the use of constricted urban space and provides enormous opportunities for technological and sociological innovation which, despite more that 100 years of skyscraper construction, are only just beginning to be realized. This thesis will explore a number of as-yet unrealized possibilities for skyscraper development to prognosticate and articulate future typologies designed to address increasing problems of energy efficiency, population density and disaster preparedness. As the human population grows, and more people move to the cities, larger and larger buildings will be necessary to house them at densities sufficient to ensure energy efficiency and minimize sprawl. The skyscraper is uniquely suited to meet these demands.

[1] *SkyscraperPage.* Skyscraper Source Media, 2016. Website. Accessed 17 January, 2016.

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Chapter 1 : The Origin of the Skyscraper

The skyscraper is perhaps the most fascinating of all modern urban forms, both for the enormity of the achievement it represents and the powerful emotional reactions it stirs. Technologically, the skyscraper as a building form is an invention of the late 19th century. The first true skyscraper was the Home Insurance Building of 1885, brainchild of architect William LeBaron Jenney who came up with the idea of using an internal steel skeleton to carry the structural loads of the building.[2] The booming economies of the time necessitated the concentration of as much usable space on constricted plots as possible, requiring buildings to reach ever higher. Unfortunately, the limitations of stone construction were soon reached. As buildings rose higher, the thickness of stone walls at the base soon became untenable, a situation exemplified by Chicago's Monadnock Building of 1893, designed by Daniel Burnham and John Root. The northern half of the sixteen-storey building has a load-bearing unreinforced masonry wall that reaches six feet thick at the base, and proved so enormously heavy that it began to sink into the ground.[3] In addition to its weight and thickness, stone is also poorly suited to resist the repeat lateral flexing imposed by wind loads, which are the largest source of structural loading on tall buildings. The demands of building tall required a transition to new structural materials, and William Jenney pioneered the solution that rapidly became the sole structural typology of tall buildings. Soon, American cities began to rise as no city ever had, producing previously inconceivable structures to astonish natives and immigrants alike.

Figure 1: The Home Insurance Building.

Figure 2: The Monadnock Building.

[2] Noderer, E.R. "US Industrial Might Rooted In Engineering." *Chicago Tribune.* 12 August 1952. Print.
[3] Nagelberg, Alvin. "Monadnock Building Found To Be Sinking." *Chicago Tribune.* 14 June 1967. Print.

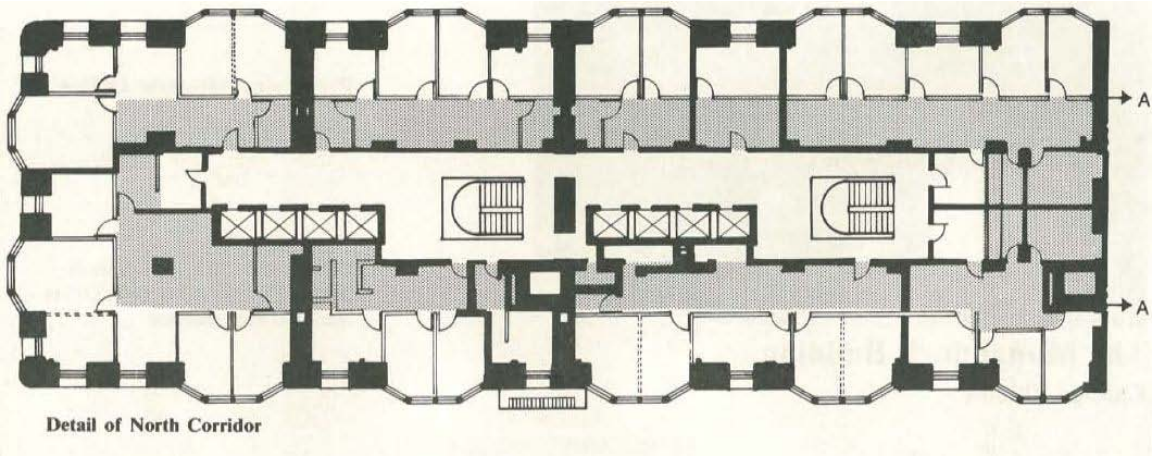

Figure 3: Monadnock Building Plan.

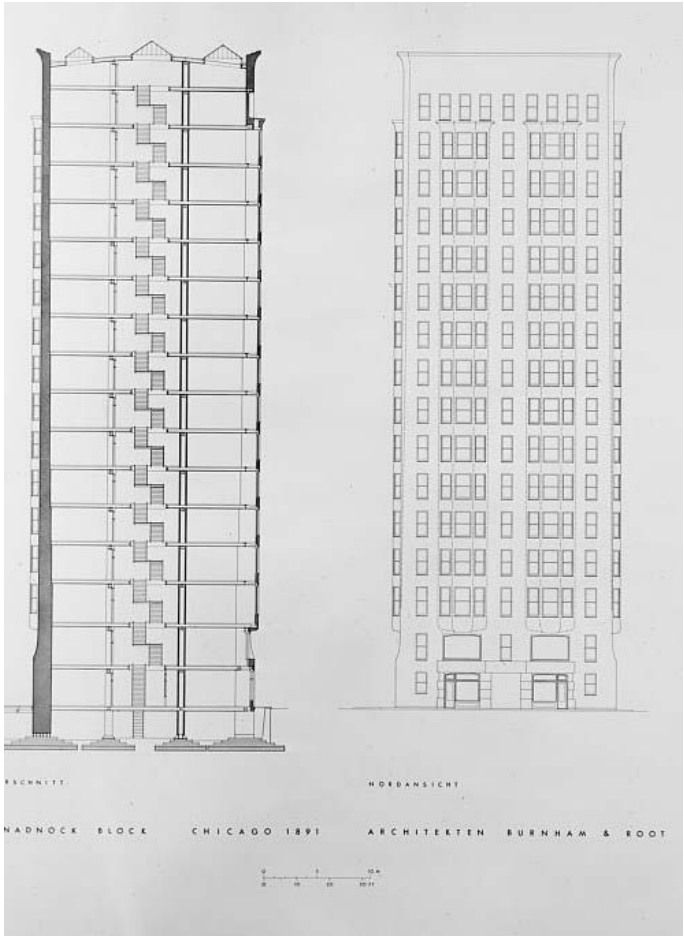

Figure 4: Monadnock Building Section.

The Monadnock Building is a veritable fossil in the skyscraper world, owing to the somewhat anachronistic support system of its Burnham and Root-designed northern half which came several years after the completion of the mostly steel framed Home Insurance Building. Visible in this plan and section are the enormous structural masonry walls which support the building. The walls flare out dramatically at the base as is typical of masonry pier construction, where the thickness is necessary to bear and redistribute the load of the structure above.

While the modern urban form of the skyscraper with its commercial and residential functions and its particular structural and mechanical typologies is a relatively recent innovation, the tall building as a cultural and social focal point is as old as human habitation itself, and its primary function was religious. Throughout history the built environment has been dominated by large religious structures which were regarded as a gift to whatever deity or deities were being worshiped therein. Such buildings were the pinnacle of design and construction, often made to be taller than any other building type and therefore demanding the most sophisticated engineering available. They were also meant to be the pinnacle of ornamentation and beauty, requiring the most advanced craftsmanship and artistry available. From the very beginning, religious structures have occupied a preeminent place in the human physical and psychical landscape. The emotional and spiritual power of the great religious building radiates from every incarnation of it, transcending the mundane considerations of style or context. From the temples of the Acropolis to the cathedrals of Europe to the mosques of the Islamic world, the religious building has historically been the metaphorical and literal height of human achievement.

Figure 5: Chartres Cathedral, Chartres, France.

Figure 6: Sultan Ahmed Mosque, Istanbul, Turkey.

Figure 7: Great Shwedagon Pagoda, Yangon, Myanmar.

This special function of the religious building was acutely realized by German architect Bruno Taut in his seminal *Die Stadtkrone*, or City Crown, of 1919.

> *Throughout every great cultural epoch, the constructive will of the time was directed at one ulterior, metaphysical building [type]. The narrow concept of building construction applied today is a complete inversion of what it was in the past. A minster, a cathedral above a historic city; a pagoda above the huts of Indians; the enormous temple district in the square of the Chinese city; and the Acropolis above the simple houses of an ancient city – all show that the climax, the ultimate, is a crystallized religious conception.*[4]

While the temples and cathedrals served the overt ritualistic purposes of organized religion, they also served a more general spiritual purpose, in that building tall has historically been emblematic of humanity's desire to touch the divine or the transcendent, and in that the ornamentation and craftsmanship involved often went far beyond the requirements of satisfying bare necessities. Taut himself objected to the Modernist idea that architecture should concern itself with satisfying only material needs, arguing that the Modernist ideal expressed as "form follows function" construed the meaning of function too narrowly.

> *To view architecture as nothing more than nicely designed functional forms or as ornamental wrappings around our essential needs is to assign it to the role of a craft and places too little value on its importance [in our lives]. In buildings that demand more than the fulfillment of basic necessities, [architecture] is an art, a play of fantasy, and only maintains a very loose connection to those purposes. However, no effort of the human imagination can lead to profound [physical] forms if it does not root itself in the inner spiritual life and existence of mankind. Therefore, the relegation of architecture to such a humble position should no longer be enough if, by explaining it by its purpose, this term "purpose" is not used in a broader and more unrestricted way.*[5]

Today, that desire for the transcendent finds its chief embodiment in the skyscraper which, though it is dedicated to a secular program of commerce or residence, nevertheless fulfills the same skyward ambitions as the temples of yore. It would indeed be folly to assume, absent an expressly religious or devotional purpose, the skyscraper wants for spiritual power. That power now derives from a burgeoning, nondenominational spirituality that finds transcendent meaning in, among other things, grand human accomplishment. To be sure, many spectacular human accomplishments can arouse such passions, from the graceful spans and gossamer cables of suspension bridges to the wonder of aircraft to the allure and nostalgia of great ocean liners. But tall buildings, in all their manifestations, touch some deeply held desire of the human mind and heart. Unlike the transience of flight, the skyscraper enables a more permanent inhabitation of the sky. Ascending to its pinnacle, one can experience a god's-

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[4] Taut, Bruno. *Die Stadtkrone.* Trans. Ulrike Altenmuller and Matthew Mindrup. *Journal of Architectural Education.* 5 October 2009. Website. Accessed 17 January 2016.
[5] Ibid.

eye view of creation. Skyscrapers are also emblematic of humanity's technological prowess, and as such have become visually synonymous with progress and civilization. As a result, they are sources of tremendous civic pride for the cities in which they are constructed, and throughout history cities have established themselves in a culture by constructing signature buildings visible from miles around. As with the cathedrals and mosques to whose civic primacy they are heir, the great skyscrapers continue to be the sites of a pilgrimage, the modern-day secular version of which is made to experience the collective sense of pride in the accomplishments of fellow human beings. Such is the impetus behind the almost ritualistic ascent to the observation platforms of the Empire State Building or the Sears Tower, and as skyscrapers have proliferated, so too have such opportunities for making use of the sky for public amenities predicated upon sweeping views and a sense of airborne elation. Despite its secular purpose, the skyscraper, being the latest iteration of the tall building, serves much the same social and political purpose as an expression of civic pride and municipal power. While the cathedrals were outwardly expressions of devotion to God, they were also the result of a very real, if unofficial, competition between various dioceses quite similar to the competition between corporations. Though bishops might have piously disclaimed any such motivation, the desire to construct the ultimate symbol of devotion drove cathedrals to ever higher, narrower and airier extremes. This quest for height culminated in the tallest ceiling of any cathedral, the severed torso of Beauvais whose nave and crossing tower collapsed under the aspirations of its builders,[6] and the colossal spires of Ulm and Cologne. Nor were cathedrals above the supposedly base considerations of commerce, since the chapter house coffers naturally needed replenishment. Throughout the Middle Ages, pilgrimage to holy sites gave rise to an economic system, particularly as relics and their veneration proliferated in Medieval Europe. Cathedrals and churches would proudly exhibit such relics, and pilgrims would travel considerable distances believing in the healing power of a scrap of cloth or shard of bone. The shrines in which they were exhibited often sold devotional medallions as souvenirs,[7] and while the veneration of relics may have waned, the commemoration of the travel today fuels a monstrous industry, and it is rare to find a salient landmark in any city that is not recreated in miniature model form. Today, the skyscraper has displaced the temple as the dominant structure in the built landscape, but the ideals it represents are scarcely any different. Only the veneration of a deity is absent. The goals of commerce, the desire to reach for the heavens, the establishment of a legacy and the inculcation of civic, national and human pride all find their modern expression in the skyscraper.

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[6] Schutz, Bernhard. *Great Cathedrals.* New York. Abrams. 2002. Print.

[7] Finucane, Ronald C. *Miracles and Pilgrims: Popular Beliefs in Medieval England.* New York. St. Martin's Press. 1995. Print.

Chapter 2 : Precedent Research

The concept for the Silver Tower arose from the consideration of several precedent developments that heralded a new direction of skyscraper planning and design. Each one is a transformative project in the history of skyscraper development, marking the inauguration of new design techniques and bold stylistic choices which would define future trends. The first precedent extends all the way back to the original World Trade Center, brainchild of visionary developer and Port Authority chairman Austin Tobin and his protégé, Guy Tozzoli.

Precedent 1: The World Trade Center.

Figure 8: The World Trade Center.

The World Trade Center was constructed on a 16-acre plot of land forcibly assembled by the Port Authority through eminent domain from a ramshackle electronics district called Radio Row. The idea of the World Trade Center was conceived as early as 1945 under Winthrop Aldrich, but the full project did not begin to take shape until the Rockefeller brothers, Nelson and David, sought to rejuvenate Lower Manhattan following the decline of the port and an exodus of businesses to the Midtown business district.[8] In 1958, the Rockefeller brothers published a radical master plan for the transformation of Lower Manhattan into a solely financial district by displacing competing uses. In the midst of this profound transformation would rise what was then the largest commercial development ever imagined, molded around an idea David Rockefeller termed "catalytic bigness," describing a project "whose sheer size and impact would provide the stimulus for further development," and which only a governmental agency could possibly bring sufficient resources to bear to realize.[9] In 1959, Nelson Rockefeller was elected governor of New York State, and began to staff the Port Authority board of

[8] "The Center of the World." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 2003. DVD.
[9] Ibid.

directors with men upon whom he could count to support David's unprecedented and highly controversial plan to bring the Port Authority, heretofore responsible for public infrastructure like bridges and tunnels, into the business of real estate development.[10] Originally intended for a site on the East River, the complex was moved to the west side of Lower Manhattan as a compromise between the governors of New York and New Jersey. Under the agreement the Port Authority would assume control of a badly outdated transit link under the Hudson River (which would become PATH) whose Manhattan terminus sat under a similarly dilapidated pair of office buildings called the Hudson and Manhattan Terminals, which were serendipitously ripe for redevelopment.[11] The placement of the World Trade Center on the site would position it directly over a nexus of public transportation links. In keeping with David Rockefeller's idea of "catalytic bigness," Austin Tobin directed his chosen overseer of the project, Guy Tozzoli, to come up with a complex to house what was simply called The Program: a staggering and nonnegotiable demand for 10 million square feet of floor space. Then, from the director of the Port Authority's public relations office, Lee Jaffe, came a fateful memo that would cement the World Trade Center in the public imagination: "if you're going to build a great project, you should build the world's tallest building."[12] The architect selected for the project, Minoru Yamasaki, produced a number of development options that featured first a cluster of towers, then a single 150-storey building, and finally the iconic 110-storey twin towers.

Figure 9: The World Trade Center's prefabricated facade sections.

