

Article

Tomás Saraceno's Art Work "In Orbit" (2013) against the Backdrop of Space Architecture

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Abstract: When discussing the correlation between technological progress and the development of modern architecture, case studies from the fine arts can be instructive. This article undertakes a close architectural analysis of Tomás Saraceno's walkable art installation "In Orbit" (2013) by releasing previously unpublished technical specifications. A brief history of envisioned and constructed space architecture of the last hundred years—which can be divided into three phases—serves to locate the installation within the currents of predictive utopia, realized architecture and technological development. It becomes clear that Saraceno not only takes up pre-existing architectural techniques, but also develops them further.

Keywords: Tomás Saraceno; "In Orbit"; utopia; space architecture; lightweight structure; flying city; aerospace; art installation; spider web

1. Introduction

In vertiginous heights beneath the glass roof of K21 Düsseldorf, a major museum for contemporary art in Düsseldorf (Germany), a giant spider seems to have woven a horizontal web in different layers. People walk, lie or stand unsteadily within it. "In Orbit" (Figure 1) is a daring walk-in installation by the Argentinian artist Tomás Saraceno (*1973), which was installed with the help of numerous specialists in 2013 and renewed in 2017. It provides the experience of virtually hovering—without a backup device—25 m above the courtyard's ground floor. As I will argue, this installation can be regarded as a self-sufficient artistic creation as much as it addresses the ideas of flying cities as they have been passed down throughout the history of utopia. To prove this, I will show in what precise ways the piece fits into a history of space architecture, which is driven by imagination as much as by the availability of new construction materials and the progress of aerospace. In 1967, the German architect Frei Otto argued in his talk "Wie werden wir weiterleben?" ("How are we going to live on?") that architectural planning which envisioned a changed future society was often called utopian. But in the long term, so-called utopian visions could be much more realistic than common architectural projects. When previously envisioned discoveries and inventions turned into reality, utopia turned into prediction (Otto [1967] 1984, pp. 72–73). When, in an interview in 2011, Saraceno was asked by the curator Marion Ackermann how essential the physical realization of previously utopian concepts was for him—in consideration of the many artistically envisioned but never realized utopian projects throughout the 20th century—he answered in a comparable manner: "The 'physical' realization plays as significant a role as the mental, social and *digital* realization of it . . . it is a learning process experience, a network of social relations that make it *real* in space, inside your subjective brain, as well out there walking upon it [. . .]" (Saraceno et al. 2011, p. 42). Imagination, collaboration and technologically driven realization mutually define each other. They are integral components of what Saraceno calls an ongoing learning process.

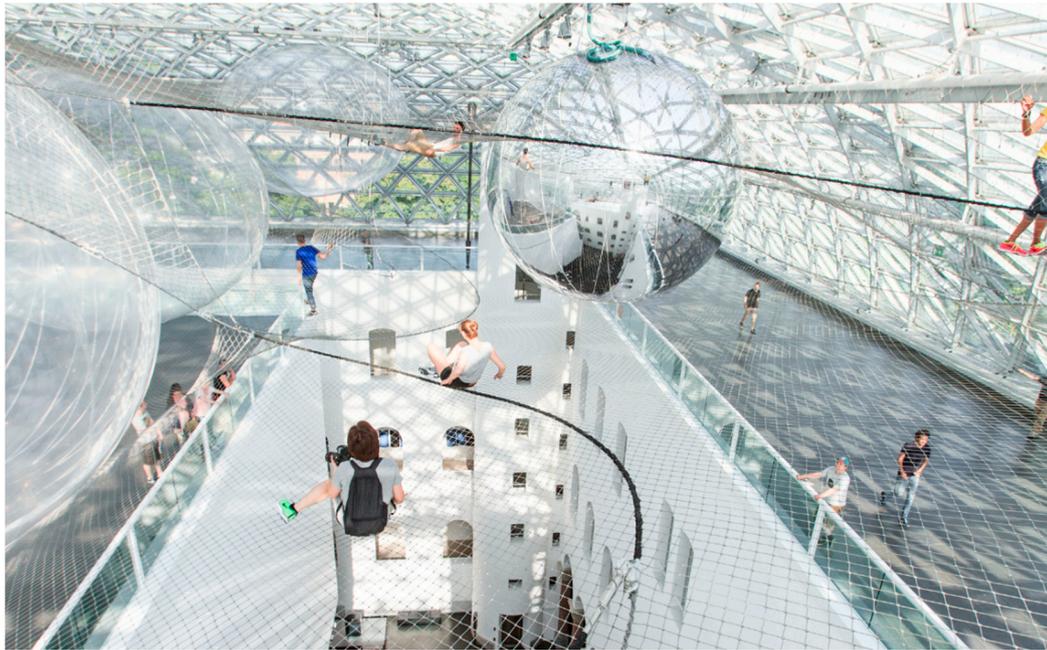


Figure 1. Tomás Saraceno, *In Orbit*, 2013. Solo exhibition at Kunstsammlung Nordrhein-Westfalen, K21 Ständehaus, Düsseldorf, Germany. Curated by Marion Ackermann and Susanne Meyer-Büser. Courtesy the artist; Tanya Bonakdar Gallery, New York; Andersen’s Contemporary, Copenhagen; Ruth Benzacar Galería de Arte, Buenos Aires; Pinksummer contemporary art, Genoa; Esther Schipper, Berlin. © Photography by Studio Tomás Saraceno, 2013.

