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A hundred-year challenge in architecture and civil engineering

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Background image: anonymous, *The Ideal City*, 1470-90 (detail, credits: Wikipedia, Public Domain)

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A hundred-year challenge in ancient Rome – Republican age

Temple of Portunus (3rd century BC)

Temple of Hercules Victor (2nd century BC)

Roman temples show that architectural evolution is not always linear, but is affected by unpredictable and sudden changes. Temple of Portunus is a typical example of traditional Italic temple: a pseudo-peripteral *sine postico* on a tall podium. On the other hand, temple of Hercules Victor (the best preserved structure of Republican age) represents the Hellenistic transformation of Roman architecture during the 2nd century BC: it is a *tholos* without podium. The main reason is historical: during the 3rd and the 2nd century BC Rome defeated Carthage and conquered Greece. No Roman could imagine such an overwhelming expansion and a consequent architectural evolution.

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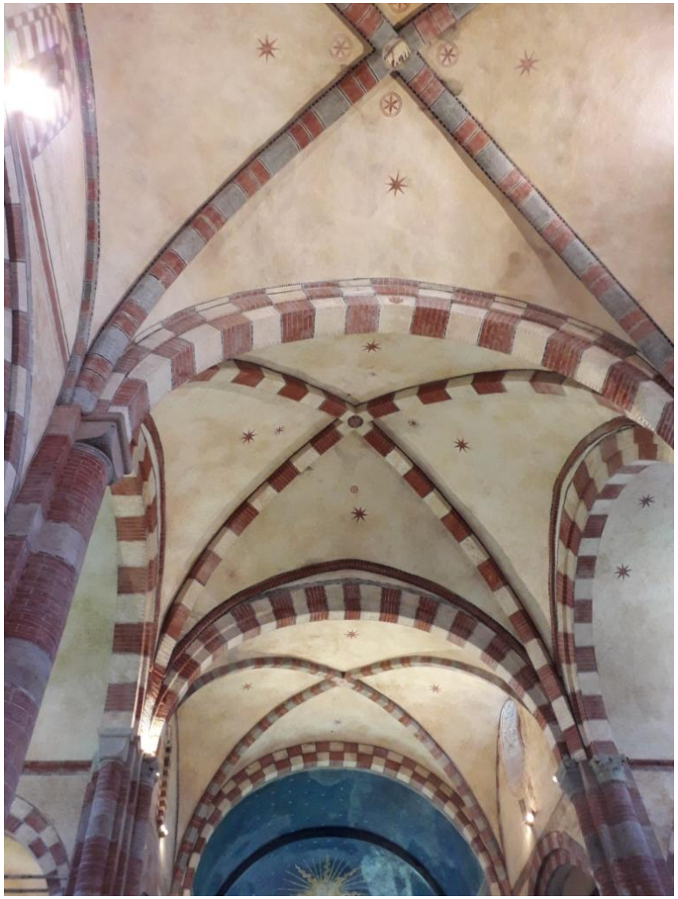
A hundred-year challenge in Middle Ages – Romanesque and Gothic architecture (1/2)



Staffarda Abbey (1135-1250)

Another remarkable and quite sudden change in buildings evolution can be found in the medieval transition from Romanesque to Gothic architecture, due to the introduction of pointed arches. Staffarda Abbey (Piedmont) shows typical Romanesque elements: mighty walls, small windows and round arches. The only Gothic structure is the bell tower, built in 1250.

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A hundred-year challenge in Middle Ages – Romanesque and Gothic architecture (2/2)

Bourges Cathedral (UNESCO World Heritage 1979) is one of the most famous examples of French Gothic churches. The introduction of pointed arches allowed buildings to become much taller than the Romanesque ones. Churches all over Europe were renewed and showed decorated facades and stained-glass windows. Nobody could imagine such a structural revolution.

Bourges Cathedral (1195-1270)

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A hundred-year challenge between the 18th and the 19th century – The Industrial Revolution – From masonry and timber to steel, glass and reinforced concrete (1/4)

Stupinigi Palazzina di Caccia (Filippo Juvarra, 1729-1733)

During the 18th century almost all structures were made of masonry, used for walls and vaults, and timber, the main roof and slab material. Simple houses, churches and luxurious palaces showed almost the same materials adapted to different structural solutions and architectural appearance. The Industrial Revolution would soon lead to great innovations thanks to new manufacturing methods and building technologies.