The World Trade Center required engineering and systems innovations far exceeding any tower that had come before. The innovative structural system was comprised of a steel core connected by trusses to an outer facade of prefabricated steel sections, eliminating the traditional grid of columns which would otherwise have eaten into rentable floor space.[13] This arrangement was unique in the world of tall towers, with buildings coming both before and after being supported internally, with the outer facade reduced to a mere curtain wall that served the purpose of enclosure. In contrast, the World Trade Center's outer facade contributed significantly to the structural rigidity of the building. This solution was pioneered both to maximize office space and realize Tobin's Program, and to reduce the weight of the building, with the inner core being protected against fire not by concrete but by gypsum paneling.

[10] "The Center of the World." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 2003. DVD.
[11] Goldberger, Paul. *The World Trade Center Remembered.* New York. Abeville Press. 2001. Print.
[12] "The Center of the World." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 2003. DVD.
[13] Ibid.

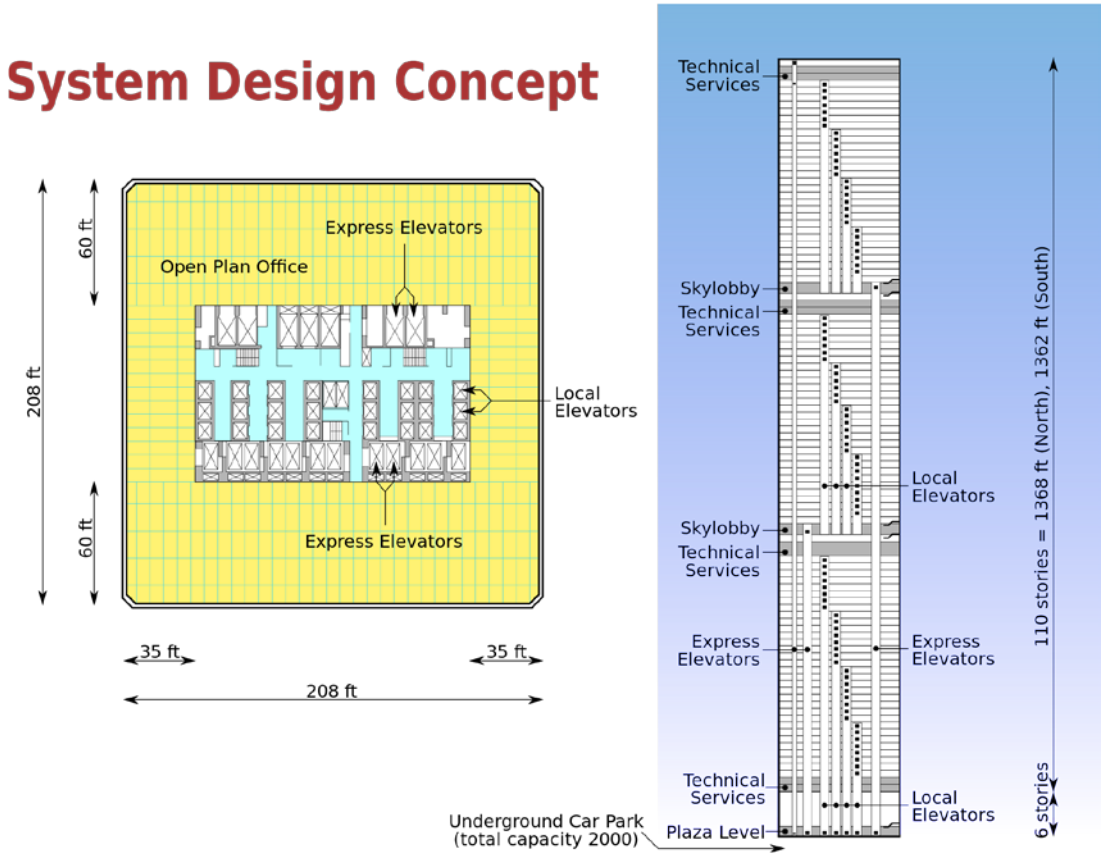

Figure 10: World Trade Center Plan and Stacking Diagram.

In order to move the enormous number of people the buildings would house, Yamasaki and structural engineer Leslie Robertson devised an express elevator system that would essentially divide each tower into three blocks of 33 floors each, with a sky-lobby between them where express elevators would debark passengers who would then take local elevators to their individual floors.[14] The World Trade Center introduced the idea of segmenting a building vertically to allow the elevator system to function over such height, and offers an instructive example of the sophisticated and decidedly undemocratic political maneuvering necessary to construct such buildings. David Rockefeller's idea of "catalytic bigness" proved prescient in more ways than he could realize. While the Trade Center initially struggled for clients, the buildings became the setting for the extraordinary public performance that was high-wire artist Philippe Petit's 1974 walk between the towers, an event which made front page headlines around the world and contributed greatly to the Trade Center's gravitas. They also attracted the very uses that skyscrapers serve best of all: public amenities in the sky, here in the form of a scintillating outdoor observation deck on the South tower, and the award-winning, record-setting Windows on the World restaurant, which food critic Gael Greene lauded by saying, "if money and power and ego can create this extraordinary pleasure, this instant landmark, money and power and ego can

[14] Goldberger, Paul. *The World Trade Center Remembered.* New York. Abeville Press. 2001. Print.

rescue the city from its ashes."[15] According to Tozzoli, the restaurant was the highest-grossing in the world.[16] The growth of the financial services sector in the 1980s and 1990s made the Trade Center more palatable to the office market, and by 1987 the World Trade Center was producing over $133,000,000 per year in net profit.[17] David Rockefeller's bold prediction was proved right, and the Trade Center was a testament to the rewards, both economic and cultural, that came with audacity and risk-taking, and with a certain disregard for democratic processes. Architecture critic Paul Goldberger captured the essence of catalytic bigness perfectly in his 2001 eulogy of the World Trade Center: "people felt drawn to their hugeness, to what they felt was an architectural expression of the greatest self-confidence imaginable."[18]

Figure 11: Philippe Petit's 1974 World Trade Center wire walk.

[15] Greene, Gael. "The Most Spectacular Restaurant in the World." *Insatiable Critic.* 31 May 1976.
[16] "The Center of the World." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 2003. DVD.
[17] Ibid.
[18] Goldberger, Paul. *The World Trade Center Remembered.* New York. Abeville Press. 2001. Print.

Precedent 2: The Shanghai World Financial Center.

Figure 12: The Shanghai World Financial Center.

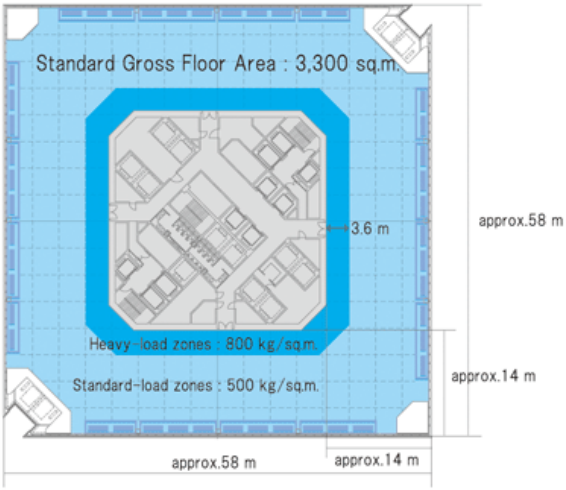

Figure 13: Shanghai World Financial Center Plan.

The second precedent is Kohn Pedersen Fox's Shanghai World Financial Center, completed in 2008. Rising 1614 feet with 101 floors, the Shanghai World Financial Center faced particular demands from wind loading and seismic stresses, and required an innovative and rigorous structural system which was devised by none other than World Trade Center structural engineer Leslie Robertson.[19] The solution was to plane off two corners of the building, creating two sweeping arcs which reduce the tower to a thin line at the top. The pinnacle of the building features a large trapezoidal aperture which greatly reduces the wind load and features an exhilarating viewing platform. The building's structure consists of four mega-columns, one at each corner of the building, two of which bifurcate as the tower rises. Each mega-column is tied to a central reinforced concrete core by outrigger trusses. The outrigger truss design helped lighten the building and allowed faster, more economical construction.[20] The building is divided vertically into 8 sections of 12 floors, sitting on a five-storey podium at the base. Every 12th floor is a dedicated fire refuge area surrounded by a belt truss which ties into the corner mega-columns. Each belt truss is further connected into the ones 12 levels above and below via huge diagonal beams, turning the entire building into one enormous truss. The refuge areas are a post-9/11 innovation in many skyscrapers which create

[19] *The Skyscraper Center*. Council on Tall Buildings and Urban Habitat. 2016. Website. Accessed 21 January 2016.
[20] "Shanghai Super Tower." *Megastructures*. National Geographic. 2008. Television.

Figure 14: The Shanghai World Financial Center under construction, showing the outrigger trusses.

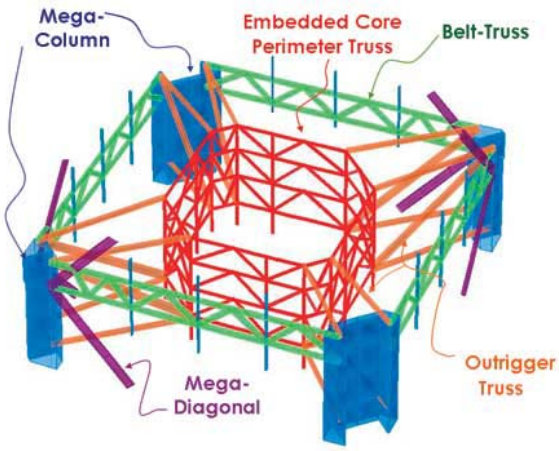

Figure 15: Outrigger truss diagram.

spaces to which occupants can retreat in an emergency. The impacts to the World Trade Center severed the towers' fire stairs and mechanical risers, disabling the sprinklers and dooming anyone above the impact point. The dense smoke of the fires also traveled through the buildings compromising the environment within. The fire refuge floors of the Shanghai World Financial Center provide an area for occupants to shelter in place and await rescue rather than attempt to evacuate. They also feature operable windows to admit fresh air.[21] Sheltering in place would be infeasible if the structure were compromised, but the Shanghai World Financial Center's outrigger truss design is intended to allow the collapse of any one section to be borne by the sections below it, ensuring that the collapse progresses no further than the highest undamaged truss.[22] Another pivotal innovation is the elevator system. While the Shanghai World Financial Center employs a similar express and local division as the World Trade Center, the tower also features elevators running up two of the corner mega-columns. These elevators take people straight to the observation deck and serve the crucial secondary function of evacuating the refuge floors. Each of these elevators can stop at every refuge floor to take any occupants sheltering therein directly to the ground, potentially allowing people above a fire and/or impact point to travel up the tower to the nearest refuge floor and then evacuate down via the observation deck elevators.[23] This critical innovation provides occupants with clear paths of emergency egress both in the core and on the periphery of the building, ensuring that no single accident or attack can cut off all means of escape.

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[21] "Shanghai Super Tower." *Megastructures.* National Geographic. 2008. Television.
[22] Ibid.
[23] Ibid.

Precedent 3: The Shanghai Tower.

Figure 16: The Shanghai Tower.

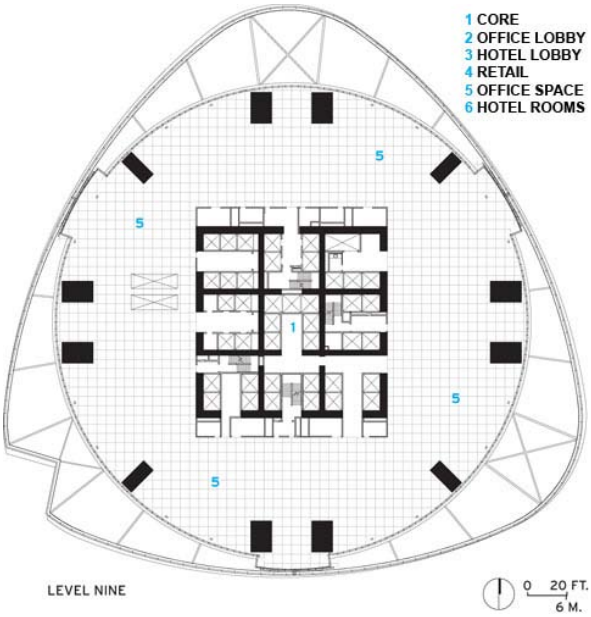

Figure 17: Shanghai Tower Plan.

The third precedent is the Shanghai Tower, designed by Gensler and completed in 2015. At 121 floors and 2075 feet, the Shanghai Tower is, as of its completion, the second tallest building in the world, surpassed only by the 2717-foot Burj Dubai. Owing to its tremendous height, the Shanghai Tower confronts wind loads beyond either of the previous precedents, and responds to this challenge by featuring a complete double skin, essentially divorcing the outer form of the tower from the functional demands of the spaces within. Contained within the outer form is a tubular office tower divided into 9 sections of 15 floors each, separated by two cantilevered floors with rounded triangular plans which rotate about the inner tower like a camshaft, delineating the twisting outer form of the building. The twist was vital to the reduction of wind load, especially in Shanghai which is buffeted by yearly typhoons. In model form, The Shanghai Tower underwent copious wind tunnel testing before the architects finally settled on a 120-degree twist that would reduce wind load and associated sway to an acceptable level without being cost prohibitive.[24] But the outer skin was influenced not only by the need to counter the enormous pressures of wind, but to respond to the unique conditions created by the interstitial spaces that accrue between the inner and outer skins. It was the intention of the architects and builders to produce a new and revolutionary kind of skyscraper, one that would have an inner life for the occupants.

[24] "The Vertical City." *Super Skyscrapers.* PBS. 2014. Television.

Figure 18: The Shanghai Tower under construction.

Figure 19: Shanghai Tower skygarden.

Just as a city features squares and courtyards that facilitate social interaction, so would the Shanghai Tower feature small fragments of courtyard framed by sweeping views of Shanghai for the congregation and interaction of its occupants.[25] These vertical gardens necessitated a minimalist support system for the outer skin so as to prevent too many shadows being cast into them by interstitial structural members, preserving the airy quality the architects intended. It was decided to support each 15-storey section of skin by suspending it from the cantilevered floor above.[26] The Shanghai Tower's outer form is thus an ingenious tension structure hung from each skygarden, being perhaps the most literal interpretation of a curtain wall yet seen in a skyscraper. In this way the architects could pursue the most effective form for wind resistance without imposing any undue restraints on the office space within. But it is the skygarden itself which is the most important contribution of the Shanghai Tower. It is a peculiar idiosyncrasy of the skyscraper that it is simultaneously a public building form and yet fails to foster the same sense of community that so many other public buildings do. Skyscrapers are experienced by the public at large chiefly as a form of urban sculpture. They do not draw the public into them except when they feature some public amenity at the top, like an observation deck or a restaurant. And they do not foster a sense of community for their inhabitants. People who work on different floors or for different firms might only ever encounter each other in lobbies or restrooms. The Shanghai Tower expands the occupants' opportunities for social interaction by having spaces expressly for that purpose, representing another radical development in the evolution of the skyscraper.

[25] "The Vertical City." *Super Skyscrapers.* PBS. 2014. Television.
[26] Ibid.

Chapter 3 : Designing the Silver Tower

Springing from these precedents, the Silver Tower is intended to carry the developments they initiated to the ultimate extreme, and create an exemplar for the future course of skyscraper development that will see the tall building become the central focus of human habitation in an increasingly dense, urban context.

Part 1: The Site.

Figure 20: Site Overview.

Figure 21: Site Close-up.

