Summary

The Architecture of Technical Images
Joachim Krausse in Conversation with ARCH+ p. 20

ARCH+: All four projects presented in this issue involve shells containing instruments of perception, i.e. for the observation of nature - the Einstein tower and the camera obscura - and for the projection of a simulated cosmos or of mental images. They all have in common that they combine different types of space, representing a window of perception which either introduces macrocosm into microcosm, as in the Einstein tower, or which open up the microcosm, as in the cyclotrons or in electronic microscopes. Hence these projectors for simulating cosmic spaces or for projecting mental worlds can be seen as transitions or links between different spaces. These buildings and their spatial dispositions are also, as it were, prototypes of an architecture of the age of communication, since by analogy telecommunication also creates a link between different spaces.

Joachim Krausse: All means of communication establish new space-time relations. The media always represent a spatial constellation which, although generally unreflected, enables them to function in the first place. Existing studies of communication science seem to have ignored this spatial aspect, providing only theories of speed, of codes, of languages, numeric systems etc. but never deal with the relationship between observer and observed and the corresponding spatial implications. That is why I based my analysis of media not so much on the theories of the humanities as on those of the exact sciences. In the discussion of physics media have always played an important role, being defined as that which is 'in between'. In this respect the media have to do with different materials and energetic states. The second aspect concerns the scientific instruments. And the third involves the relationship between observer and observed - a universal theme addressed not only in the exact sciences. As far as the subject of this issue, the context of architecture and world view is concerned, I have decided to focus on the technological aspects of certain media, beginning with the astronomical monuments orientated to the stars. These structures go back to the Stone Age, the earliest and most famous being Stonehenge, and establish a correlation between house and cosmic space. This can only be achieved on the basis of measurements and hence a certain amount of technology. The crucial element here is the spatial disposition which presupposes a clear concept of the correlation between inside and outside.

In the fifteenth century Europe begins to show a strong interest in scientific studies, leading to the development of exact methods and regimes during the Renaissance. Here we find the first spatial dispositions which fundamentally change our views, our perception, and our image of a world no longer defined by religion. The first installation of this kind is the camera obscura used for observing solar eclipses. The camera obscura is an astronomical structure which was developed in oriental civilizations and later found its way to Europe. It is an instrument which defines a certain relationship between observer and observed. Originally it is nothing but a sleeping chamber with a small hole in the roof through which the sunlight enters the room, making it possible to observe an eclipse. Here the observer is still enclosed within this installation before being removed in later developments, as the relationship between observer and observed changes by placing the 'camera' in between: the chamber is removed from the house and becomes mobile; it can be put on wheels and transported at will. It can now be reduced in size, leading to a process of continuing miniaturization.

Thus the house turns into an inportant technological medium, the black box which subsequently fills a variety of functions for scientific observation. Still its origins go back to the house: The darkened chamber gives rise to an apparatus which becomes increasingly mobile and can even be transported into orbit and to distant planets.

This spatial disposition still exists in our modern visual media, even if is has become unrecognizable and appears only in the structure of the programs. All that electronic simulators of space do is to translate the accumulated experiences of the history of perception into programs, e.g. perspective or isometric representations, which can be used to create spaces. Thus the original spatial disposition disappears, surviving only in the conceptual model of these programs. The house is not only an object of transformation through the media, it is also their very origin. The relationship between architecture and the media is twofold: The visual media are originally architectural spaces which are increasingly miniaturized and turned into independent mobile objects, before returning to the house as instruments of perception and communication.

An early example for the re-introduction of such an instrument is Cassini's installation in the Bologna cathedral. It consists of an aperture in the roof through which light enters the interior, thus creating a measurable link between the course of the stars and one's own position. This installation not only serves as a kind of sundial - the beam of light wandering across the floor can be used to measure time - but also makes it possible to determine one's geographical position: the meridian, running at an angle to the axis of the building, is marked on the floor in the shape of an inlaid line. All in all it is a scientific installation which has no implications for the architecture as yet. In the course of scientific development, however, spatial installation and spatial disposition begin to play a more important role, leading in turn to changes in the architecture as well. A good example of this is Boullée's monument to Newton. In his cenotaph, Boullée introduces a new kind of spatial disposition, establishing a new relationship between observer and observed. He develops a new space-time concept by adapting concepts of Newtonian physics - the concept of infinite space - to the realm of visual perception, i.e. to the relation between observer and observed. His architecture strives to create an analogy to Newtons concept of infinite space, not by means of an infinite structure but by creating a sensory experience of infinity, of limitless space. This can only be achieved with small apertures in an otherwise dark chamber. In this way he succeeds in visualizing the highly abstract scientific concept of space developed at the time, rendering infinite space visible, as it were. This spatial effect discovered by him also served as the model for modern simulators and cinematographs.