This article will start with a close description of the structure of “In Orbit” by releasing previously unpublished technical specifications which were collected in an e-mail conversation with Sebastian Steinboeck, an architect at Studio Saraceno, in the summer of 2018 (Steinboeck and Wattolik 2018). Afterwards, a brief history of envisioned and constructed space architecture serves to locate Saraceno’s piece within the currents of predictive utopia, realized architecture and technological development. In so doing, I will concentrate on the last hundred years of space architecture, which I divide into three phases. My inductive strategy basically relies on description and comparison, and aims to identify analogies and differences between different objects of investigation. At the end of my article, I will give a temporary answer to the question as to how technological developments, utopian visions and realized architectures lead to Saraceno’s installation and, conversely, in which ways Saraceno’s work has enhanced new techniques.

2. The Lightweight Structure of “In Orbit”

The lightweight structure of “In Orbit” is built up of three interconnected nets made out of three-millimeter diameter stainless-steel cables which, with the help of large air-inflated membrane shells, form three levels. The lower level hangs about 25 m above the ground of K21’s courtyard and, with 880 square meters, spans the whole walkable area, whereas the middle level covers 475 and the upper level 580 square meters. Because of the complexity of the three-dimensional web and the unpredictability of stress peaks, design decisions were taken with the help of numerous physical models true to scale. These again underwent a process of digitalization and processing with CAD software (Saraceno 2011). A life-sized model served to resolve material as well as structural issues, and helped to compare expected with measured forces. As Steinboeck reports, the major challenge was to ensure the walkability of the installation and to guarantee a rapid evacuation of visitors in case of emergency. Only the life-sized model proved that it was possible to quickly walk within the given time to one of the emergency exits at the two towering staircases of K21. It also helped to find the mesh widths: Too small-meshed nets would have brought about slippery surfaces, whereas too large

ones would have turned—depending on the inclination of the web—into trip hazards. As a result of the empirical experiments, the net’s mesh width varies between 100 mm on the upper two levels and 80 mm on the lower level. All borders and the net’s intersections are reinforced.

The structure is supported by a scaffold wall through which a maximum amount of eight visitors at the time—provided with trekking shoes and overalls—are allowed to enter the construction through a door. Moreover, the net is prestressed by six steel pylons which are anchored in the building’s floor on steel base plates. Ball joints help to absorb vibrations. The web is taut to K21’s roof with the help of so called “branch trees” which uniformly distribute the tensile forces along the border cable: stainless-steel cables bifurcate in two iterations, while diameter is decreasing until a single one-centimeter cable ends with a loop around the glass dome’s construction. The web’s three levels are spread apart from each other by five air-inflated shells in the form of spheres which are made of PVC and are enveloped by PVC-mantled steel nets to keep them in form. Their diameters range between three-and-a-half to eight meters, and they are connected to a pumping system to maintain pneumatic tension. During the summertime, when the glass roof’s environment strongly heats up, valves regulate the increasing pressure. One of the spheres shows a reflecting surface. It is built of a PVC-envelope which is connected to the pumping system and which is mantled by a second envelope out of mirroring foil which contracts when heated, thus forming a homogeneous surface.

The use of stainless-steel cables for a large walkable area such as “In Orbit” is, due to the relatively high self-weight, not an obvious choice. Light nylon fabric would be the standard in comparable settings, e.g., on construction sites. Since 2010, the industrial designers of the collective “Numen/For Use” (Sven Jonke, Christoph Katzler and Nikola Radeljkovic) have been successfully using strings or ropes made out of fabric to create walkable tubes which are lifted several meters above the floor. But the implementation of the textile was not in line with Saraceno’s wish for transparency. Moreover, the airspace of the courtyard would function as the only smoke outlet for the whole building in case of an emergency. Thus, a web out of nylon also conflicted with fire safety regulations. Stainless steel nets have been implemented as fall protection under bridges and helipads, and could serve as a reference point for Saraceno’s project (Steinboeck and Wattolik 2018).

“In Orbit” can be seen in a line with Saraceno’s prior works such as the experiments with (hybrid) spider webs woven by different species of spiders (Figure 2) and space-filling installations with tensioned cables derived from those spider webs—best known is “Galaxies Forming along Filaments, like Droplets along the Strands of a Spider Web,” which was shown at the Central Pavilion of the 53rd International Art Exhibition of the Venice Biennial in 2009 (Saraceno 2009; Saraceno and Schaschl 2017). Particularly noteworthy is Saraceno’s investigation into the three-dimensional scanning of spider webs, which he successfully mastered in cooperation with the Institute for Photogrammetry and Cartography at the Technical University of Darmstadt. Afterwards, various research organizations were interested in the newly developed technique, and contacted the artist’s studio (Saraceno 2009; Saraceno and Schaschl 2017, p. 101). “In Orbit” is also comparable to walkable pneumatic structures such as “On Space Time Foam” (Figure 3), which was installed at HangarBicocca in Milan (2012/2013), and which allowed visitors to walk beneath and upon several layers of inflated plastic foil. In so doing, they were displacing air, and thus affecting the environment of any other visitor in the installation (Saraceno 2014). “In Orbit” can also be seen as part of the overarching project “Air-Port-City” which deals with the realization of flying cities in the form of agglomerating inhabitable spheres (Wesseler 2011, p. 88). Many of Saraceno’s works reflect upon the interconnectedness and entanglement between people and their environments; they show an interest in scientific ideas and experiments such as the concept of the multiverse and the biosphere. Moreover, Saraceno draws inspiration from prevalent scientific and sociological metaphors such as the “galaxy as a spider web” or the “network of globalization” (Saraceno 2009; Latour and Saraceno [2011] 2014). Scholars immediately connect his work with the history of utopian concepts (Scheiffele 2015, pp. 370–72; Wesseler 2011, p. 88).