The first requirement is to secure a site. Here, the World Trade Center development offers an instructive precedent. The Silver Tower is sited on a large assemblage just above Lower Manhattan, bounded by Broadway and Lafayette Street to the West and East, respectively, and by White and Worth Streets to the North and South, respectively. The site is 400 feet by 675 feet and totals 6.2 acres in area. This site was chosen for its centrality, being visually in line with the Empire State Building in Midtown, and for its proximity to a number of New York City Subway stations and public parks. The nearest parks are Columbus Park, Collect Pond Park, Thomas Paine Park and City Hall Park. The site is also located near the terminus of the Brooklyn Bridge, giving inhabitants the option of enjoying the scintillating walk across. This large assemblage is proposed to be acquired through a combination of private buyout and the use of eminent domain by a governmental entity like the Port Authority, using media savvy and legal maneuvering to overcome community opposition. One avenue that will prove critical is the air rights transfer. New York City code allows for the transfer of air rights from site to site. Air rights are the developer's rights to the space above the property he or she owns. In New York and other cities, city code will prescribe a certain limit to what can be built in the form of height limits, Floor Area Ratios (the ratio between the

Figure 22: Site Perspective and Local Parks.

floor area of the building and the land area of the site) lot coverage and, where applicable, setback requirements. Taken together, these codes define the allowable building envelope beyond which a developer may not build without variances. When a building is built below the allowable building envelope, an air rights transfer enables the owner of that property to sell the remaining undeveloped space in the building envelope to another site, and so increase that site's allowable building envelope.[27] The enormous financial forces which must necessarily marshal behind a project of the Silver Tower's scope would grant the opportunity for numerous air rights transfers. Such transfers often involve the preservation of landmarked buildings, as such buildings benefit tremendously from the sale of air rights which creates new funding sources for preservation and upkeep. While many may yearn for the democratic involvement and satisfaction of community voices, it is here propounded that no great accomplishment arises from a desire to appeal to and satisfy every constituency, but rather from dedicated individuals with some combination of money, power and ego who can see projects through to completion despite the fickleness and vagaries of markets and public opinion, often making maximum use of every legal tactic available to them. This single-mindedness and confidence in the vision has in fact characterized every precedent studied and virtually every great landmark ever created, all of which have faced detractors, naysayers and skeptics whose criticisms, if they are remembered at all, amount to footnotes.

[27] "Glossary of Planning Terms." *New York City Department of City Planning.* City of New York. 2016. Website. Accessed 26 January, 2016.

Part 2: The Structure

The second requirement of the Silver Tower is a robust structure suited to the enormous loads of the building and designed to make optimal use of post-9/11 safety and structure improvements. To this end, a study of the damage to the World Trade Center provides a starting point. One major aspect of the Trade Center was that the structure was shielded against fire by a combination of gypsum wallboard and spray-on fireproofing, both of which, while furnishing excellent fire resistance, provided nothing in the way of impact resistance. The World Trade Center was originally designed to withstand the impact of a narrow-body Boeing 707, then the most common passenger aircraft, operating under the assumption that such an aircraft would be lost in fog and traveling at approach speed.[28] Manhattan skyscrapers have been struck by aircraft before, as when the Empire State Building was struck by a B-25 bomber that was lost in fog on July 28, 1945.[29] What the designers of the World Trade Center did not anticipate was than an aircraft would be turned into a purposeful suicide weapon. On September 11, 2001, each of the towers of the Trade Center was struck by a wide-body Boeing 767, a significantly larger aircraft, being piloted at full cruising speed. Nevertheless, the initial impact did not impart catastrophic damage to the skyscrapers, whose structural redundancy ensured the gravity load could be carried by intact columns. However, the fireproofing protecting the structural members of the World Trade Center was extensively damaged by the impacts. The National Institute of Standards and Technology's report on the collapse considered the effect of aircraft and office debris, but admits its estimate of fireproofing damage did not model fireproofing dislodged by the jet fuel itself or the vibrations that resulted from the impact, which reached up to 20 inches at the roof.[30] Despite the towers' withstanding the initial impact, the instantaneous fire that resulted was sufficient to compromise the steel's structural integrity. The fire damage to the steel was twofold: first, the fire caused the steel to soften, and secondly, the uneven temperature loading caused thermal stresses as portions of the steel members expanded at different rates.[31] The final verdict from NIST was that the fire caused the steel trusses supporting each floor plate to sag. Since each truss was connected to the core and the outer facade, the sagging trusses pulled on the exterior columns, causing them to bow inwards until they failed under the stress.[32] The collapse of the World Trade Center was the result of the uncontrolled fire which erupted immediately across multiple floors and the obliterated fireproofing which gave the fire direct access to the steel.

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[28] "The Center of the World." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 2003. DVD.
[29] "Empire State Building Withstood Airplane Impact." *Journal of Minerals, Metals and Materials Society.* Issue 53. 2001. Web. 4-7. Web. Accessed 26 January, 2016.
[30] Gross, John L. and McAllister, Therese P. *Structural Fire Response and Probable Collapse Sequence of the World Trade Center Towers.* NIST. Washington, D.C. 2005. Print.
[31] Eager, Thomas W. and Musso, Christopher. "Why Did The World Trade Center Collapse? Science, Engineering and Speculation." *Journal of Minerals, Metals and Materials Society.* Issue 53. 2001. Web. 8-11. Accessed 26 January, 2016.
[32] Gross, John L. and McAllister, Therese P. *Structural Fire Response and Probable Collapse Sequence of the World Trade Center Towers.* NIST. Washington, D.C. 2005. Print.

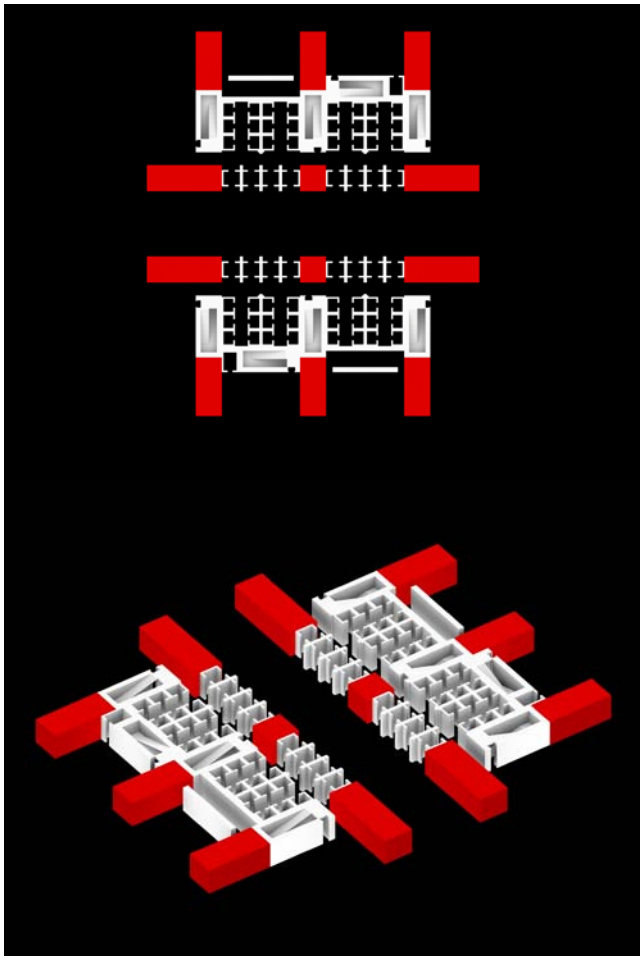


Figure 23: Core Mega-columns.

The Silver Tower relies upon advanced concrete formulations and a design that is intended to ensure no single attack on the building can compromise the structure or the safety features. 12 solid mega-columns constructed with the newest 21,000 psi concrete provide primary structural support. These columns flare out at the base and taper towards the top, reducing the weight of the structure as it rises. The design and layout of each column is predicated upon resisting a 9/11 style attack in such a way that not only can occupants escape the building safely with plenty of time to spare, but the building itself can absorb the impact and eventually reopen. A study was conducted of numerous commercial airliners currently in service. For design purposes, airliners are grouped into categories set up by the Federal Aviation Administration called Aircraft Design Groups or ADGs, which run from Group I through Group VI. Groups I and II are small regional and commuter aircraft that do not pose a threat. Group III aircraft are short haul planes like the Boeing 737 and Airbus A320, and while any aircraft impact with the tower would be destructive of people and property, it would take more than one to impair the tower's structure. The Boeing 767s used against the World Trade Center belonged to ADG Group IV. The 767 is the only Group IV still in production, as competitor aircraft like the McDonnell Douglas MD-11 and DC-10 have ceased production and been phased out of civilian use in favor of cargo transportation. ADG Group V is the most significant, as aircraft in this group have proliferated. The Airbus A330, A340, A350, Boeing 777, 787 and all models of Boeing 747 save one belong to this group, and it represents the biggest threat in terms of the number of aircraft in circulation. ADG Group VI is represented on the civilian market by the Airbus A380 and Boeing 747-8[33] which, while their size presents a serious threat, are not common aircraft due to their cost and the limited desirability of four-engine planes, as airlines generally prefer large twinjets for superior fuel economy and maintenance regimes.

[33] O'Donnel, Michael J. *Advisory Circular*. Washington D.C. Federal Aviation Administration. USDOT. 2014. Print.

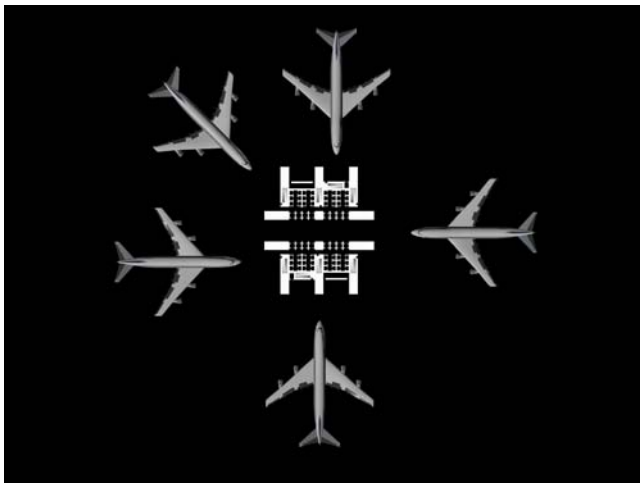


Figure 24: Core Column Layout vs. Possible Impacts.

The core layout of the Silver Tower takes advantage of the layout of aircraft themselves to create a structural system that combines rigidity with openness in resisting attacks. In examining the damage to the World Trade Center, the largest sources of damage to the towers came from the heaviest and most solid elements of the aircraft: the fuselage, fuel tanks and engines. The fuselage is a heavy framework which is supported by a keel beam, and contains a large portion of the aircraft's dead weight load along with the live loads of passengers, crew, and luggage. The engines contain large, heavy turbines, and the wings contain the fuel tanks. All three of these elements are the densest and heaviest parts of the aircraft, whose force is concentrated over a small cross-sectional area thus maximizing the pressure and damage they inflict. These were the only portions of the planes which severed exterior and interior columns, with the outer portions of the wings failing to sever even exterior columns.[34] For the Silver Tower, each mega-column is intended to absorb the impact of an aircraft fuselage. A direct impact with any one mega-column will impart extensive damage, or with larger aircraft, sever it, but the remaining columns will be intact, with the shear walls helping to slow components such as engines. Should an aircraft impact the shear walls directly, debris will be slowed and major columns will be avoided. A section of elevators will be taken offline, but the majority will remain in operation, and any debris that penetrates through whichever wing of the core is impacted will fall into the interstitial space. An impact in line with this interstitial space will mean the fuselage passes harmlessly between the two halves of the core. An impact that passes through the fire stairs themselves will avoid the major structural elements of the building and still fail to take out the fire stairs on the other half of the core. And an oblique impact will be deflected and concentrated by two of the mega-columns, serving to contain the damage. A computerized command and control system can monitor damage to the building and direct evacuees around damaged areas. The combination of advanced concrete formulations and the layout and spacing of the major structural elements ensures that no single impact can prevent evacuation and compromise structural integrity to the point of failure. The concrete itself, coupled with advanced fire control systems will also ensure no failure due to fire.

[34] Kirkpatrick, Steven W., Bocchieri, Robert T. *et alia*. *Analysis of Aircraft Impacts into the World Trade Center Towers.* NIST. Washington D.C. 2005. Print.

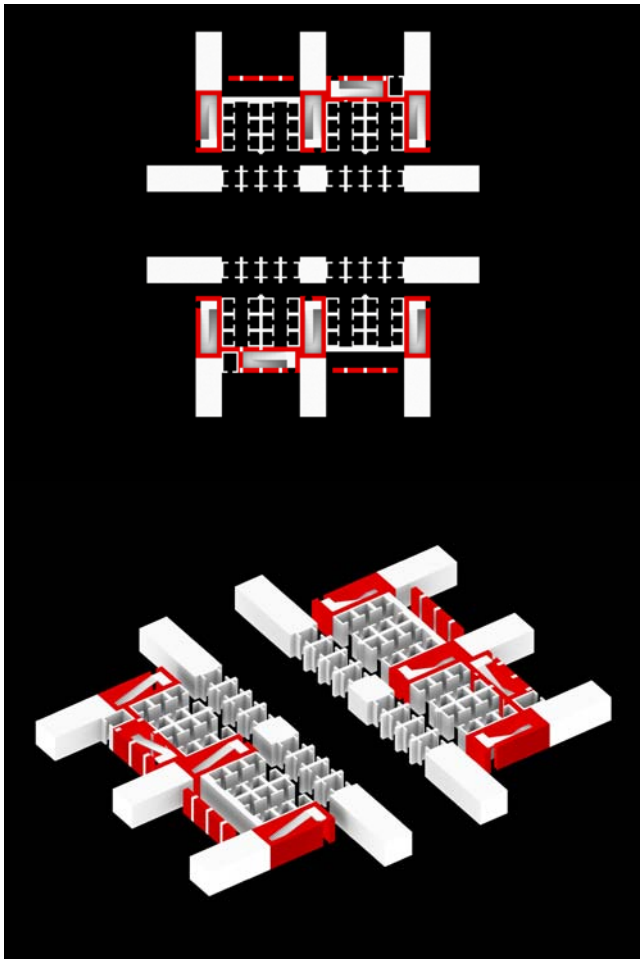


Figure 25: Core Shear Walls.

Between the mega-columns is a web of smaller columns and shear walls that impart additional support and serve to shield vital elements of the core. In the event of an aircraft impact, the shear walls will aid in both slowing debris and compartmentalizing the interior to slow the spread of fire.

Part 3: The Systems

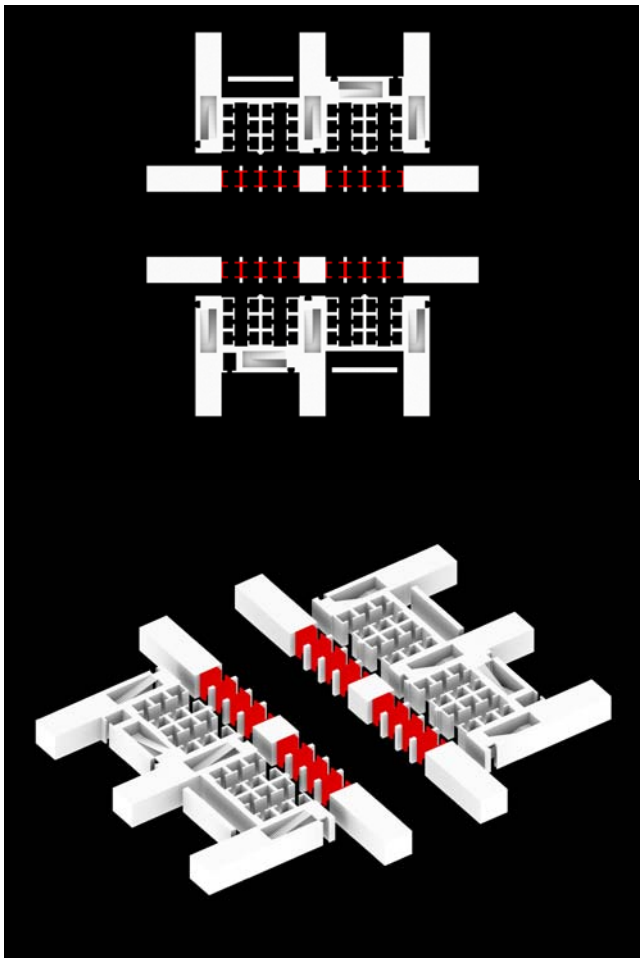


Figure 26: Express Elevators.