What is interesting about the objects presented in this issue is the fact that they all appear to reverse the spatial relationships. There is first of all Boullée's attempt to recreate infinite space in a fully enclosed room without windows. Secondly, the installation is used to visualize nighttime conditions during the day - this inversion of time later becomes the basis for the technology of visual media. Similarly, his concept of total space also begins as an architectural idea which is subsequently realized by technology. Architecturally the impression of infinite space is achieved with the help of a circular horizon and the motions of the observer. Cinematography later reverses this relationship: The movement of the observer in relation to the fixed image is replaced by moving images presented to a fixed observer - the horizon changes due to the movement of the image, thus allowing the fixed observer to experience the totality of space.

Another important step for the development of cinematography is of course the reversal of the direction of light in the magic lantern. The laterna magica represents an inversion of the spatial disposition of the camera obscura: instead of observing entering light, light is being projected. The origin of this inversion is also found in Boullée's design.

In your texts you are referring to the term trans-classical architecture; in other words, you attempt to outline a trans-classical concept of architecture. How does this differ from a classical or modern concept of architecture?

To begin with, I would like to replace the traditional concept of styles with other, more relevant criteria. That is why I refuse to enter into a discourse about modernity and the post-modern, which after all is only an attempt to consider modern development as completed and to extend it with a subsequent linear piece of history. This is characteristic of a highly conventional view of history which ironically also contradicts the post-modern axiom of a non-linear history. I have great difficulty in determining the chronological time-frame of so-called modernity. In fact, the term itself is highly ambiguous: sometimes it is used to describe the entire period of modern history, sometimes it is applied to a specific school of functionalism. Thus it is not very useful. In my view, we should not use the term 'modernity.' There is, however, a process of modernization independently of categories of style, and one of the characteristics of modern development is precisely the simultaneity of different stylistic traditions and movements which are in fact competing with each other. Instead of this chronological model of succeeding styles I would like to suggest a new classification on the basis of the terms classical and trans-classical in order to stress the point that the process of modernization has from the very beginning always included both elements, both movements. The term trans-classical refers to the fact that descriptive patterns of explanation based on mythology are replaced with abstract models of thought based on scientific knowledge. It seems to me that we should resume the debate concerning the relationship between architecture and our concept of the world. This is an important theme which goes back to the very beginning of architecture. The question is how architecture is influenced and determined by a specific concept of the world. This question has not been debated since the decline of church architecture, although it may be of immense significance for the way we think today.

All the contributions in this issue deal with this problem of the relationship between architecture and the changing view of the world presented by science. Of particular interest in this respect is that period in history in which the creation of a view or concept of the world is no longer a matter of mythology or religion but is increasingly determined by the means and media of perception.

In the beginning, the spatial disposition of the media, the instruments of perception, is no subject-matter for classical architecture, until it suddenly crosses paths with architecture, as it were, resulting in a clash with tradition. Essentially this was a consequence of the development of the exact sciences, especially physics. It is in the context of this confrontation that the classical concept of tectonics as the basis of architecture is called into question by science. In a sense, religion and mythology were used to explain the valid architectural principles of tectonics and construction - the classical orders are linked with the image of Atlas holding up the heavens. This concept of the firmament was thoroughly destroyed by the findings of science.

Does that mean trans-classical architecture refers to the application of science to architecture?