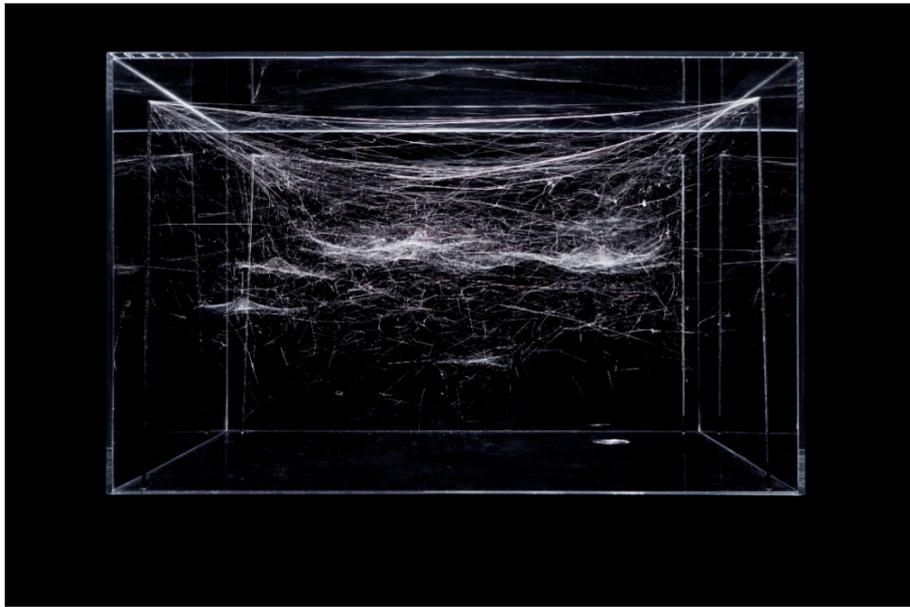


Figure 2. Tomás Saraceno, *Andromeda 6 Cyrtophora citricola* (working title), 2013. Technique: Spidersilk, carbon fibre, LED light, Manfrotto tripod. Courtesy the artist; Andersen's Contemporary, Copenhagen; Ruth Benzacar Galería de Arte, Buenos Aires; Tanya Bonakdar Gallery, New York; Pinksummer contemporary art, Genoa; Esther Schipper, Berlin. © Photography by Studio Tomás Saraceno, 2013.



Figure 3. Tomás Saraceno, *On Space Time Foam*, 2012. Exhibition view Hangar Bicocca, Milan, Italy. Solo exhibition curated by Andrea Lissoni. Courtesy the artist; Tanya Bonakdar Gallery, New York; Andersen's Contemporary, Copenhagen; Ruth Benzacar Galería de Arte, Buenos Aires; Pinksummer contemporary art, Genoa; Esther Schipper, Berlin. © Photography by Studio Tomás Saraceno, 2012.

3. Utopia and Aerospace in Art and Architecture

3.1. Utopian Concepts of Expressionism and Constructivism

The idea of inhabiting outer space is not exclusively modern. But the developments in the field of aerospace throughout the 20th century brought a fundamental change in the way artists and architects approached the issue. Already the first balloon flights undertaken by the Mongolfier brothers in the 1780s turned the dream of flying into reality. In 1863, the photographer Nadar (Gaspard-Félix Tournachon) was the first to take aerial photographs of Paris while riding in a hot-air balloon. And it was also in Paris where, in 1889, a well-known iron structure built for the Paris Exhibition allowed its visitors a whole new viewing experience from above. With a height of 324 m, the Eiffel Tower was, at that time, the world's tallest building. However, the years around 1900 mark a crucial turning point in the history of aerospace. There are the first attempted gliding flight by Otto Lilienthal in 1891, the first ascending airship by Count Ferdinand von Zeppelin in 1900, the first motorized plane flights by the Wright brothers in 1903, and Louis Blériot's flying over of the English Channel in 1909 (Höhler 2007, pp. 31–32). Of course, these inventions had their impact on the fine arts.

In 1906, the Expressionist painter Wenzel Hablik started to sketch flying buildings which should enable mankind to travel the universe. In "Aerial Building" (1907), he noted "technische Dinge sind nie unmöglich/sofern sie auf Naturgewalten aufgebaut sind" ("technical matters are never impossible/if they are based on natural forces"). Another sketch, "The Building of an Aerial Colony" (1908), shows a bundle of six interconnected and inhabitable cylinders in upright positions which were intended to fly with the help of air-screws and sails fixed on the top of each of the roofs. Attached to the outer edges of the habitat's bottom, a narrowing net in the style of a fish trap would encase elevators and provide an anchor for landing. On Hablik's space ships, different races were supposed to intermingle while traveling to the planet Mars, thereby generating a universal family of humankind. Not only fantastic literature by Paul Scheerbart, H.G. Wells, Kurt Laßwitz and Jules Verne inspired the artist's visions, but also concepts about independent communities which were popular against the backdrop of the life reform movement (Feuss 2017, p. 61). Hablik's "Aerial Buildings" would never have navigated through outer space because air-screws and sails depend on the atmosphere's winds and on air resistance.

Just like Hablik, the architect Bruno Taut was deeply impressed by Scheerbart's visions of a crystalline architecture jointly built by a united world population (Feuss 2017, p. 58). Taut's appreciation of the poet's writings and his spiritually charged view of the crystalline and the cosmic is obvious in two of his projects: the "Glashaus" (1914) and the portfolio "Alpine Architektur" (publication 1919/1920). The "Glashaus" was the pavilion of the Luxfer-Prismen-Syndicate at the Werkbund Exhibition in Cologne in 1914. Of special interest is a ring holding its 7.5-m tall, latticed dome made up of rhomboid glass segments in different colors. In the manner of a frieze, it showed engravings with rhymes by Scheerbart that originated from his theory on glasshouses: "Das Licht will durch das ganze All und wird lebendig im Kristall" ("Light wants to penetrate the whole of outer space and comes alive in crystal") (Feuss 2006, pp. 111–13; Kiefer 2015b, pp. 82–83). Later on, in "Alpine Architektur", which was comprised of 30 colored drawings in five parts, Taut designed different kinds of glass architecture overarching the alps and building an expressionistic landscape out of light, color and structures which ought to resonate with the cosmos and house a socially and spiritually advanced society. In the fifth part of the portfolio, Taut focused on outer space as a site for purely fantastic astral buildings such as the "The Cathedral Star" (plate 26) or the "Grotto Star with Floating Architecture" (plate 27) (Schirren 2004).