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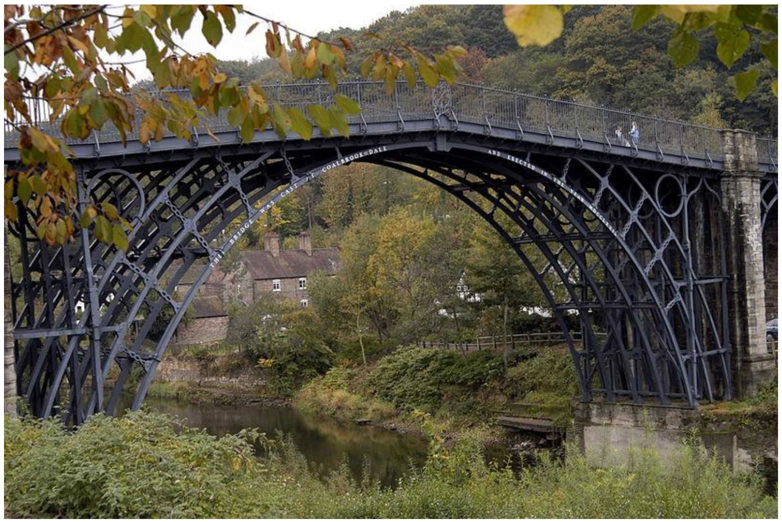
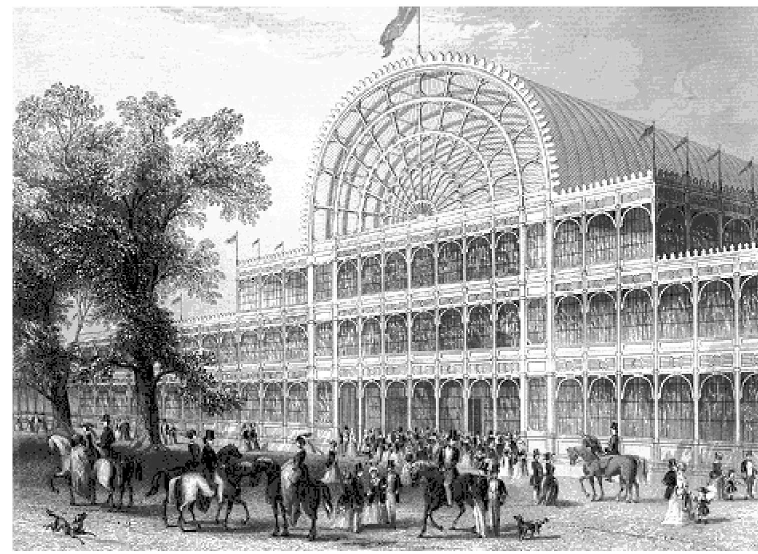
A hundred-year challenge between the 18th and the 19th century – The Industrial Revolution – From masonry and timber to steel, glass and reinforced concrete (2/4)



The Iron Bridge, the first bridge made of cast iron, on the River Severn (John Wilkinson and Abraham Darby, 1775-79, credits: Wikipedia, Jasonjsmith)

The introduction of new materials revolutionised all kinds of structures. Cast iron, steel and reinforced concrete made it possible to build bridges unthinkable before and to raise buildings that would become skyscrapers.



The Crystal Palace, made of cast iron, originally built in Hyde Park, London, to house the Great Exhibition of 1851 (Joseph Paxton, 1850-51, credits: Wikipedia, J. McNeven - collections.vam.ac.uk)

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A hundred-year challenge between the 18th and the 19th century – The Industrial Revolution – From masonry and timber to steel, glass and reinforced concrete (3/4)

James Wilson Carmichael, *A view of Murton colliery near Seaham*, United Kingdom, 1843 (credits: Wikipedia, Public Domain)

Bessemer converter, the most important technique for making steel from the 1850s to the 1950s, Sheffield (credits: Wikipedia, Chemical Engineer)

The Industrial Revolution caused new materials, such as steel and glass we have just dealt with, to be introduced. The change from an agrarian to a factory-based economy affected all the fields of manufacturing. As far as construction and machinery are concerned, new methods of coal-mining allowed iron-making industries to increase and improve the production, since a lot of energy was needed. Steam-power and later electricity provided it. At the same time, raw materials and the results of manufacturing had to be moved and distributed around cities, being the cause of an enormous increase in wheeled and rail traffic. Roads and railways had a great development.

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A hundred-year challenge between the 18th and the 19th century – The Industrial Revolution – From masonry and timber to steel, glass and reinforced concrete (4/4)

Buildings in reinforced concrete appear in the second half of the 19th century, later than the ones made of steel.

Paris, House in Avenue Franklin (August Perret, 1903, credits: Wikipedia, CVB)

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A hundred-year challenge during the 20th century – Skyscrapers (1/5) – The first, second and third generations

The first generation of skyscrapers consists of buildings much taller than the ones built before. The second generation is characterised by the use of non-combustible materials. To the third generation belong the "campanile" skyscrapers, so called for their shape that allows to go higher and higher.

Chicago, Home Insurance Building (William Le Baron Jenney, 1885, torn down in 1931, credits: Wikipedia, Chicago Architectural Photographing Company)

New York, Flatiron Building (Daniel Burnham, 1902, credits: Wikipedia, G. Edward Johnson)

New York, Woolworth Building (Cass Gilbert, 1913, credits: Wikipedia, Urban)

New York, Empire State Building (Shreve, Lamb & Harmon, 1931, credits: Wikipedia, Sam Valadi)

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A hundred-year challenge during the 20th century – Skyscrapers (2/5) – Fourth generation – Rationalism

Rationalist skyscrapers belong to the fourth generation. They are simple tall boxes covered with glass: elegant, but inexpressive. The main technical problem is that the regular shape doesn't allow height to grow limitless. Too tall regular buildings are deeply affected by wind actions.