It is not so much a question of the direct application of science to architecture as of the simple adaptation of the results of scientific development, e.g. new ways of construction. After all, the significance of Einstein's world view is not limited to theoretical physics, it also led to the development of highly useful network structures. That amounts to a break with the classical concepts of adapting tectonic/structural measures to our perception. The task of trans-classical architecture is to integrate into the culture those technological innovations which do not conform with the traditions of our sensory perception. This problem recurs again and again in modern architectural history. When Mendelsohn works on the sculptural form of a building, for example, he has in mind the effects of forces, electro-magnetic fields etc. which cannot be perceived by the senses. He recognizes the problem that a translation is necessary here which is not based on the principles of the traditional canon. That is what is meant by distinguishing between classical and trans-classical architecture.

The Miracle of Jena

Joachim Krausse

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The object that was to spark off one of the greatest revolutions in building history, like its originator, does not make an appearance in the history of architecture. The structure that Walter Bauersfeld designed at the Carl Zeiss Company in Jena after the First World War and that became known throughout the world as the Zeiss projection planetarium has only been recorded as part of the history of civil engineering. It is here, in the history of concrete construction, that our object is to be found, as the first application of monocoque construction or 'shell building'. By 'shells' one understands curved surfaces which are cast or sprayed in a thin layer of concrete and possess a high load-bearing capacity. A model in nature is provided by the shell of an egg. Which monocoque construction, an element was introduced into architecture which had not hitherto been known. Of interest to us in what follows, are the starting point and the conjunction of circumstances from which this innovation emerged - the point of contact linking, in this instance, optics and scientific instrument-making with building.

In 1913 Carl Zeiss Jena had received the contract to build a planetarium for the Deutsches Museum then under construction in Munich, the first museum of science and technology in Germany. The museum's founder and director Oskar von Miller was obsessed by the idea of getting the general public to understand the scarcely imaginable processes of science and technology through appropriate models and exhibits.

Miller had a feeling for the experimental dimension of machines, instruments and experimental arrays, and enjoyed such things as dioramas, mises-en-scène and special effects. For the planetarium, he wanted "a journey through the Copernican universe" - while of course retaining the greatest possible degree of scientific accuracy. The observer should be placed at the centre of cosmic events, in such a way that he can comfortably follow the simulated movements of the heavenly bodies with the naked eye.

On the basis of considerations like these, Carl Zeiss in Jena was commissioned to build two models of the heavens. The first was a so-called Copernican Planetarium, a panoramic room 9 metres in diameter with, on the ceiling, a mechanical model of our planetary system in which the Sun and the planets, represented by shining globes of varying size and brightness, hang down from the mechanism as from a rigging-loft in the theatre, with the fixed-star background painted as a panorama of the zodiac on the enclosing wall and starlight penetrating the interior from filament lamps behind tiny openings.

The second model that Oskar von Miller commissioned from Zeiss was to "place the viewer, in accordance with the ideas held by the astronomers of antiquity, on Earth, conceived as being at rest, on a fixed platform which was to be built inside a large, rotating tin globe; the sphere of the fixed stars and the planets of the ancients attached to special mechanisms were to be moved inside this globe in accordance with their apparent paths."

The second model was to be constructed at the Zeiss factory by Dr Walter Bauersfeld, an engineer who was at home in the specialist field of optics and precision engineering.

Work on this project was interrupted during the First World War, but was taken up again after the end of the War. Then, over the next five years, the projection planetarium took shape as the exemplar of a modern universe simulator.

The failure of the first mechanical experiments had let Bauersfeld to the following conclusion: "To obtain a replica faithful to nature seems to be out of the question so long as one insists on achieving the objective with heavy machinery, that is, with equipment that will never be equal to the task of convincingly reproducing that mysterious and soundless world-movement of nature." Bauersfeld's plan simply stood the problem on its head: "The basic idea of the solution was to make the shell of the sphere fixed and produce an image of all the stars on its inner surface by means of a system of projectors set up close to the centre of the sphere. For this, it was necessary to colour the surface of the sphere above the horizon white in order for it to receive the projected images. Below the horizon, on the other hand, special measures had to be taken to render the images invisible."

We see here how the possibilities for omnidirectional photographic projection form the starting point for a revolutionary construction. It followed the projection idea that Bauersfeld not only had to develop a new and - because it had to be programmable - quite complicated type of photographic projector, but also a new, spherically curved projection screen. There was no immediate precedent for either. The approach to a solution was not found until after the War, but wartime experiences nevertheless seem to have prepared the way for it.