Later, the Russian Constructivists dreamed of aerospace and weightless architecture, as well as of creating habitats floating above already existing settlements. Very well-known are Vladimir Tatlin's "Letatlin", a flying apparatus worked out in three different variations between 1929 and 1931, and his design for the monument to the "Third International" (1919) which, being inclined by 23 degrees, simulated the rotating axis of the earth. El Lissitzky, who between 1909 and 1914 had studied architecture at the Polytechnic School of Darmstadt in Germany, envisioned in "Wolkenbügel"

(1924–1926) eight statically daring office buildings designed as elevated archways at the crossroads of Moscow's central eight-lane garden ring. The workspaces were located high above the ground. Lissitzky travelled to Berlin regularly and had his first presentation of the "Wolkenbügel" at the Große Berliner Kunstausstellung in 1926. In Berlin, he also encountered Taut ([Meuser 2013](#), pp. 17–21).

But first and foremost, mention must be made of Kasimir Malevich, a contemporary of Albert Einstein who showed continuing interest in physics and astronomy. His stage design for the two-act opera "Victory over the Sun", a collaboration between him, the musician Mikhail Matyushin and the poets Velimir Khlebnikov (prologue) and Aleksei Kruchenykh (script), marked the starting point of nonobjective Suprematism. The piece was performed at Luna Park Theater in St. Petersburg on 3 and 5 December 1913. In the play, the "Victory over the Sun" suspended the laws of nature and bore the aviator, the man of the future. In 1919, after he had moved from Moscow to Vitebsk, Malevich began to translate Suprematism into space and, at the turn of the year 1920, created his first of about 20 "Architectons", stereometric plaster models whose compositions were developed out of deliberately assembled cuboid blocks. On the one hand, the models were derived from Suprematism and were nonobjective. On the other, they were visions of what Malevich in his drawings of that time called "Planits", satellite cities for the aviators who would be circling the earth. In his eyes, the technical realization of aerial cities—he sometimes called them sputniks—was possible. In his sketch "Future Planits for Terrestrials" (1920), Malevich even specified the construction materials concrete, steel and glass, which were modern at that time. Sufficient electric energy for the "Planit" was supposed to be generated from the radial forces of the earth and the moon ([Boersma 2013a](#); [Boersma 2013b](#); [Heinrich 2012](#), pp. 10–11; [Shatskikh 2013](#), pp. 219–21).

In 1928, at the same time when Malevich ended his work on the "Architectons", Georgij Tichonovic Krutikov graduated from Nicolai Ladovski's studio in Vkhutein with the project "Flying City". It consisted, firstly, of an analytic part, a portfolio of 16 tables that reflected the development of transportation, its effect on housing, the world's population growth and the limited amount of land mass. On that basis, Krutikov offered, secondly, a design for a future high-tech city in socialist society. With the aim of protecting the earth's surface, he envisioned a gigantic inhabitable upside-down paraboloid structure which would soar in the air while being stationarily connected to earth-based industrial areas. Noteworthy are the cabins, universal travel capsules which in some ways anticipate the much later space shuttles. They would not only connect the hovering dwellings with the ground, but would also travel along the ground and through water. They were also designed as living spaces with flexible shells adaptable to the inhabitant's position and equipped with collapsible, multifunctional furniture which would provide maximum comfort in minimum space ([Burgos and Garrido 2004](#), p. 18; [Kiefer 2015a](#), p. 49; [Herwig and Thallemer 2005](#), pp. 134–37).

The Expressionists as well as the Constructivists enthusiastically linked their keen concepts for space architecture to the emergence of a future humankind. Especially the sketches by Hablik and Krutikov were obviously informed by contemporary technical developments in aerospace. None of the designs reflected the vital problem which aviators and astronauts face at the fringes of the troposphere, or way above in outer space: radiation, weightlessness, oxygen and diet. Coming back to "In Orbit", the great aesthetic difference becomes obvious. The installation can best be compared to Malevich's "Architectons" inasmuch as it deals under certain preconditions with the problems of a three-dimensional abstract form which, at the same time, can be related to the utopia of the flying city. The site of the installation, under the glass dome of K21, accidentally but nicely resonates with Taut's concept of spiritually charged glass architecture. Indeed, it can be seen as an approach to bettering the world that entering "In Orbit" ought to create an awareness of an inevitable interconnectedness. But in contrast to Taut's pure optimism, Saraceno seems to be motivated by a rather negative future scenario: the possible destruction of the Earth as a basis for life. Referring to Slavoj Žižek, and thereby expressing skepticism with regard to the dynamics of global capitalism, the artist states: "The true utopia is when the situation is so hopeless and impossible to resolve within the coordinates of the possible that you have to invent a new space purely for survival. Utopia is not a matter of imagination—it's an emergency

one is forced to imagine as the only way out, and this is what we need today" (Saraceno et al. 2011, p. 42). However, although we do find some links to Expressionism and Constructivism, the technologies used for the lightweight structure of "In Orbit" were only developed from the mid-1950s on.