The Silver Tower's design approach is heavily influenced by the systems. An extra layer of redundancy and security was sought to enhance occupants' safety and experience of the building. The elevator system is divided between local and express elevators to speed movement through the building, much like the New York City Subway features express and local lines. The express elevators are located in the interior of the core, lining the interstitial space. These double deck elevators take occupants and visitors to the transfer floor sky-lobbies where they can debark for local elevators. The added advantage of their interior location is that the express elevators will feature views into the interior atria and out over New York, enhancing the occupants' daily commute.

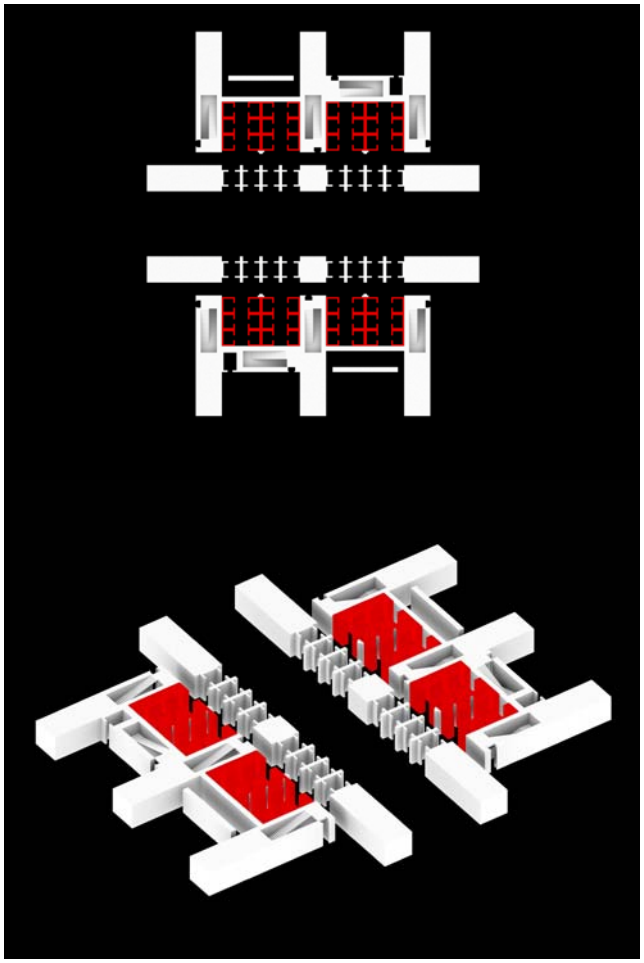
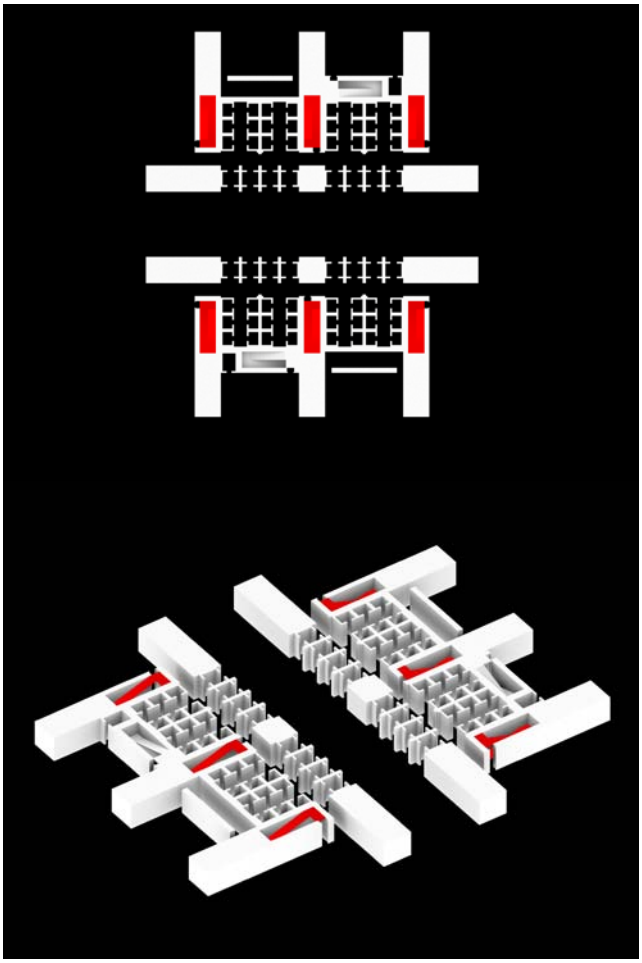


Figure 27: Local Elevators.

The tower's local elevators are arranged into blocks alongside the express elevators. Local elevators extend only the height of each building section, allowing maximum flexibility for maintenance and repair. If any single elevator needs to be taken offline for service, the deficit impacts only that section of the building and the loss can be easily compensated for by remaining elevators. This also ensures that only a small portion of the overall elevator system would be compromised by an aircraft impact. As with the Shanghai World Financial Center, it is intended that the elevator system would remain in operation to speed evacuation in emergency situations.



The Silver Tower possesses six fire stairs, three on each side of the core, encased in the thick concrete shear walls which brace the mega-columns. This imparts significant fire and impact resistance to the fire stairs. Their spacing ensures that all floor area is covered by a 75-foot travel distance. At every transfer level evacuees can move from any one fire stair to any other, ensuring flexibility in choosing escape routes and avoiding damaged areas. The fire stairs are designed to the maximum allowable widths, and feature displays that provide evacuees with real time updates about building conditions, so they can know about any damaged areas in advance and avoid them.

Figure 28: Fire Stairs.

Figure 29: A view down a Fire Stair.

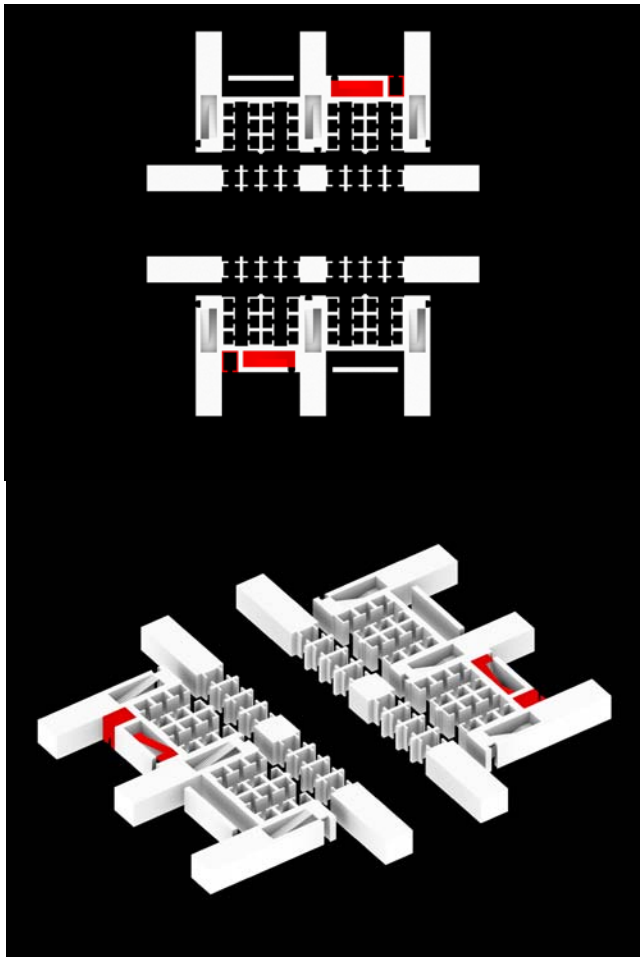
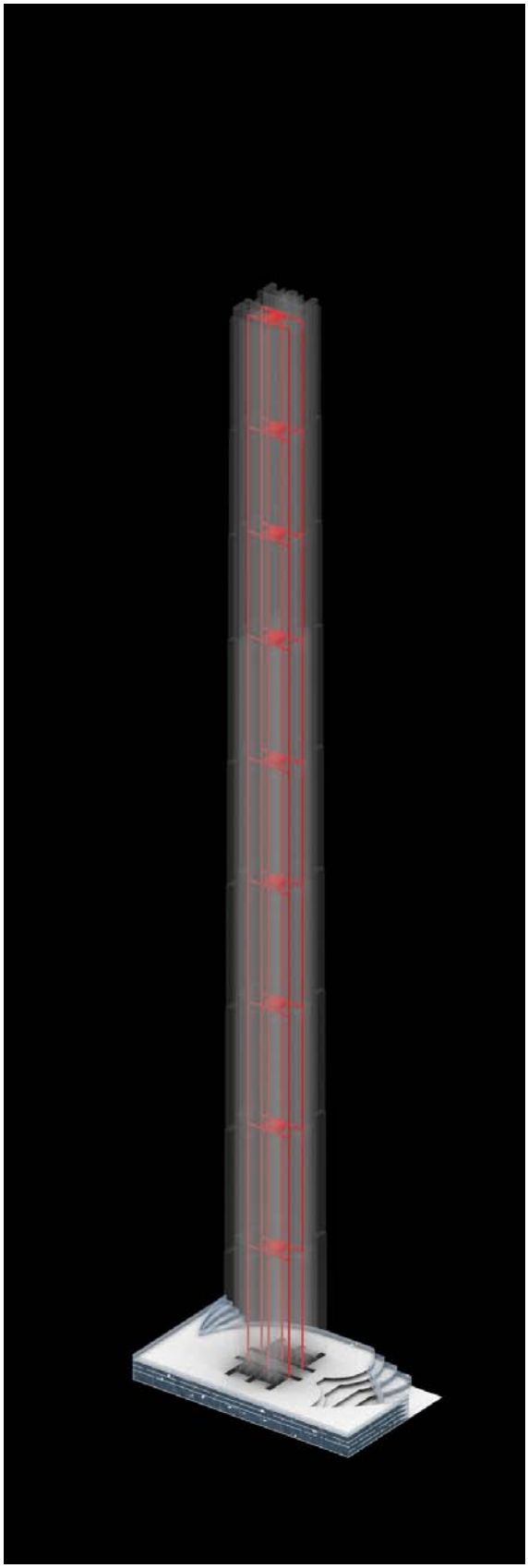


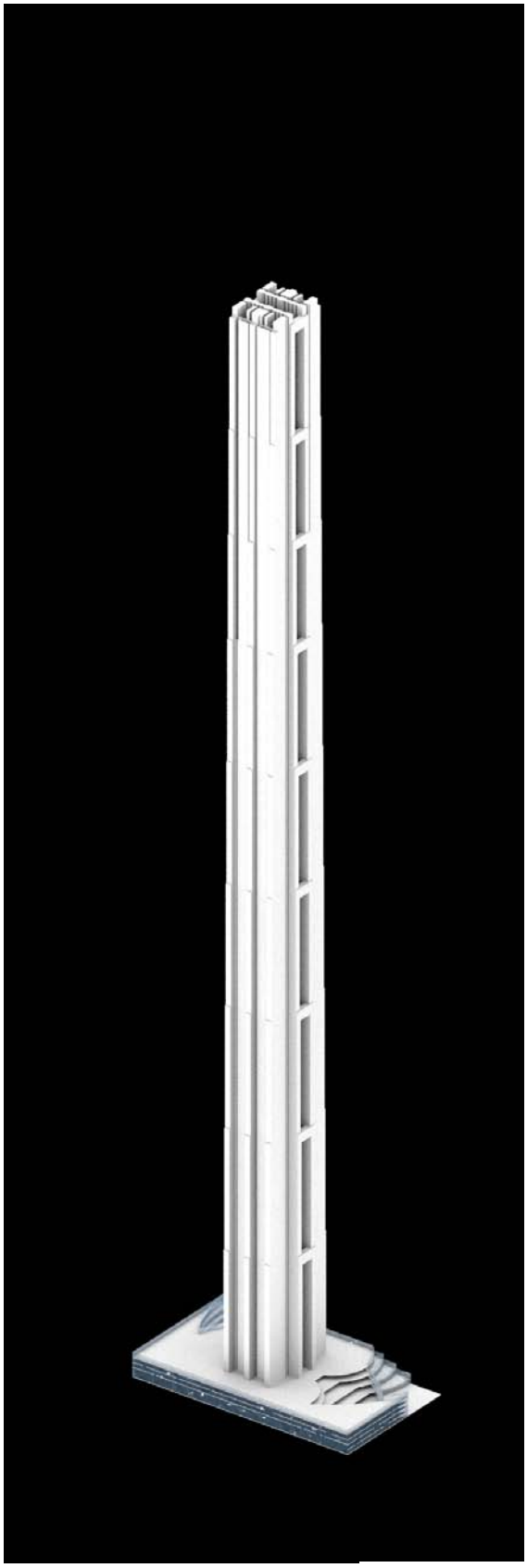
Figure 30: Fireman's Towers.

The Silver Tower possesses two Fireman's Towers, a pair of dedicated fire stairs and elevators reserved exclusively for the use of the fire department in an emergency. The Fireman's Towers ensure than any firefighters entering the building have a separate and unobstructed means of ascent, meaning that they will not be contending with evacuees coming down the stairs at the same time. They also allow for an area in which to stage relevant equipment such as oxygen tanks and gurneys. While the Fireman's Towers do subtract from the building's revenue floor area, they are a vital addition to the safety features of modern buildings.



The Silver Tower is essentially divided into nine individual buildings, and it was decided to maximize the independence of each section. Each package of floors has its own electrical generators, HVAC units, water tanks and pumping stations. This separation allows the building to react dynamically to changing conditions across its great height. The division of the HVAC systems allows the interior environment to be modulated to best respond to changing conditions of temperature and pressure, which will vary greatly across 226 floors, while the division of the electrical systems creates redundancy in case of an emergency. The division of the water supply also creates redundancy for the fire suppression system, so that if an attack were to occur and disable the sprinkler systems of one section, that system could take backup supply from the system above it.

Figure 31: The Division of Systems.



The Silver Tower's core is the structural and programmatic backbone of the building. It contains the elevators and stairways, system risers and ductwork, and provides the building's primary structural support. It is comprised of new formulations of concrete that reach above 20,000 psi of compressive strength and also allow greater performance in tension. Assuming a baseline density of 150 pounds per cubic foot, the combined weight of the core elements is 2,116,859 tons, a figure which greatly out-masses entire skyscrapers. By comparison, the iconic Sears Tower in Chicago weighs in at 225,000 tons, a figure which accounts for the mass of the whole building.[35] The Silver Tower's enormous core defends itself against attack by sheer mass, offering its occupants and visitors a virtually impregnable fortress for their safety and peace of mind.

Figure 32: The Core.

[35] *The Skydeck.* Skydeck Chicago, 2013. Website. Accessed 30 January, 2016.

Part 2: The Program

As befits a building of its enormity, the Silver Tower is intended to be far more than simply a workplace. Building upon the precedent of the Shanghai Tower, it is intended to be a veritable neighborhood in the sky, with amenities meant to cater to all the city's inhabitants rather than just the stratospherically wealthy. The Silver Tower is divided into nine 22-floor sections, each divided by a four-storey set of transfer floors which cantilever out from the main shaft of the tower to define the outer profile. These large floors serve several functions. The first function is a structural transfer, connecting and stabilizing the two wings of the core. The second function is a fire-rated refuge area that ventilates through the outer facade, creating a space that occupants can retreat into to wait out a fire or recuperate as they evacuate the building. These refuge areas also connect all six fire stairs together, allowing evacuating occupants to move between fire stairs in case a section of a particular stair is impassable. The third function is social: the large platforms created by the transfer floors provide for a simulated pedestrian thoroughfare that replicates the sidewalk, complete with greenery and commercial functions all looking out on sweeping vistas of New York City. While typical skyscrapers afford their occupants magnificent views, residential towers do not generally allow for neighbors to see each other or interact the same way one does on the sidewalk inside the building. Office towers are even less conducive to such interactions. The Silver Tower creates spaces where the kind of social interaction normally reserved for the sidewalk can occur within the building itself, generating opportunities for a more cohesive community.