If one wants to get an idea of the scale of magnitude of arms commissions in the optics industry, it is sufficient to visualize that for every gun barrel - be it a cannon, machine gun or rifle - there was a telescopic device - be it telemeter, periscope or field glass. The number of photographs taken in the War came close to the number of projectiles fired. Optics came to occupy a complementary position alongside ballistics.

It was in particular the air war, the use of airships and aircraft both for reconnaissance and for air attacks, that threw up new problems for equipment and instrument making. There emerged the tasks of constructing and rapidly manufacturing very precise instruments for determining the direction and speed of aircraft, and the construction of sighting devices in which the correct angle could be obtained without calculation.

The aeroplane had turned the four-dimensional time-space continuum into a reality.

The first people for whom this concept of space and time had any practical validity were the flyers. To them, and to nobody else, the Earth also appears as a flying object. But not only did the validity of the concepts of absolute space, time and movement come to an end here, but also the geometry of euclidean space.

The alteration of the experience of space for those beyond the small circle of aviation pioneers and members of the avant-garde became complete during the years of the First World War. The possibility of attacks from the air gave rise to its inverse: the need for air defence. It was anti-aircraft batteries, with their guided fire mechanisms, that provided the model for cybernetics and the development of computers. Computers, which are a result of the search for a solution to the prediction problem of AA fire, have their forerunners in relatively simple analogue calculating machines, which had already been developed for air defence during the First World War. In the 4-D space-time continuum, aiming by eye was no longer sufficient.

In optics the methods developed for aerial reconnaissance, especially precise aerial photographs with special cameras and sensitive photos and films, refined the procedures for searching for moving objects which could not be seen with the naked eye. As telescopic observation glasses became more and more efficient for the task of locating aircraft even at high altitude, reconnaissance flights were deferred until the hours of dusk or darkness.

"This led to the creation of devices by which the enemy's movements could be made out even in the dark." This was written by Zeiss worker and former Captain Leineweber, and it was the Zeiss Company that - together with Goerz - developed and manufactured so-called optical aids for the military. The extent to which the Zeiss people were convinced of their technical superiority during the War is revealed in the following comment: "Even though, as captured equipment showed, our opponents were not negligent in technological development, nonetheless it can be right stated that we remained far ahead of them in the field of optics."

Bauersfeld's projector thus had the characteristics of a searchlight that reproduced in a relatively small mechanism in the centre of a sphere the patterns of movement traced on a large scale by the stars and planets. The apparatus integrated the various projectors for the fixed stars, the Milky Way and the planets. Sun, Moon and the other planets were simulated by separate planet projectors which were stacked on top of one another around the ellipse axis. The Milky Way was projected independently of the fixed stars, because in its case - as opposed to the projection of the stars with its sharp images - it was a question of hazy outlines and nebulous patches.

The image of the fixed stars was created by means of a special purpose-built projector consisting of a spherical bowl half a metre in diameter. A lamp in the centre served as a common light source for the projectors, which rested like spray nozzles on 31 round openings in the spherical bowl. Each one exactly mapped a hexagonal or pentagonal section of the image of the fixed star background onto a section of the spherical projection wall.

Bauersfeld describes the structure of the sphere as follows: "If one starts with the familiar regular solid whose surface consists of 20 equilateral triangles, and makes a straight cut across each of the 12 vertices which this solid possesses, then 20 hexagons and 12 pentagons are formed on the surface. With the cuts in the right places it is easy to ensure that the circles circumscribing the pentagons and hexagons are all equal. If one then imagines the edges of this solid projected out from the centre onto a spherical surface with the same centre, then the division of the sphere as described is formed."

We are still dealing here with the description of the projector, but note that this also applies to the structure of the reticulated sphere that encloses the room as a projection screen. The 31 sectional images of the night sky with 4,500 individually visible fixed stars on the cut faces of the polyhedral projection - the 32nd surface is occupied by the axis - fit together on this screen in such a way that an overall image free of gaps or distortion is formed. There is thus nothing accidental about the correspondence between the projector and the projection wall; it derives rather from the concept of projective geometry. The regular polyhedron which Bauersfeld chose as the shape of this projector could be replaced by another regular polyhedron, for example a tetrahedron, octahedron, cube, etc. without altering the principle.