3.2. Utopian Concepts and Environmental Planning Since the 1950s

After the First World War, even architects such as Taut turned away from utopian concepts and glass buildings towards the construction of settlements and housing on the subsistence level. During the period following the Second World War, once again heavily destroyed cities had to be reconstructed. At the same time, Western societies saw a strong economic upturn. Due to automation, mechanization and rationalization, most industries strongly increased their volumes. People moved into the cities to profit from the booming sectors of commerce and service, which is why urban planners faced the task of creating new housing space either through redensification or the development of the surrounding areas. Mobility increased, and television became part of the household. A new pop and protest culture questioned the norms and values of the parental generation. Nuclear and missile technology had been strongly supported during war time. In the postwar period, those technologies were further developed for civil purposes. The superpowers competed with one another in a space race. In 1957, the Soviet Union put the satellite Sputnik into orbit and shortly afterwards Sputnik 2, which had on board the first living being, the dog Laika. When in 1961, John F. Kennedy announced his support for a manned moon landing and promised to achieve this ambitious aim by the end of the decade, great enthusiasm for outer space arose among the public. Lunar colonization seemed to be in sight (Düesberg 2013, pp. 9–13; Escher 2017, p. 14; Joedicke 1980, p. 114).

Against this background, a new generation of architects dissatisfied with the current architectural situation returned to utopian architecture. "Archigram" started in 1961 as a rebellious magazine by the London-based group of the same name (Warren Chalk, Peter Cook Dennis Crompton, David Greene, Ron Herron and Michael Webb) and developed into an influential voice of London's vibrant young generation. Adapting the collage technique and the ironic comic style of Pop Art, the issues before 1964 centered on the question of what properties characterized the modern city. Many of the collages were pervaded by motifs of aerospace. One of the leading figures of Archigram, Peter Cook, noted retrospectively that rockets, futurist designs and the idea of the space colonies helped to carry architectural concepts first to the extreme, and then to refer them to concrete architectural tasks (Cook [1964] 1991, p. 29). In 1964, the ideas which Archigram had been developing found their way into two major concepts for living machines. The "Walking Cities" by Herron were designed as huge, bug-like-structures which would even be able to walk through hostile environments. Cook's "Plug-in City" consisted of a large-scale structure which would house technical services and connecting routes. With the help of cranes, capsules could be attached to the structure and removed at any time in order to be replaced by improved elements. Especially the living capsules were supposed to be equipped with a standardized set of machines and electronics to support daily work. Archigram's concepts owed some part to Yona Friedman's "Paris Spatiale" (1959) or Arata Isozaki's project "Cluster in the Air" (1962) inspired by the Metabolists. Richard Rogers, who was a friend of Cook's, adopted, together with Renzo Piano, ideas of a Plug-in City when he designed the Centre Georges Pompidou in Paris (1977) (Cook [1964] 1991, pp. 38–39; Fils 1980; Joedicke 1980, pp. 114–17; Sturm 2016, pp. 8–9).

The context of Archigram is relevant when establishing Saraceno's early investigation of utopic architecture. In fact, after the artist had studied art and architecture at the Universidad de Buenos Aires (1992–1999), followed by two years of postgraduate studies at Escuela Superior de bellas Artes de la Carcova, he entered the internationally renowned Städelschule in Frankfurt, Germany, where he studied with Thomas Bayrle and Cook from 2001 to 2003. Here, he found confirmation for his confidence in the productiveness of utopian concepts, as well as in the application of design principles such as modularity and flexibility.

Even more obvious is Saraceno's connection to Buckminster Fuller and Frei Otto. The two highly influential architects developed, independently from each other, different sorts of lightweight

structures. They were in loose contact with each other from 1958 on. Fuller's point of reference was chemistry. He started out from the assumption that the tetrahedron was the smallest building block in nature, and therefore, would give him clues to the understanding of the overarching structure of the world. Otto, however, saw himself as an engineer who developed his concepts out of biological structures such as the cell, the basis of life (Krohn 2004, pp. 83–84; Wigley 2015, p. 225). Otto certainly derived his designs also from complex natural structures such as animal dens. Referring to the observations that arachnologist Ernst Kullmann had made when using an electron microscope for his studies, Otto emphasized the similarities between cable-net structures and spider webs' meshes, borders and adhesion sites (Otto 1982, p. 20). As Kullmann had stated, spider webs can be regarded as tensile and flexible lightweight structures with meshes which are stabilized through prestressing. Great strength goes with a minimum amount of material (Wirth 1988, p. 7).

Both, Otto's and Fuller's work mark a change in the understanding of architecture from building construction to environmental planning. Otto defined this aspect very well in the sixth chapter of his dissertation titled "Haus, Klima und Großhüllen" ("House, Climate and Large-scale Coverings"). Architecture was not the house in the common sense of the word, but a man-made environment which would provide, with the help of technology, a convenient climate (Otto [1954] 1990, p. 114). Fuller, from 1951 onward, used the metaphor of the spaceship Earth to express his comprehensive view of architecture and contemporary problems such as the accelerated growth and global mobility of the world population or the limitations of natural resources. The design of extraterrestrial structures was not his first concern, whereas Otto, already in the scope of his dissertation on "Das hängende Dach" ("The Suspended Roof") from 1954, reflected on urban large-scale coverings in extreme climate zones such as the Antarctic or outer space. In three sketches, he elaborated concretely on how to cover an Antarctic mining colony with the help of a glass roof held by a cable net supported by an arch, how to design the individual dwellings, and how to regulate the climate within and to provide electricity through wind power generators. Large-scale coverings for extraterrestrial colonies would consist of plastic foil and function to maintain oxygen. It was only seven years later that Fuller proposed the construction of a transparent dome with a diameter of one mile over Manhattan (Krohn 2004, p. 39; Wigley 2015, pp. 226–28). It is worth noting that Otto also gave thought to designing mountain landscapes, but in completely different ways than Taut. Just like spider webs, as Otto wrote, large-scale coverings made out of concrete, steel or glass could be woven over poles or across large valleys to conceal industrial plants, to provide avalanche protection, or to create a suitable climate for greenhouse cultures. In 1971, Otto presented, together with Kenzo Tange and Ove Arup & Partners, a model of a city in the Arctic which was meant to house 40,000 inhabitants. In accordance with the recent availability of synthetics in construction, it was built as a pneumatic tensioned envelope in the form of a shallow dome spanning two kilometers. Between two layers of transparent synthetic material, a cable net was to distribute the tensile forces (Otto 2017, pp. 304, 306–9).