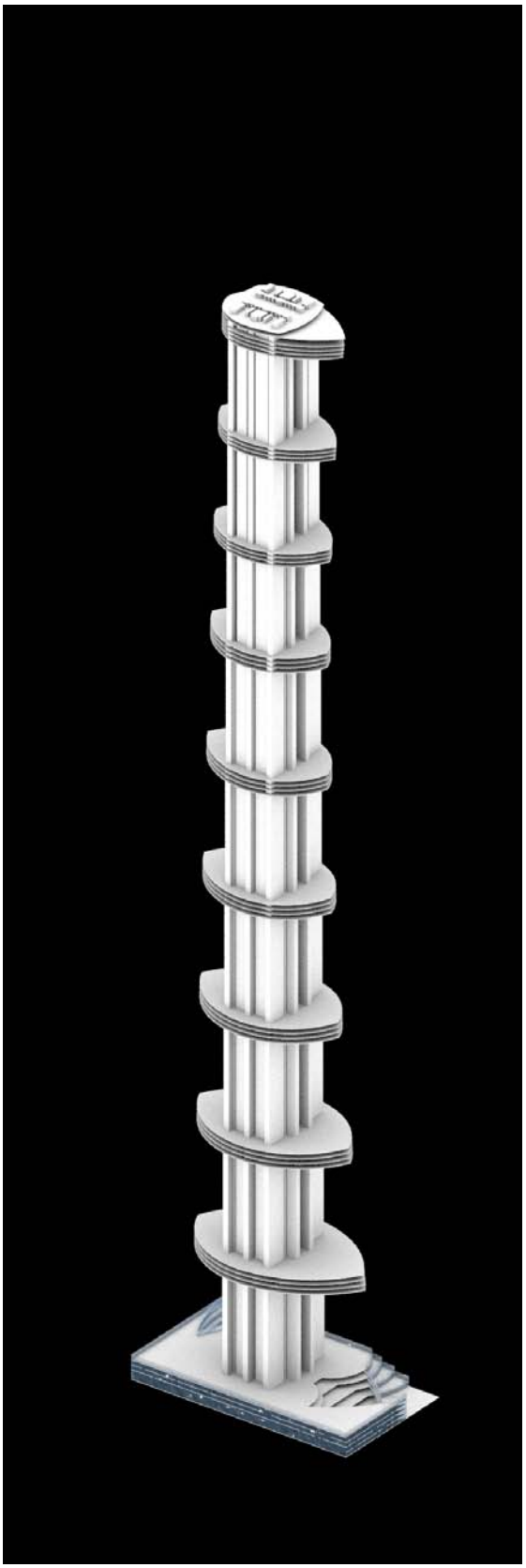


Figure 33: Transfer Floors.

The transfer floor packages of the Silver Tower provide for refuge spaces and fragments of sidewalk and green space in the sky, allowing occupants to socialize in a manner not normally possible in a skyscraper. These floors also define the external form of the building, which is influenced chiefly by the demands of wind resistance. There are a total of 38 transfer levels totaling 2,700,000 square feet of floor space. The uppermost transfer floor package not only braces the core at the top, it also contains a restaurant and the building's public observation deck, situated 3000 feet above Manhattan island. Owing to the building's form, the deck is shaped like the prow of a ship, creating a thematic bridge across time. Facing South, visitors to the deck can look out across the harbor and down at the Statue of Liberty, enjoying a complementary echo of the city's past when immigrants crowded onto the prows of ocean liners to enjoy the same view in reverse.

Figure 34: The RMS Queen Elizabeth approaching Manhattan, circa 1940s.

Figure 35: The prow-shaped Silver Tower Skydeck, looking down on the same view.

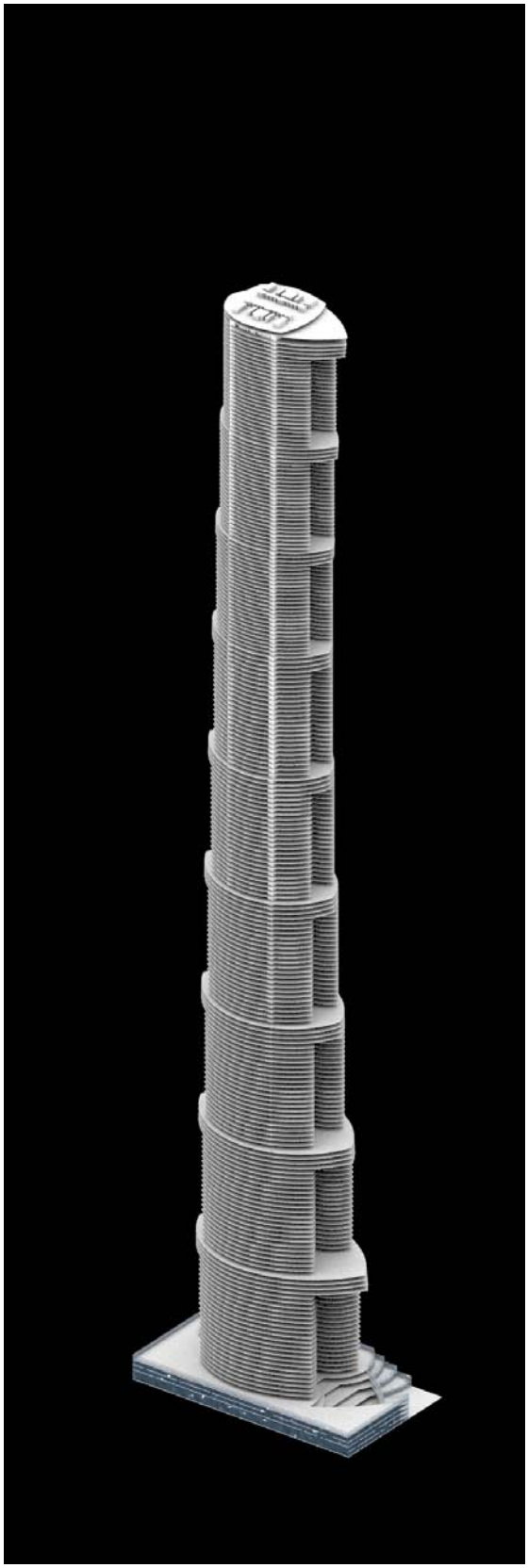


Figure 36: Program Floors.

The program floors of the Silver Tower consist of residential and commercial space, totaling 188 floors with 10,700,000 square feet of floor space. Office and residential floorplans are customizable to suit various tenant needs and/or market segments.

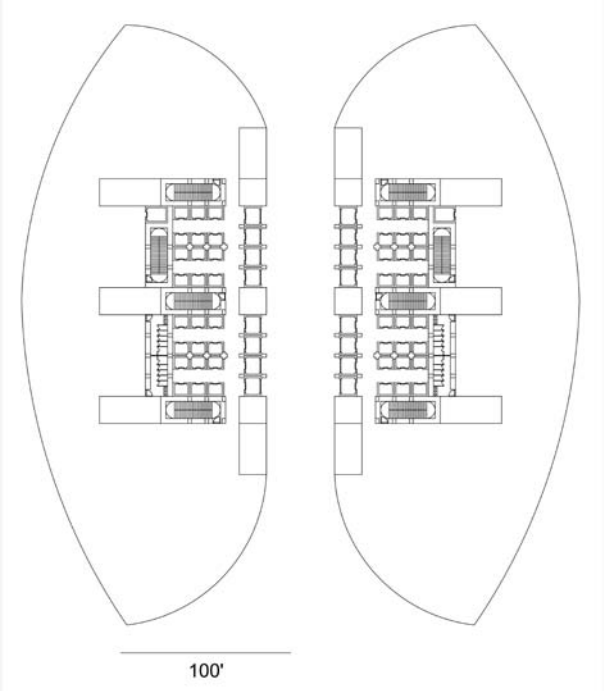


Figure 37: Typical office floor plan.

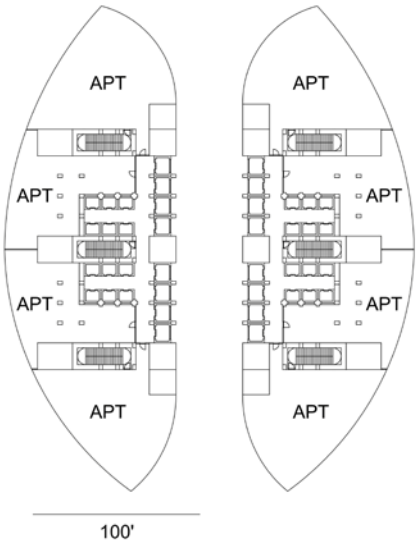


Figure 38: Typical residential floor plan.

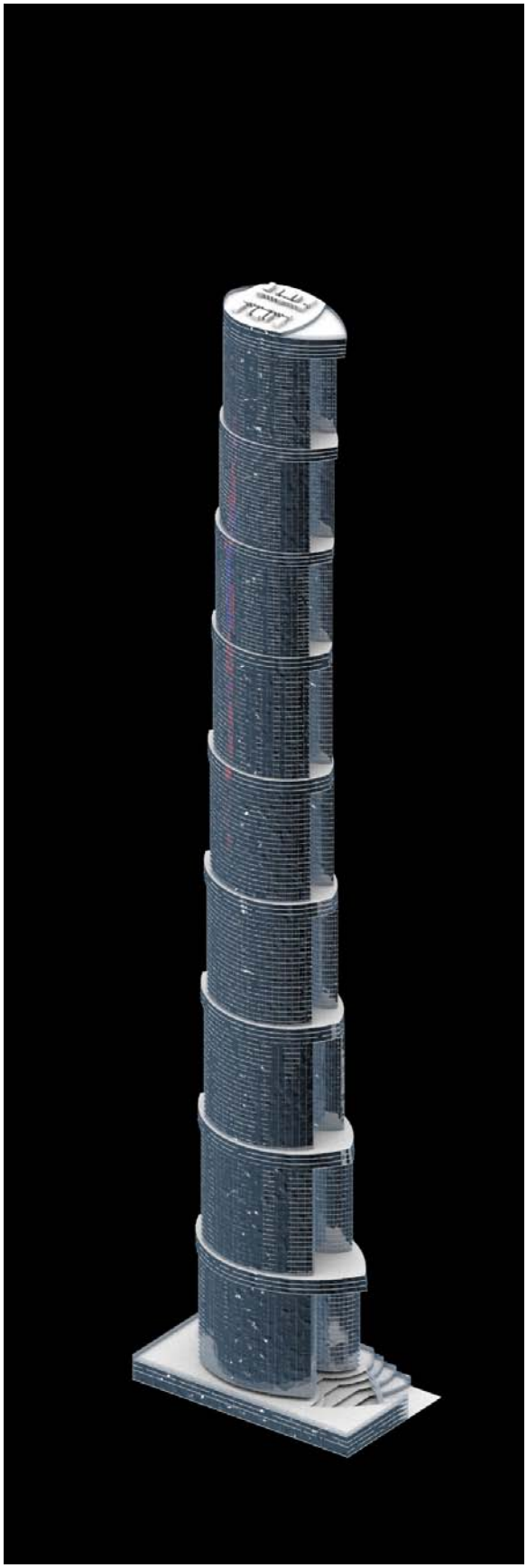


Figure 39: Inner Facade.

Part 3: The Facade

The facade of the Silver Tower consists of two layers. The inner layer encloses the building's programmatic spaces and features integral photovoltaics attached to the spandrels to generate energy. Being on the inner layer, the photovoltaics are protected from wind, debris and ice that would otherwise build up were they on the outer layer, lessening their maintenance requirements.

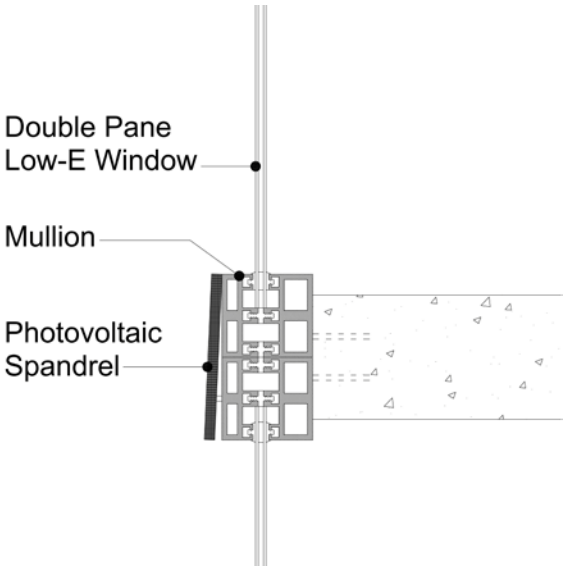


Figure 40: Inner Facade Section.

Figure 41: Inner Facade Assembly.

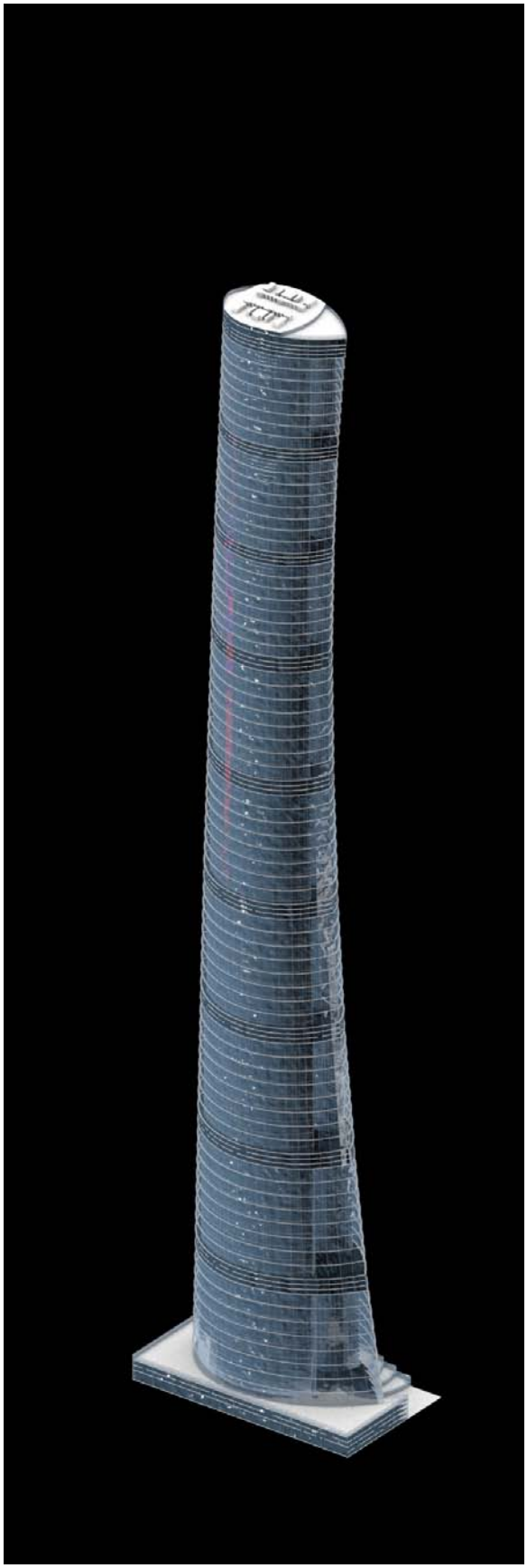


Figure 42: Outer Facade.

The outer layer is suspended between the transfer floors and encloses the large internal atria that contain the building's social areas. This outer layer deals with rainfall by using an integrated gutter to catch rainwater and transfer it through the structural steel tube sections that support the facade. This water is then transferred to holding tanks for use as grey-water for toilets and irrigation of the greenery in the atria.