This method of projecting a regular polyhedron onto the surrounding sphere creates on the latter's surface a network of lines which is known as geodesic, because the edges all lie on great circles, or 'geodesics'. Their radius is the radius of the sphere. But the geometric structure that Bauersfeld used in practice for the shape of his spherical projector, as well as that of the projection wall, was now also to become the structure for an architectural solution: the supporting structure for the dome of the planetarium. Bauersfeld thereby became the pioneer of a form of construction from which two revolutionary developments immediately followed: lightweight supporting structures, which were later developed so successfully by Konrad Wachsman, Richard Buckminster Fuller, Max Mengeringhausen and many others; and monocoque construction, which opened up completely new possibilities for reinforced concrete in coping with large spans. It was the optician and precision engineer Bauersfeld who introduced this development, even though it belongs entirely in the field of building construction.

The novelty has very ordinary roots. Bauersfeld informs us about the circumstances: "In 1922 the first planetarium mechanism, which had been developed for the Deutsches Museum in Munich, was nearing completion. It was to be set up in Munich in a hemispherical room about 10 metres in diameter. For mounting and testing purposes, a similar spherical room was needed in Jena. Since no indoor space large enough for this purpose was available, a light-weight spherical building had to be erected outdoors, and needed to stand up to the effects of wind and weather at least for a few months. At first we thought of a construction along the lines of a circus tent. But that was ruled out because canvas, like all textiles at that time of very high inflation, was much too expensive. By contrast, steel, being a purely German product, was very low in price. So we ended up going for a steel construction. Since we attached great importance to creating the hemispherical shape very exactly, the construction of a hemispherical network out of steel rods seemed to us to be the most promising building technique."

The Jena network dome was a model of radical light-weight construction. The structure had to be light, because there was no space for the construction except on the roof of the Zeiss factory. Bauersfeld describes the unique properties of this light-weight supporting structure thus: "Although it appears very fragile, it is strong enough for a number of people to be able to clamber about on it without any noticeable deformations occuring, and it is composed only of iron rods 80 x 20 mm in cross-section and about 60 cm in length. The essential feature is the configuration of the nodal points. The rods stand on end, they are grooved at the ends and are held firmly together by round plates fitted with appropriate necks. A high degree of rigidity of the nodes was thereby achieved. The dead weight amounted to only nine kg per square metre. Of course, the lengths of the rods had to be very exact, with a tolerance of some 1/20 mm, in order for the spherical shape to work out exactly. Some 50 different lengths of rod were required, and close to 4,000 rods in total. You will recognise in these details the involvement of the designer geared towards precision engineering."

Zeiss obtained a patent for Bauersfeld's nodal construction. It takes account of the fact that "in a network, the various nodes by no means present the same geometrical pattern at every point. The number of rods is not the same at all nodal points, and the same is true of the angles of inclination of the rods to each other and to the plates." In order to guarantee this, the Zeiss nodes have notches running around the plates and the rods have ball pivots. The two angles in space are therefore not fixed in advance; the node can be used both for varying geometric figures and for differing sphere radii.

The time was not yet ripe for this structure to be covered with light alloy panels or fibreglass, as was done experimentally by Richard Buckminster Fuller after the Second World War. On the other hand, there was already in Germany a developed concrete industry which was increasingly competing with iron and steel construction.

One of the leading concrete building firms, Dyckerhoff & Widmann AG (Dywidag), had already done various building work for Zeiss. It was natural for Bauersfeld to consult the people from Dywidag about manufacturing the shell. At first he assumed that the surface could be filled in with plaster. But since the smoothest possible surface was needed for the projection, another idea took shape: "namely the spraying on of a concrete mixture using the shotcrete technique. This concrete spraying technique had only been developed a short time before, but had yielded very good results. The smooth inner surface was to be achieved by fitting a wooden casing with spherical curvature onto the network from the inside, so that the wire mesh and the rod structure itself were completely encased in concrete. The spherical shape offered the further advantage that the wooden casing, which was to be made about 3 x 3 m in size, could be removed after the concrete had hardened and used several times for the same purpose. By happy circumstance, there was also the possibility of using very finely ground cement, which only required a very short time to set, and which had also only very recently been introduced into concrete construction."