Otto's models and sketches described so far were never realized on site. Nevertheless, since the 1960s, he had developed numerous lightweight structures and large-scale coverings which turned into real architecture, thereby collaborating with experts from different fields. Already in the 1950s, Otto successfully worked together with tent maker Peter Stromeyer and structural engineer Fritz Leonhardt, who had gained experience in lightweight construction for aerospace during the Second World War. Otto's approach was to construct scale models on which he could reliably test the planned structure's behaviors. The Institut für Leichte Flächentragwerke (Institute for Lightweight Structures, IL), founded in 1964, provided an institutional framework for his extensive research. The then newly-developed planning techniques are still of great relevance today (Meissner and Möller 2015, p. 15).

The international breakthrough of both architects, Fuller and Otto, was marked by their national pavilions for the Expo 1967 in Montreal. The world fair, whose theme was "Terre des Hommes" ("Man and his Worlds"), concentrated on the display of lightweight structures, and discussed the future of humankind. The German pavilion by Otto, Rolf Gutbrod and Fritz Leonhardt was based on Otto's novel model of a cable net which is prestressed upwards and downwards in regular alteration through

eye-shaped cable-loops. On site, the net supported an 8000-square-meter fabric out of polyester that was partly transparent, partly opaque, and was lifted by eight masts which were up to 38 m high. As the tensile structure was highly original and its performance not in all ways predictable, Otto built a model on a scale of 1:1 which, from 1968 on, housed part of the IL. The project inspired Behnish & Partner's roof design for the Olympic structures in Munich in 1972. Those again induced Jörg Gribl to involve Otto in the construction of the new aviary for the Munich Zoo Tierpark Hellabrunn (1979–1980). In cooperation with Ted Happold's engineering company, a fine-meshed wire netting out of strips of stainless-steel, corrugated trellis was developed to solve the corrosion problem. Attached to clamping plates, it was held by ten masts up to 20 m high and prestressed by one low point and circumferential ground anchoring. Due to the net's mesh width of 60 mm and its thickness of 3.5 mm, the cage is hardly visible from below. It covers an area of about 5000 square meters, providing a habitat for numerous species of birds, and is accessible to visitors (Meissner and Möller 2015, pp. 27, 63; Otto 2017, p. 380).

Saraceno's "In Orbit" can basically be understood as being developed according to the logic of a suspension roof which gains complexity through layering and walkability. Walkable roofs can be experienced in everyday life on construction sites or be seen on documentations of these. Well-known is a photograph of workers sitting on the shell construction of the Zeiss Planetarium in Jena. In fascination, Lazlo Moholy-Nagy compared them with an aircraft squadron in the air (Escher 2017, p. 150). Another example is the often reproduced motif of a man seen from below walking on the Munich Zoo's aviary (Figure 4). Asked by Ackermann if he was inspired by photographs such as these, Saraceno answered: "Yes, I love Frei Otto . . . I was walking badly for over three months after illegally climbing (and falling) from the roof of the *Olympic Stadium* one night in Munich! I'd say that his buildings need to be navigated and accessible in more dimensions—become an ant or a spider or an astronaut and the world becomes another . . . *In Orbit* at K21 is similar to his aviary at Munich's Tierpark Hellabrunn, but now open to the human-spiders willing to walk along it everywhere [. . .]" (Saraceno et al. 2011, p. 43). To enhance walkability, the mesh-width of 'In Orbit' was designed 20 to 30 mm larger than those of Tierpark Hellabrunn's aviary.



Figure 4. Jörg Griebel and Frei Otto, aviary of the Munich Zoo Tierpark Hellabrunn, 1979–1980. Photograph by Frei Otto, July 1980. © saai | Südwestdeutsches Archiv für Architektur und Ingenieurbau am KIT Werkarchiv Frei Otto.

Just as did Otto, Fuller complemented his calculations with scale models. Already in 1948 during the legendary summer at Black Mountain College, he started to experiment on geodesic domes that were built by the addition of rigid triangular structures which would form an extremely stable hemisphere. In December 1950, Fuller first succeeded in constructing a hemispherical dome out of aluminum tubes with a diameter of 15 m. At the time, aluminum was still rationed in the United States, which explains why Fuller undertook the experiment in Montreal. Although the invention of the geodesic dome is today mainly associated with Fuller, he was not the first to build one. Strictly speaking, the earliest known example of a geodesic structure is the above-mentioned Zeiss Planetarium in Jena constructed by Walter Bauersfeld and Franz Dischinger in 1924/25. It was built on a skeleton out of steel rods covered with meshed wire which was finally sprayed with concrete in a way that resulted in a with a thickness of only three centimeters. The spraying of concrete called the Torkret process was a new practice at that time (Addis 2007, pp. 481–85; Pfammatter 2005, p. 32). In comparison, Fuller had new lightweight cladding systems made of aluminum or plastic at hand, which would allow him to span wider distances and to set up the structures more rapidly than ever before.