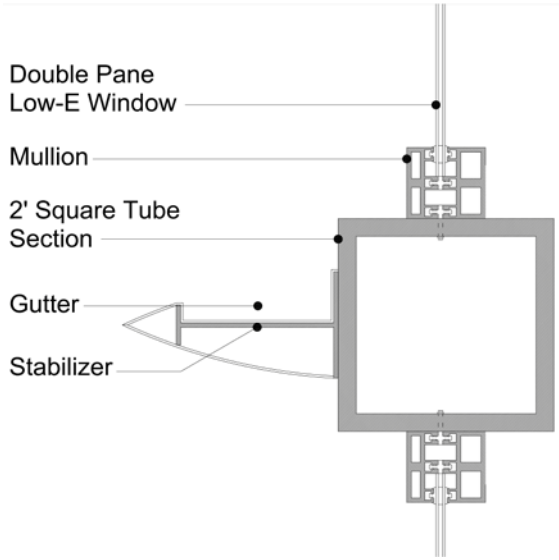
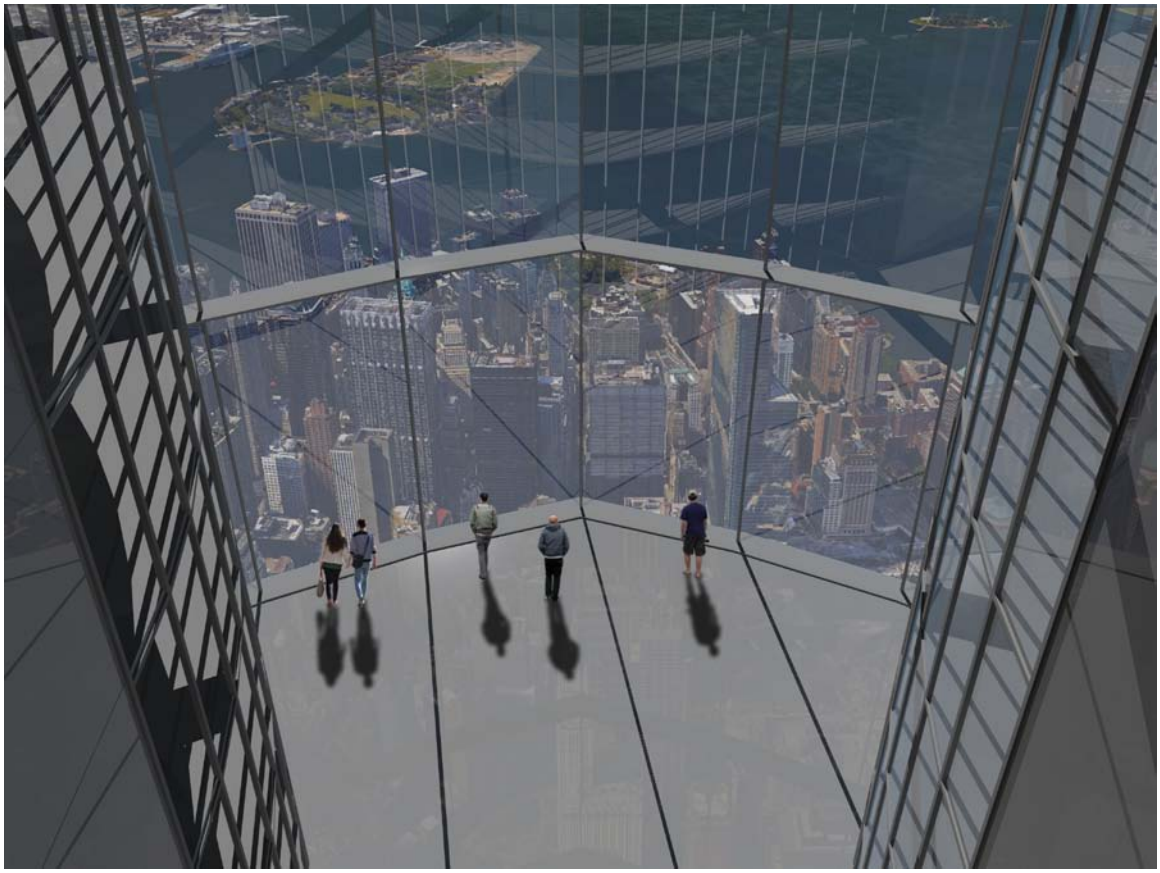


Figure 43: Outer Facade Section.

Figure 44: Outer Facade Assembly.



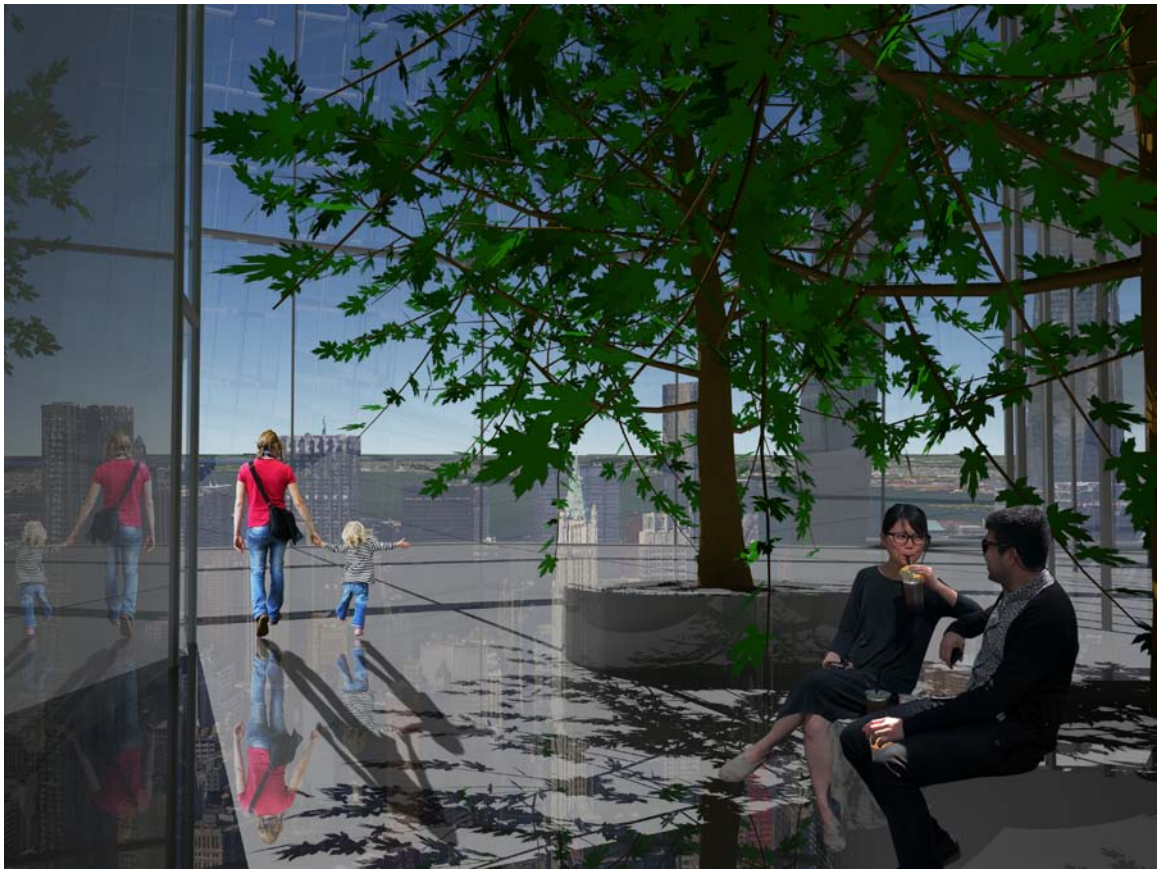


Figure 45-46: Internal Atria.

Part 4: The Base

The base of the Silver Tower started as a simple extrusion of the lot, which was then intersected by extensions of the arcs which define the tower's program and transfer floorplans. These arcs carved out a series of stepped terraces on the east side which created openings facing two of the public parks adjacent to the site, Thomas Paine and Collect Pond. This allows the green spaces at street level to flow into the tower itself and creates courtyards which welcome workers and visitors into the building. On the west side the base confronts a denser urbanity, and so the streetwall is preserved.

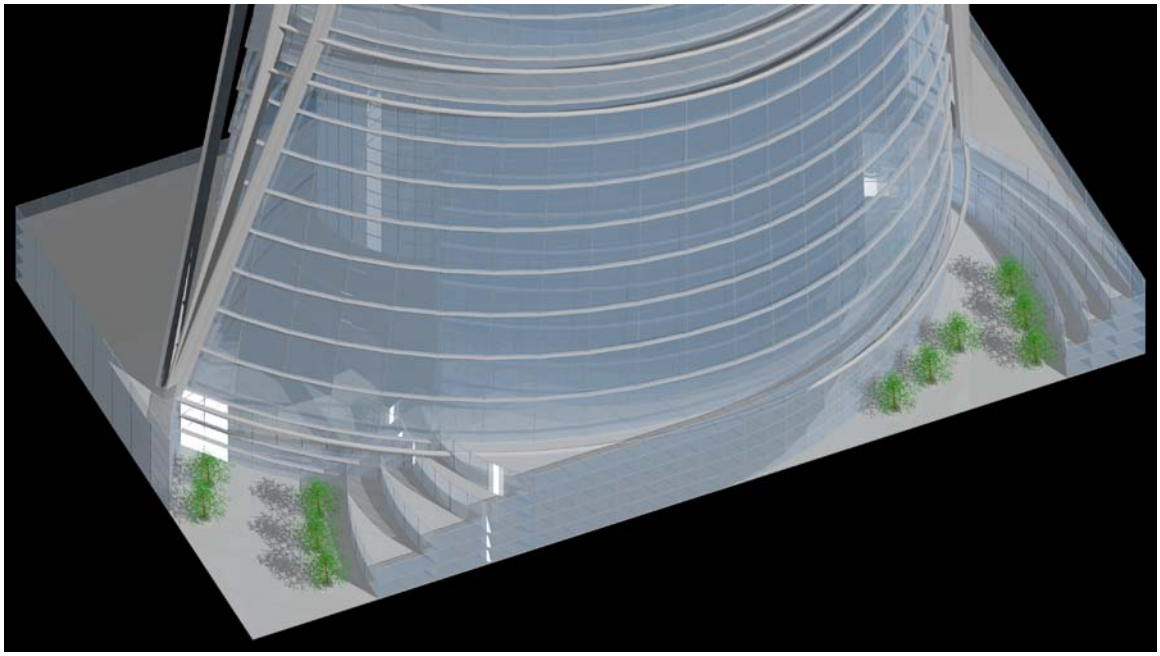


Figure 47-48: Silver Tower base and context.

Chapter 4 : Power

Part 1: Wind Power

The Silver Tower is large enough to be considered a neighborhood in its own right, with 13,400,000 square feet of floor space, larger than the entirety of the World Trade Center. With 8,000,000 square feet, the office portion of the tower alone would support 80,000 workers at an average 100 square feet per worker, resulting in enormous energy demand and associated cost. Several strategies were pursued to lessen the burden the tower would place on New York City's already stressed power grid, the first of which was a design intended to take advantage of the significant wind load the tower would be expected to resist. This wind load was the principal factor influencing the outer form of the tower already seen. The teardrop-shaped plan of the transfer floors was the result of analyzing the wind patterns of New York City. The wind rose taken from John F. Kennedy Airport shows that the primary wind vector of the city lies in line with the tower's site, enabling the building to slice into oncoming wind like an airfoil, creating flows which break over the building and create opportunities for wind harvesting. Unfortunately, as wind turbines have been integrated into more and more buildings, the limitations of many designs are becoming apparent. One notable test case for this is the Bahrain World Trade Center, designed by Atkins and completed in 2008. The towers were designed to take advantage of wind vectors, being oriented to the primary wind direction and sporting three 225-kilowatt wind turbines attached to bridges connecting the towers. The turbines currently produce about 1,300 megawatt-hours per year.[36] Watts are defined as either joules per second or volt-amperes, while watt-hours is utility shorthand. A watt is a unit of power (energy being consumed) while a watt-hour is actually a unit of energy.

1 Watthour = 1 Joule/second * 3,600 second = 3,600 Joules or 3.6 kilojoules.

Once this distinction is clear, it is apparent that the total installed capacity is far greater than what the turbines actually produce, which shall be demonstrated in the following calculations. W is the symbol for watts, J for joules, and s is for seconds. Since the figure given is in megawatt-hours, we must remember to include the extra powers of ten in the calculation.

1,300 mWh/year = 1,300,000,000 J/s * 3,600 s = 4,680,000,000,000 J
1 year = 60 s/min * 60 min/hr * 24 hr/day * 365 day/year = 31,536,000 s
4,680,000,000,000 J/31,536,000 s = 148,401 J/s = 148 kW

[36] "Bahrain Propels Wind Energy to Urban Future." *WorldWatch*. WorldWatch Institute. 5 February 2016. Website. Accessed 5 February 2016.

Figure 49: The Bahrain World Trade Center.

The total actual output of *all three turbines combined* is barely half the rated output of one of them. This discrepancy is explained in several ways. A subsequent review of the Bahrain World Trade Center's design undertaken by Professor Bert Blocken of Eindhoven University discovered that the tower's design relative to the wind was suboptimal. A further complication with traditional bladed gearbox turbines is that they cause uncomfortable vibrations and noise and are often turned off entirely, a problem typified by London's Strata Tower.[37] For the Silver Tower it was clear another direction was needed, especially as servicing turbines at the heights the building reaches would greatly increase maintenance costs. It was decided to turn to the field of piezoelectrics for a new kind of turbine. Piezoelectrics are materials which exhibit the piezoelectric effect, which is the ability of certain materials to either produce electrical current in response to applied mechanical stress, or undergo mechanical deformation in response to applied electrical current.[38] Patents have already been filed for piezoelectric wind turbines which can turn mechanical stresses applied by the wind directly into energy.[39] For the Silver Tower it is proposed to employ long horizontal strips of piezoelectric material. The major advantages of piezoelectric turbines over traditional gearbox turbines is that they can operate at higher wind speeds, as the gearboxes typically limit the rate at which bladed turbines can actually turn.[40] The piezoelectric turbine would also eliminate many of the problems of vibration and noise that currently inhibit the operation of geared turbines.

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[37] "Bahrain World Trade Center is exactly the wrong way round." *News and Press.* Eindhoven University of Technology. 23 April 2014. Website. Accessed 5 February 2016.
[38] "The Piezoelectric Effect." *Nanomotion.* Johnson Electric. Website. Accessed 5 February 2016.
[39] "Piezoelectric-Based Vertical Axis Wind Turbine US20150086368 A1." US Patent and Trademark Office. 26 March 2015. Website. Accessed 5 February 2016.
[40] Kishore, Ravi Anant and Priya, Shashank. *Piezoelectric Wind Turbine.* Society of Photo-Optical Instrumentation Engineers. San Diego, CA. 2013. Print.