In this way, it was possible to produce thin-walled dome shells with which even large spans could be vaulted. The Munich Planetarium had a diameter of 10 metres, the first Zeiss dome on the factory roof 16 m, the second for the neighbouring glass factory of Schott und Gen 40 m; the later polygonal domes, for example that of the Market Hall in Leipzig, which created the effect of opened-out umbrellas, each had a diameter of 76 m, more than Max Berg's Centenary Hall in Breslau, with only a third of the weight. The Schott dome, at 40 m, came close to the span of St. Peter's in Rome, which is 42.6 m. The shell had a wall width of only 6 cm, and weighed only 330 tonnes, a thirtieth of the weight of St. Peter's dome at 10,000 tonnes. Around 1930 there were already plans for shell domes with a span of 150m. And it is likely that Speer's design for a Congress Hall for the capital city 'Germania', crowned with a dome of 250 m in diameter, could only have been built using the technology of monocoque construction. In any event, there was a proposal in existence by the Dywidag monocoque builder Franz Dischinger for a concrete dome with double shells, which even made allowance for bomb strikes.

A number of further steps were still necessary in order to make monocoque construction practical for usable buildings of every kind, and these steps were made as a result of the cooperation between Bauersfeld on the one hand and Dywidag's construction engineers.

A major step was made with the discovery that not only double-curved shells - such as the sphere - can be made using monocoque construction techniques, but also simple curved shells, such as cylinders, which can easily be erected over rectangular groundplans. This opened up the enormous field of contracts for hall buildings to this construction technique: market halls, exhibition and trade halls, railway stations and hangars - for all these building tasks the Zeiss-Dywidag method was used. And more patents were filed.

Another major discovery was made on the occasion of the 1926 Gesolei Exhibition in Düsseldorf: the network no longer needed to be concreted into the shell, and could therefore be re-used. The tetrahedral supporting rod structure now serves only to hold the formwork on which the actual concrete shell is applied with normal reinforcement.

The first architect to understand these revolutionary developments was Adolf Meyer, the Bauhaus architect and for many years the associate of Walter Gropius. Meyer, whose importance for the development of modern architecture has up to now been totally undervalued - a result in part of his early death in 1929 - was deeply involved in the new construction method, and in the work he did for the city of Frankfurt, he erected some remarkable buildings using monocoque techniques. When a competition was advertised for designs for the public planetarium in the Prinzessinnengarten in Jena, Adolf Meyer took part. But in 1926 a design was picked for execution which was not Meyer's but that of Schreiter & Schlag. While Meyer parabolically superelevates the shell slightly and thereby emphasizes it as a shape (association: egg in eggcup), the more conventional design of the building actually erected, with its ring of colonnades and wide entrance hall on supporting columns, makes allusion to the Roman model of the Pantheon. It had not been understood that the dome had removed all justification for the existence of the column as a support.

Adolf Meyer had recognised the relationship with the natural sciences, and in a short article for the first volume of the Werkbund journal Die Form in 1925 states: "The dome buildings of the Zeiss planetariums are, because of the audacity and grace of their construction, among the most remarkable phenomena in the field of the architecture and engineering of the age, and their influence on architecture as a whole cannot yet be foreseen."

It took nearly another 30 years for this knowledge to be converted into a series of constructional and aesthetic experiences for architecture. This took place principally in the USA, through the work of R. Buckminster Fuller, who - like Bauersfeld - had developed his geodesic dome constructions out of the ideal of projection. During the Second World War he was employed at the Board of Economic Warfare working on logistic studies; in 1943 he published a polyhedral map projection of the Earth, which, when folded and stuck together, formed a folding globe. In 1951 he filed a patent for domes; like Bauersfeld's, his Geodesic Dome was once again created through the projection of an icosahedron onto the circumscribed sphere. In the following 30 years more than 300,000 geodesic domes were built: from the radar stations of the DEW Line to the US Pavilion in Montreal in 1976. They have become the symbols of the most diverse currents and movements all over the world.

Translation by Peter Norman