More obviously than the geodesic domes, a photomontage entitled “Cloud No. 6” (1962) by Shoji Sadao and Fuller is a source of inspiration for Saraceno (Figure 5). It exemplifies the idea of the flying geodesic sphere. Fuller calculated that the weight of the air enclosed by a one-mile-diameter dome would come close to the weight of the structure itself. If the sphere were heated up by sunlight, it would start to fly. Fuller envisioned several thousand people living in such flying structures. To enjoy moments of conviviality with the inhabitants of other clouds, they would occasionally anchor on mountaintops (Krohn 2004, p. 75). Spheres are a recurring motif in Saraceno’s work. Those at K21 mainly fulfill a space-defining function within the whole of the lightweight structure. Nevertheless, they are associated with the idea of flying. In the context of Fuller’s and Sadao’s “Cloud No. 6”, all visitors to “In Orbit” could be imagined as the sphere’s residents going for a stroll; they turn into an integral part of the scene. Saraceno holds five patents in Germany, of which the first—No. DE 000020206527 U1 registered on 25 April 2002—suggests the use of porous aerogel for multilayered airship envelopes. Aerogels, extremely light substances of lowest thermal conductivity, were originally developed for aerospace. For Saraceno, they open up a new vista for the realization of flying cities (Saraceno et al. 2011, pp. 43, 46–47).



Figure 5. Buckminster R. Fuller and Shoji Sadao, *Cloud No. 6*, 1962. Collage. Courtesy the Estate of R. Buckminster Fuller.

The 76-m diameter “Biosphere” for Expo 67 was the largest dome Fuller and Sadao ever made. It consisted of a steel net which rose up to 62 m in height and whose nineteen hundred meshes were filled with prefabricated, translucent Plexiglas elements. In fact, their standardized size determined the dimensions of the structure. A computer regulated the ventilation and lighting of the building. Mark Wigley has set out the often-neglected material effect of the “Biosphere’s” Plexiglas which gave the structure the appearance of a “huge plastic ball” (Wigley 2015, pp. 134–35). Only from the 1960s on have prefabricated synthetic elements—for shell structures, facade claddings or floor coverings—been available in the building sector. Synthetics became very fashionable after they had entered the market. Artists and architects used them for designing interactive sculptures mimicking and reflecting living capsules (Hegger et al. 2006, p. 90). In London, for example, Archigram presented the “Cushicle” (1966), a one-person habitat in the form of an inflatable plastic sphere with mattress included. In Vienna in 1967, the architects and artists group Haus-Rucker-Co (Laurits Ortner, Günter Zamp and Klaus Pinter) staged the “Ballon für Zwei” (“Balloon for Two”), a colorful balloon made out of PVC and offering space for two persons (Figure 6). It was attached to a steel construction and held out of an apartment’s window in Apollogasse 3 in Vienna. In 1969 in Amsterdam, Jeffrey Shaw and others walked on water with the help of a 3-m-high plastic balloon shaped like a tetrahedron and accessible through a zipper; and in 1971, Coop Himmelb(l)au (Wolf D. Prix, Helmut Swiczinsky and Michael Holzer) used the same principle to walk a “Restless Sphere” with a diameter of four meters through Basel (Herwig and Thallemer 2005; Bina 2007). As is the case with many of Saraceno’s installations, artists and architects working with plastic spheres during the second half of the 1960s intended to create an altered form of spatial perception.



Figure 6. Haus-Rucker-Co, Ballon für Zwei, 1967. Installation view Apollogasse, Vienna. © Haus-Rucker-Co L. u. M. Ortner.

Fuller's dome, which housed seven platforms that were interconnected by the world's longest escalator (37 m in length), presented the latest developments in American aerospace. On the highest platform, the requisites of the forthcoming Apollo 11 mission to the moon featured capsules, satellites, lunar excursion vehicles, parachutes and, of course, the astronaut's aluminized nylon space suit with a spherical helmet made out of fiberglass and Plexiglas wrap-around visor. The latter resonated formally with the building. Protected by the synthetic shell of his space suit, Neil Armstrong, on 20 July 1969, was the first man ever to set foot on the moon (Fuller 1985, pp. 206–7; Krohn 2004; Wigley 2015).

3.3. Space Architecture for Long-Term Ventures Since the 1970s

With the continuous progress of aerospace since the 1960s, and especially with astronauts' prolonged stays in outer space since the mid-1960s—even before the first Soviet orbital station “*Saljut 1*” (1971) and the first American “*Skylab*” (1973) were launched—the interior design of space ships and space stations turned into a necessity. When, in October 1964, the multiseated space ship *Woschod 1*, part of the Russian program *Wostok*, was intended to transport three astronauts for up to five days into space, living space was to be added to the technical work space. Galina Balaschowa, an interior designer married to one of the physicists of the Experimental Design Bureau (OKB), was commissioned to develop the design of Russian spacecrafts such as the “*Soyuz 19*” and the orbital station “*Mir*” (1996–2001). “*Mir*” later turned into a design model for the “*International Space Station*” (ISS), which was launched in 1998 (Demydovets 2013). At the same time, mainly since the 1990s, test stations for isolated ecological systems such as “*Biosphere 2*” (since 1991) in Arizona, USA, or comparably, the “*Eden Project*” (since 2001) in Cornwall, England, have been working on methods to maintain human life in outer space or to create an awareness of terrestrial nature and the urge to preserve it. (Sloterdijk 2004, pp. 350–56). Even if space stations such as “*Mir*” or “*Skylab*” (1973–1979) already had allowed prolonged stays in orbit, only the turn of the millennium marked an obvious shift from short-term pioneering expeditions to long-term projects such as the colonization of space and tourism (Leach 2014a, p. 10). The ISS—built as a flexible and expandable modular architecture (Leitenberger 2010; Adams and Jones 2014)—has, since 2000, been providing a continuously inhabited international research platform for microgravity investigations such as biotechnology, material science and technology development. As the private space company SpaceX recently—on 18 September 2018—announced through the international press, the Japanese billionaire Yusaku Maezawa will, in 2023, be the first private person to travel to the moon. Maezawa plans to invite eight people, preferably artists, to join his trip.