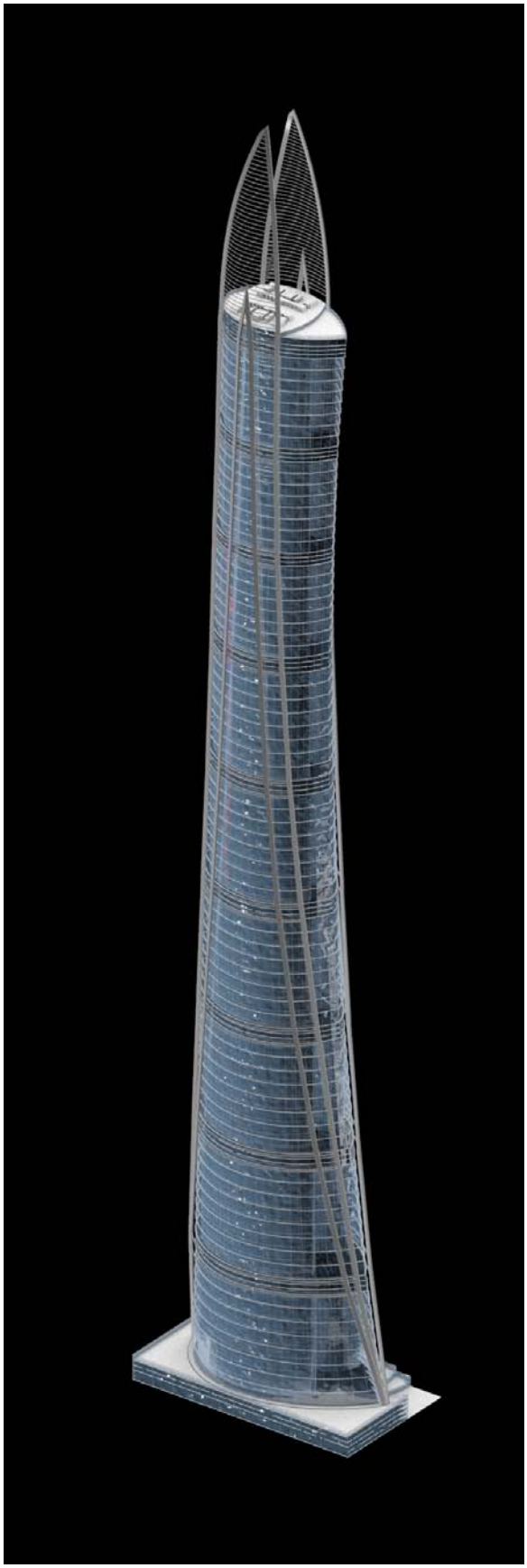

Figure 50: The Arrays.

The last components of the Silver Tower's design are twin external structures that flank the tower and contain the piezoelectric turbines. These arrays also create the crowning feature of the building, a pair of wing-like sails filled with turbines.
The long thin strips of piezoelectric material are intended to flutter in the breeze to produce energy, and unlike geared turbines whose rotational speed is limited by the actual gear mechanism, the only limitation on the fluttering of the piezoelectric turbine is the actual yield stress of the material. The fluttering action will produce harmonic vibrations and noise, and so the arrays are held out and away from the tower itself, with the connections back to the main structure serving to dampen vibrations.

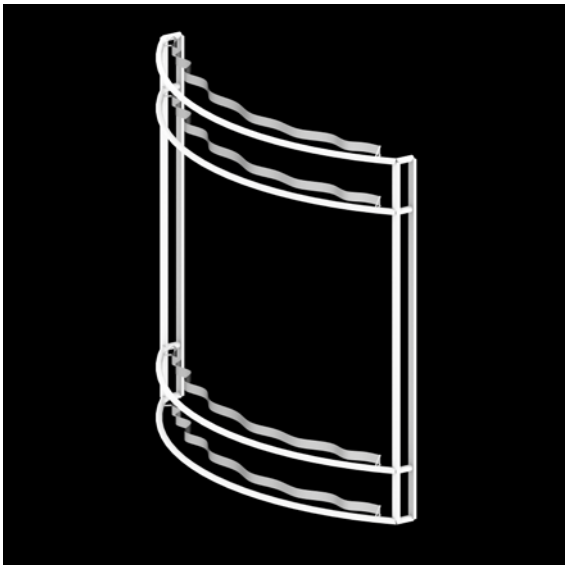

Figure 51: Array and Piezoelectric Turbine Assembly.

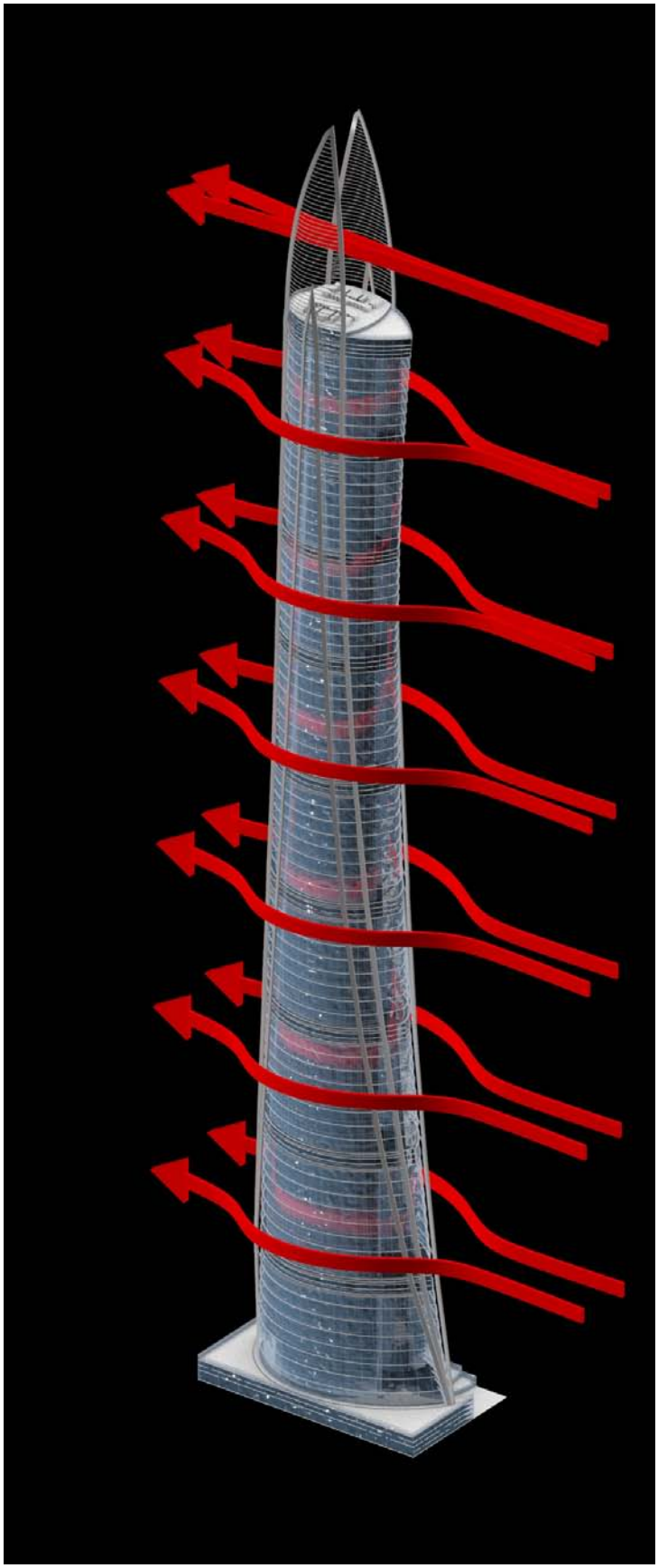

Figure 52: Wind Action.

The Silver Tower site lies in line with several major wind vectors in New York City. The most powerful winds come from south/southwest, while a significant amount also comes from northwest. Since the piezoelectric turbine does not depend as much on wind direction as standard turbines, some portion of the arrays will generate power even with suboptimal wind vectors.

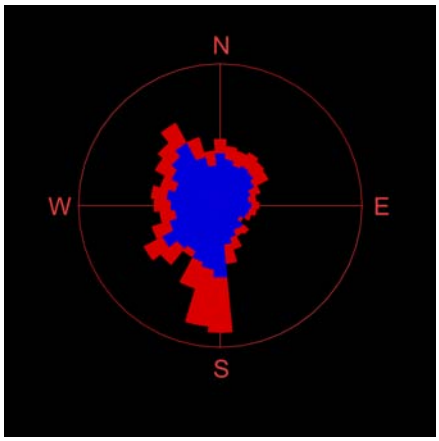

Figure 53: NYC JKF Wind Rose.

Figure 54-55: The Site.

Part 2: Nuclear Power

The aforementioned strategies of solar and wind power are effective supplements, but the Silver Tower is intended to supply all its own power. The final and most significant source that will enable complete grid independence is a new generation of nuclear reactor, the Liquid Fluoride Thorium Reactor or LFTR. Buried deep within the tower's foundations, taking advantage of the enormous weight and thickness of the foundation concrete to double as shielding, this burgeoning new technology solves most of the problems of traditional Water Reactors. The Water Reactor is a proven and capable design originally developed to satisfy the demands of the Navy for long-endurance vessels. The basic components of a nuclear reactor are the fuel, moderator, control rods, coolant, pressure vessel, steam generator and containment shield.[41] The fuel, typically uranium-235, is crafted into pellets and placed into zirconium tubes to make fuel rods, which are then bundled into fuel assemblies. The moderator is any material which slows down neutrons to increase the likelihood of fission, as the faster a neutron moves, the less likely it is to fission any atom it impacts, a relationship expressed by the nuclear cross section.[42] The control rods are made of neutron-absorbing material and are intended to slow the passage of neutrons between fuel assemblies, controlling the rate of reaction.[43] In an emergency, all control rods can be fully inserted into the reactor core to achieve a complete shutdown, a process known as SCRAM. The coolant serves to cool the reactor core components. The pressure vessel is a necessity in water reactors, which operate at temperatures well above the ordinary boiling point of water. However, since phase changes are dependent on pressure, raising the pressure of water (or any other material, for that matter) will also raise its boiling point. Water reactors typically operate at temperatures between 285 C (545 F) and 325 C (617 F) and between 75 and 150 times normal atmospheric pressure.[44] Because of this, failure of a pressure vessel can lead to extremely rapid expansion of the water into steam, resulting in a steam explosion. The steam generator is a heat exchanger which transfers heat to a secondary water line, creating steam to drive a turbine to produce energy.[45] The final component, the containment, is a thick structure of reinforced concrete designed to shield the reactor from damage and, in the event of an emergency, contain any radiation.[46]

While the water reactor has numerous advantages, the downside is that water serves as both coolant and moderator, which can lead to problems. Reactors are designed to have *inherent safety*, a natural feedback mechanism that slows the reaction as the temperature rises. In the water reactor, loss of water means loss of both moderator and coolant, which can lead to dangerous

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[41] "Nuclear Power Reactors." World Nuclear Association. January 2016. Website. Accessed 6 February 2016.
[42] "Glossary." World Nuclear Association. March 2014. Website. Accessed 6 February 2016.
[43] Ibid.
[44] "Nuclear Power Reactors." World Nuclear Association. January 2016. Website. Accessed 6 February 2016.
[45] Ibid.
[46] Ibid.

situations involving residual heat, which is heat resulting from the decay of highly radioactive nuclei called fission products which are the result of fission of fuel nuclei such as uranium.[47] Residual heat must be bled off or it can seriously damage the core, as happened at the Fukushima nuclear plant in 2011, where the tsunami inundated and disabled backup generators used to drive the Residual Heat Removal system, resulting in an eventual meltdown.[48] Another source of danger is the interaction between the zirconium fuel rod cladding and steam, which can oxidize the zirconium to produce elemental hydrogen which can then explode, as also happened at Fukushima.[49]

A competing reactor design began development in 1944 called the Molten Salt Reactor. This design was the result of a development project for the US Air Force which wanted to test the feasibility of nuclear powered strategic bomber aircraft.[50] While the program never resulted in a nuclear powered aircraft, a test prototype developed from the Convair B36 strategic bomber was successfully flown with an operational reactor to test the aircraft's radiation shield.[51] Given the rigors of flight and the problem of water supply in flight, a water reactor was unsuitable, necessitating a new, shock resistant, water-free design.

Figure 56: The Convair NB-36H Crusader. Note the nuclear trefoil on the vertical stabilizer.

[47] "Glossary." World Nuclear Association. March 2014. Website. Accessed 6 February 2016.
[48] "Fukushima Accident." World Nuclear Association. January 2016. Website. Accessed 6 February 2016.
[49] Ibid.
[50] Campbell, Joseph. *Report to the Congress of the United States: Review of Manned Aircraft Nuclear Propulsion Program.* Atomic Energy Commission and Department of Defense. Washington D.C. 1963. Web.
[51] Ibid.

The Molten Salt Reactor was developed at Oak Ridge National Laboratory in Tennessee, and used both uranium-235 and 233 as fuel in a molten mixture with fluoride salts and coolant and graphite as the moderator. This combination allows the reactor to run at much higher temperatures than water reactors but at ordinary atmospheric pressure.[52] Being able to operate at standard pressure without water removes two of the major explosion risks associated with water in the water reactor, namely steam and hydrogen explosions. The MSR also has significantly greater passive safety than the water reactor. Since the fuel mix must be kept molten, in the event of an emergency where temperatures rise beyond design range, thermal expansion of the fuel mix will level off the power output. Additionally, in the event of a power loss, many MSR designs employ a freeze plug at the base of the core which is kept solid by active cooling. If that cooling is interrupted, the freeze plug melts and the molten core contents drain out of the reactor into a holding tank where they cool and solidify, and can be reheated and reintroduced to the reactor core when power is restored.[53] This is a form of passive safety beyond what is found in the conventional water reactor.

The liquid fluoride thorium reactor can employ thorium as a fuel source through a type of nuclear reaction called breeding. Breeding uses a multi-step process to turn fertile nuclei into fissile nuclei. The process first involves a neutron capture. The nuclear cross section mentioned previously refers to the probability that a neutron will fission an atom. If it fails to fission the atom, it may be absorbed by it, which makes an unstable isotope. This isotope then decays through a particular type of decay called beta decay, wherein a neutron decays into a proton and a high energy electron which is emitted from the atom. The result is that the atom in question has kept the same total number of particles in the nucleus but has gained a proton, moving *up* the periodic table.[54] This is the process by which plutonium is produced for nuclear weapons from uranium-238. Similarly, thorium-232 can be bred into uranium-233, which is the basis of the liquid fluoride thorium reactor's fuel cycle. Thorium is much more abundant than uranium, and the molten fuel mixture results in much greater fuel efficiency than solid fuels, greatly reducing waste products. These advantages combine to make MSRs in general, and the LFTR in particular, a very attractive concept for next generation reactors, and numerous developments are currently underway in several countries. As skyscrapers continue to grow, they will increasingly need dedicated power sources that can meet their needs without placing undue strain on aging power infrastructure. Small scale nuclear reactors are ideally suited to meeting those needs, as well as satisfying the demands of disaster preparedness such that, in the event of another Hurricane Sandy or similar natural disaster, the building will be able to keep lights, HVAC, pumps and all other systems online for the safety and security of its occupants and any who may need to shelter inside it.

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[52] "Molten Salt Reactors." World Nuclear Association. January 2016. Website. Accessed 6 February 2016.

[53] "Liquid Fluoride Reactors." Flibe Energy. 2016. Website. Accessed 7 February 2016.

[54] Koelzer, Winfried. *Glossary of Nuclear Terms.* Karlsruhe Institute of Technology. Karlsruhe, Germany. 2010. Web.