To give a brief insight into design development since the 1980s, two architects will now be exemplarily introduced. Between 1980 and 1987, the London-based architectural office Future Systems (Jan Kaplický and David Nixon) worked on three designs for the NASA program: a “*Space Station Compartment*” (project 129; 1984), a “*Lunar Base*” (project 136; 1985) and a “*NASA Wardroom Table*” (project 144; 1986). In contrast to the utopian designs described above, those projects were, of course, closely oriented to the concrete environmental conditions of outer space. “*Lunar Base*”, for example, shows a canopy system that is designed in three layers: a frame of graphite and epoxide resin supports a net of graphite fibers on which rests a two-meter layer of moon rocks whose lightness is due to low gravity. The construction is supposed to protect three NASA space station capsules from rays and meteor showers. Even if the structure and material differ from Otto's suggestions for large-scale coverings of colonies in space, the idea of distinguishing between living unit and overarching, protecting shield is maintained. Besides these commissioned projects, Future Systems also designed rather utopian transportable living capsules which were presented as collages in the style of Archigram. “*Vehicle*” (project 018; 1980), for example, is a capsule in the form of an aircraft; “*Une Petit Maison*” (project 023; 1982) can be transported by a helicopter; and “*Bubble*” (project 117; 1983)—a design evincing affinities with Saraceno's project—is conceived as an inflatable pneumatic living capsule secured in the surrounding wilderness by four taut cables (Sturm 2016, p. 13).

In 2014, the magazine “Architectural Design” published an issue on “Space Architecture” which was guest-edited by Neil Leach, an architectural educator and author who also works for NASA. The issue testifies to an ongoing discussion about utopian concepts, and shows how projects have been adapting to the current state of knowledge with regard to outer space. In 2009, for example, the Munich-based architect Andreas Vogel, giving consideration to the site-specific conditions, carefully chose the rim of the South Pole’s Shackleton Crater as the site of a lunar habitation planned for the year 2069. “MoonCapital” would house about 60 inhabitants and, due to its modular system, would be expandable. Interconnected capsules would be protected from radiation and meteor showers by domes that would be constructed by inflatable and self-hardening concrete technologies, and reinforced by a three-meter thick layer of sandbags filled with lunar soil—a mixture of Otto’s inflatable envelopes and the concrete-based technology used by Bauersfeld and Dischinger. Vogel reflects on the best possible living conditions, takes low gravity into account when designing the habitat’s dimensions, and gives consideration to the fixed sizes of the space shuttles which would transport materials to the moon (Vogler 2014, pp. 32–25). Inasmuch as the transport of construction materials to outer space is extremely costly, major attention is drawn to the processing of lunar resources. Current research projects by NASA and ESA explore methods for 3D printing in space with the perspective of building space structures, spare parts and even food on site (Leach 2014b, pp. 110–13).

Simply because his installation struggles with very terrestrial tasks, none of the described projects developed for the space industry has anything in common with K21’s “space station”. Despite the contemporaneity of the projects introduced, there is only one utopian design, the “Bubble” of Future Systems, which resonates with Saraceno’s “In Orbit”.

4. Conclusions

Saraceno’s “In Orbit” is part of the artist’s continuing investigation regarding the project of the flying city, and is thereby oriented towards artistic and architectural concepts since the 1950s. Among the utopian concepts, it is first and foremost Fuller’s and Sadao’s flying geodesic spheres which have to be cited as a source of inspiration. Technologically, Saraceno’s points of reference lie not in the recent state of aerospace—even if Saraceno has patented the use of aerogel for airship envelopes—and the architectural problems posed by radiation and meteoroid showers, but in lightweight construction since the 1950s, especially by Otto. These technologies seek to overcome the architectural limits posed by gravitation. In one sense, “In Orbit” aims at simulating an experience close to low gravity under the conditions of gravity. Taking the principles of the suspension roof or, generally, tensile lightweight structures as a starting point, Saraceno developed the already established construction principles further by creating a three-dimensional walkable web spread apart by spherical air-inflated membrane shells.

At the beginning of the design process—which included analog and digital methods—was the artist’s familiarity with different forms of (horizontal) spider webs. In order to generate processible data out of the natural structures, he cooperated with experts from different fields and succeeded in scanning spider webs for the first time ever. Comparable to Otto’s research methods developed at the Institute for Lightweight Structures, numerous physical models—including a life-sized model of the net—were built in order to predict the physical behavior of the structure. The gathered empirical data was again processed by CAD software to apply it to the whole installation and to anticipate its future appearance.

Saraceno did not create a flying city. Neither are the spheres accessible, nor does the construction literally fly. But “In Orbit” does offer the possibility of a bodily and a perceptual experience which, also with respect to scale, comes as close as possible to the reality of a spider moving in its web. In this regard, his work is comparable to the interactive living capsules by architects and artists such as Archigram, Haus-Rucker-Co, Shaw and Coop Himmelb(l)au from the second half of the 1960s. Similar to Malevich’s “Architectons”, Saraceno’s “In Orbit” can be understood as a self-contained abstract piece of art. At the same time, it addresses the ideas of flying cities as they have been passed

down throughout the history of utopias. We cannot yet know in which ways “In Orbit” will actually contribute to the realization of flying cities in the future, but we can assume that it could. As Otto stated in the initially quoted talk from 1967, it was possible to stretch large and unfixed space lattices out of changeable three-dimensional nets through the air and to place living units into them. The city in the sea or even on the moon, greenhouses in the Antarctic, and much more, no longer were utopias but predictions for planning (Otto [1967] 1984, p. 78).

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