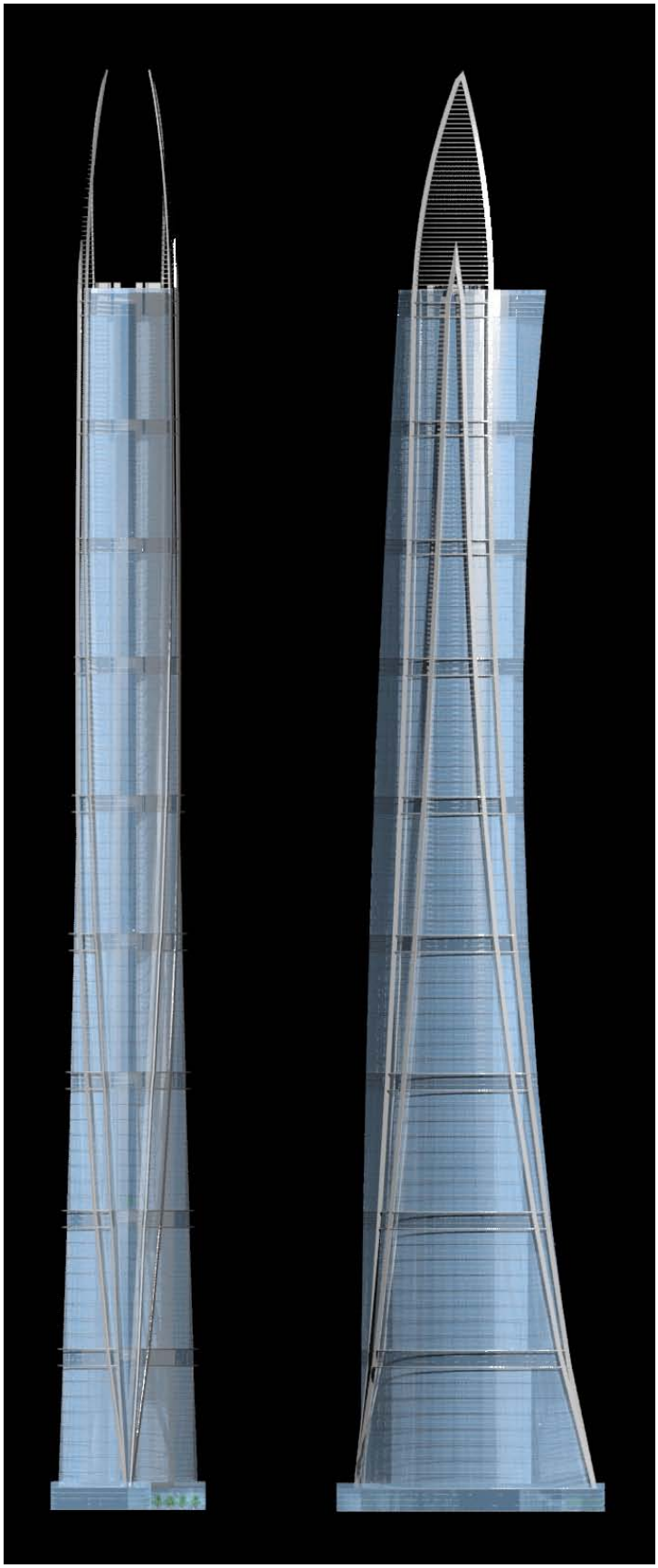

Figure 57: Silver Tower Elevations.

Silver Tower at a glance.

Height to tip: 3648 ft/1112 m

Height to roof: 3248 ft/989 m

Floor count: 226

Floor area: 13,400,000 sq ft

Elevators: 376

Mass: app. 5,000,000 tons

Structure: 21,000 psi reinforced concrete

Power: 50 MW Liquid Fluoride Thorium Nuclear Reactor, supplemented by photovoltaic panels and piezoelectric wind turbines

Chapter 5 : Context and Contrast

One of the most pertinent questions of architecture is the question of context. The meaning of the word context is highly variable, ranging from mere stylistic conformity to complex interrelations between major landmarks both natural and manmade across space and time. Much of the time, in dealing with community activists, most especially of the committed, crusading NIMBY (Not In My Back Yard) variety, it is the former, shallower definition which is in use. NIMBYism is an understandable phenomenon, especially among certain segments of the population. One person might not want a new tower to spoil his or her views, or might not want a new building to cast shadows on his or her property. Oftentimes it is merely a desire not to see the familiar, relatable landscape change in any way. But being able to acknowledge and understand a motivation does not require the architect to condone or accommodate it. The architect is not merely the executor of the client's and community's demands. Architects also have a responsibility to their own artistic integrity, and must balance context against another, equally important consideration: contrast. A landmark is a landmark because it stands out from its surroundings, either due to its height and size, or its stylistic uniqueness.

Figure 58: Pennsylvania Station, circa 1910.

One of the most important landmarks in New York City's history was McKim, Mead and White's Pennsylvania Station, opened in 1910 to great fanfare. The station's demolition in the 1960s helped spark the preservation movement and led to the establishment of the Landmarks Preservation Commission, which was eventually able to protect numerous other landmarks and entire historic districts.[55] The destruction of Pennsylvania Station was a traumatic moment for the city and its residents, who viewed it as a source of enormous civic pride and an indispensible component of the city's fabric, so much so that its loss prompted historians and critics like Ada Louise Huxtable and Vincent Scully to wax elegiac of it. Scully lamented that "we used to come into New York like gods when we came into Penn Station; now we come into the present Penn Station like rats." A similarly mournful Huxtable observed that "we will probably be judged not by the monuments we build but the monuments we destroy."[56]

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[55] "The City and the World." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 1999. DVD.
[56] Ibid.

Pennsylvania Station's loss was traumatic because it was a great public building, and because it was rendered in an architectural style that was universally understood in the West. As a rail terminal, it saw tremendous passenger traffic, so numerous people experienced it on a daily basis. Being on the site for more than fifty years made it a part of the lives of many New Yorkers from their earliest days. Above all else, its sheer size made it unavoidable on the landscape. As a Beaux-Arts structure, based on the Roman Baths of Caracalla, it drew upon a reference that was deeply embedded in the Western psyche, which only added to its preeminence in the built environment.[57]

Figure 59: Sagrada Familia, Barcelona, Spain.

Great landmarks need not draw upon established styles to make themselves stand out, however. Oftentimes, architects who achieve a certain public fame and cachet become a brand name in and of themselves, often associated with an inimitable style. The concerns of contextuality fade into the background when such architects design major public buildings, which are often intended to be signature showpieces. Such buildings are often completely out of style, scale and context with their surroundings, and yet many go on to become beloved public landmarks enjoyed for the very idiosyncrasies that should earn them the ire of those who value tradition and similarity, and even among those who dislike such buildings can be found a certain respect for their audacity and daring.

Of course, context is a thing that changes, with the resultant expectation that a building which is out of context when constructed can become contextual with the passage of time and the construction of commensurate neighbors. It also requires, somewhat paradoxically, a certain humility on the part of the architects of great landmarks to accept that their buildings might not be appreciated until after their deaths. The great Art Deco towers of the 1930s which once soared over New York are today being subsumed by a new generation of towers set to rise higher than ever. The venerable spires of 40 Wall Street and 70 Pine Street, which once ruled the Lower Manhattan skyline, are being gradually overtaken by new towers. The Chrysler building, once the tallest building in the world and the undisputed king of Midtown East, has long since been joined by large slabs of buildings like the Metlife Building and Trump World Tower, and is soon to be utterly eclipsed by the future 1500-foot One Vanderbilt and other redevelopments resulting from the rezoning of Midtown East.

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[57] "The Power and the People." *New York: A Documentary Film.* Dir. Ric Burns. PBS. 1999. DVD.

Figure 60: The Chrysler Building (left) in context, circa 1931.

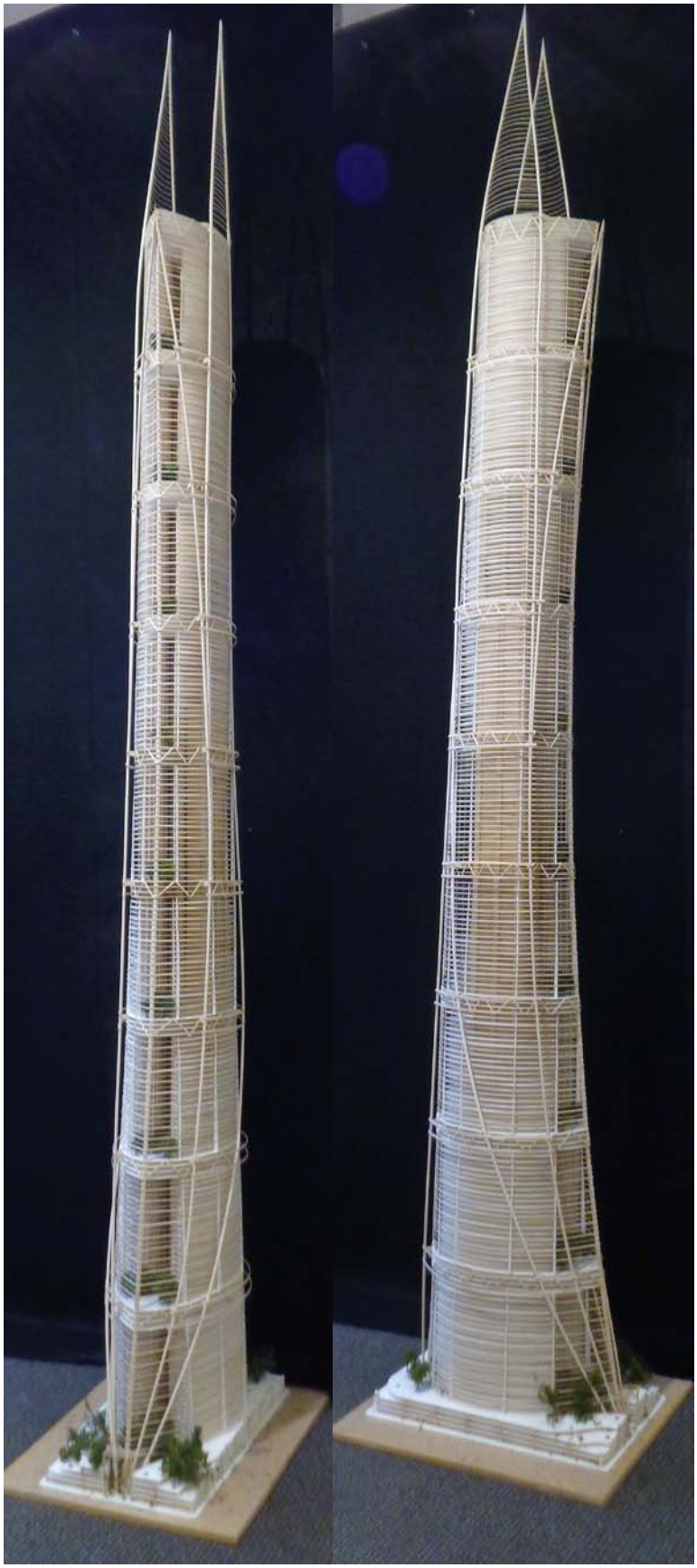
Figure 61: The Chrysler Building with One Vanderbilt, circa 2020.

The reality is that both context and contrast are temporally malleable, and a contrasting building will eventually become contextual through the construction of new neighbors. But there is a more immediate and obvious concern facing those who insist upon contextual appropriateness. Even if the similarly large neighbors do not materialize for whatever reason, contextuality will be established in the minds of the populace by the mere passage of time. Put simply, people will get used to things that are built, even if their resignation never rises to the level of appreciation, and children born after a building's completion will regard its presence on the skyline as naturally and unquestioningly as they regard the sun in the sky.

Conclusion

For the architect who sets out to design a landmark to astonish the world, context, in the sense of conformity with existing scale and style, cannot and should not be a primary concern. The attraction of the landmark is that of contrast and juxtaposition, the audacity of transgression and the spiritual power of grand achievement. Throughout its history, New York has been characterized by such achievement enabled by a can-do spirit of architecture and engineering. This spirit saw the construction of unprecedented marvels, and in this historical context the tallest building in the world is entirely appropriate to New York. The great philosopher David Hume admonished that reason must be the servant of passion. There is much architecture which is utilitarian and rational, but in great architecture, the mundane and the practical must be the servant of the spiritual and the emotional. Great buildings draw together all the world's people in the commonality of wonder. Great buildings bring people joy, make people hope and inspire people to dream, and though they may dwarf people in scale, such buildings magnify their audience in spirit. The buildings that accomplish these feats will outlive their clients, their programs, and their contexts. Perhaps most important of all, in triumphing over economic and physical considerations that skepticism and "common sense" hold insuperable, the great landmark expands the limits of humanity's vision of what is possible. An architect could not wish for a greater legacy.

Figure 62: The Silver Tower triumphant.



The Silver Tower was constructed in model form at a scale of 1/32"=1'0". This resulted in a model 9'6" high. This was done to test the building's structure at a scale large enough to enable it to perform almost as the actual building would. Care had to be taken to ensure all elements were plumb as the model rose. Construction proceeded as the building's actual construction would, with the core rising first, followed by floorplates and finally facade.

Figure 63-64: Silver Tower 1/32" scale model.

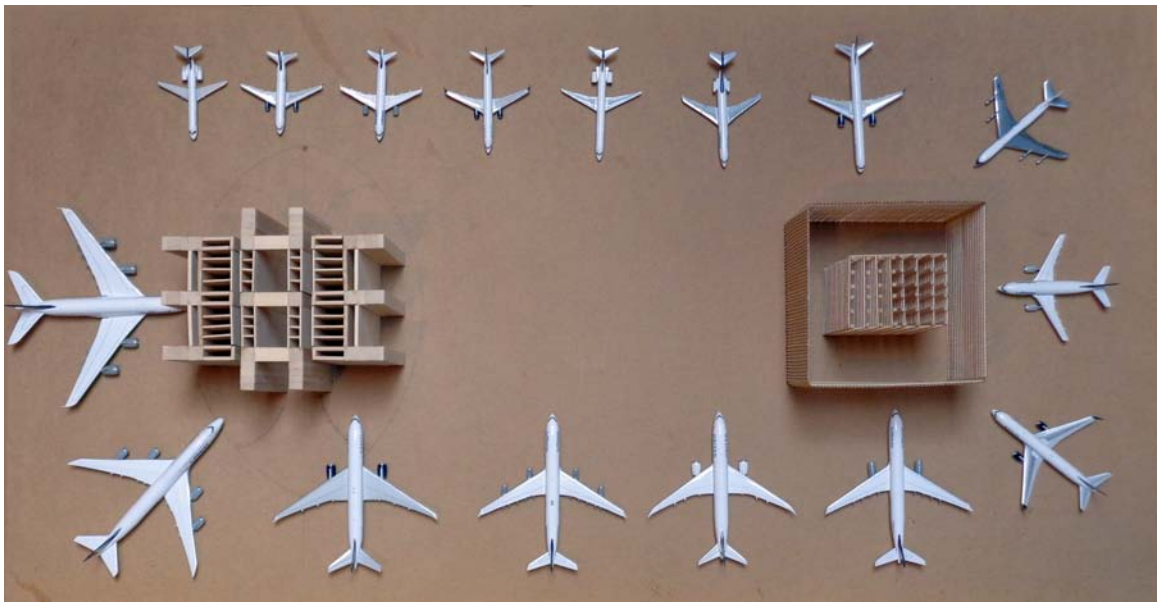


Figure 65: Silver Tower and World Trade Center 1/32" comparison model.

A structural comparison model was built at 1/32"=1'0" to contrast the World Trade Center structure at right with the Silver Tower structure at left. A series of model aircraft at the same scale provides a sense of the threats posed by some past and currently serving airliners to each structural system. The airliners and their Aircraft Design Groups (ADG) are as follows, from smallest to largest, clockwise from upper left.

1. Boeing 717-200: ADG III.
2. Airbus A319-100: ADG III.
3. Airbus A320-200: ADG III.
4. Boeing 737-900: ADG III. (Current largest 737 model.)
5. McDonnell-Douglas MD90: ADG III.
6. Boeing 727-200: ADG III.
7. Boeing 757-300: ADG IV (The 757 was used to attack the Pentagon)
8. Boeing 707-320: ADG IV (The World Trade Center was designed around the impact of this plane.)
9. Airbus A310-300: ADG IV.
10. Boeing 767-300: ADG IV (This was the aircraft used to attack the World Trade Center.)
11. Airbus A330-300: ADG V.
12. Boeing 787-9: ADG V.
13. Airbus A340-300: ADG V.
14. Boeing 777-200: ADG V.
15. Boeing 747-8: ADG VI (The current and largest model of 747. All previous models fit into ADG V.)
16. Airbus A380-800: ADG VI. The largest passenger aircraft yet built.

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