New York, Seagram Building (Ludwig Mies Van Der Rohe, 1958, credits: Wikipedia, Epicgenius)

A hundred-year challenge during the 20th century – Skyscrapers (3/5) – Fifth generation – Towards Symbolism with Fazlur Rahman Khan

Chicago, Willis Tower (formerly Sears Tower, Fazlur Kahn, 1969, credits: Wikipedia, Carol M. Highsmith - Library of Congress Catalog)

Structural solutions start to give architectural appearance

Chicago, John Hancock Center (Fazlur Kahn, 1969, credits: Wikipedia, Epicgenius)

Between the late fifties and the early eighties Fazlur Khan, who is considered the greatest structural engineer of all time, invents almost all the new design techniques for skyscrapers building. Some of those are still used nowadays:
- the **outrigger beam** to prevent deformations;
- the **trussed tube**, X-bracing elements applied to the tube to resist to horizontal actions;
- the **tube in tube** to create ultra-rigid structural systems, made up of an internal tube which contains stairs and lift, and an external one that is the skin of the skyscraper, but has a structural function, too;
- the **bundled tube** that is the use of several vertical tubes linked together.

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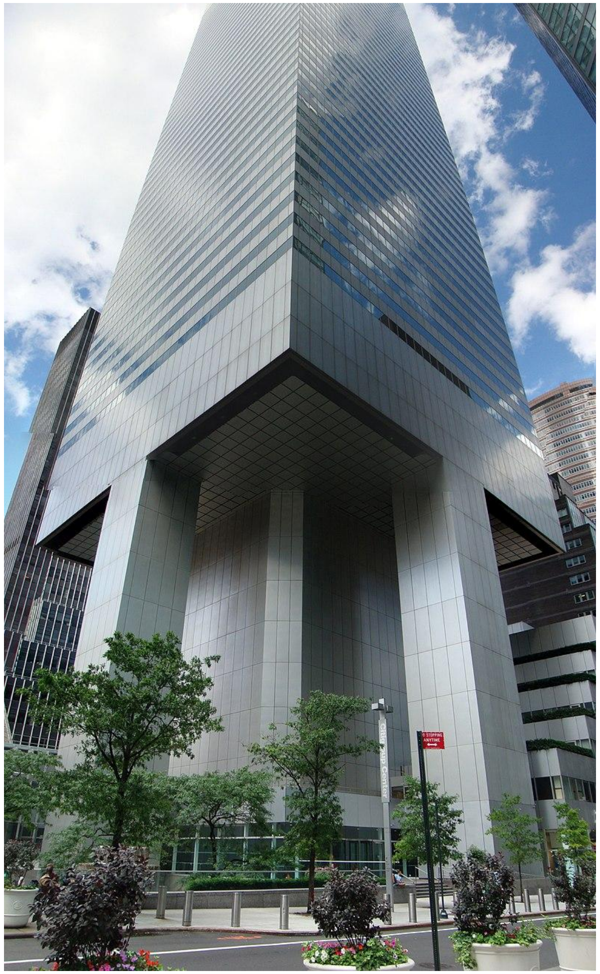
A hundred-year challenge during the 20th century – Skyscrapers (4/5) – Fifth generation – Symbolism



Symbolist skyscrapers are characterised by new shapes, particularly at the base and at the top, but also new skin (e. g. metal instead of glass). All these aspects can be found in Citicorp Building.

New York, Citicorp Building (Stubbins Associates, Emery Roth & Sons, 1977, credits: Wikipedia, Pablo Costa Tirad and Daniel Schwen respectively)

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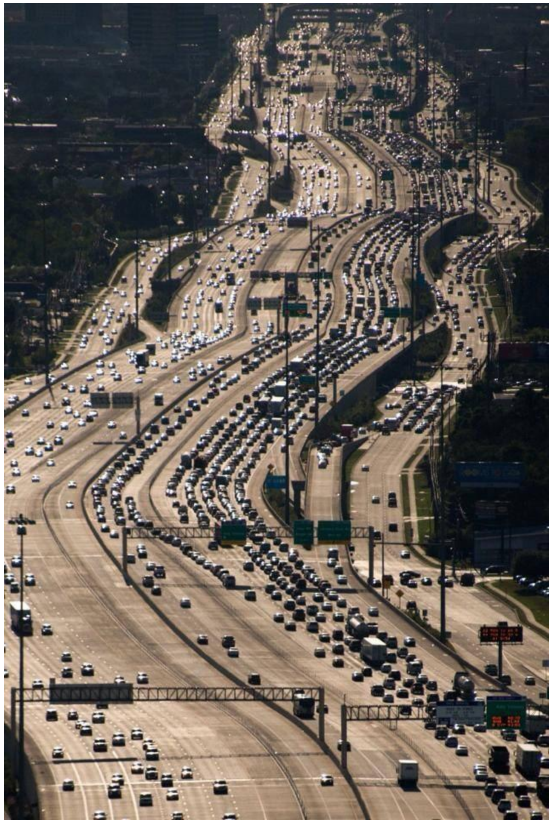
A hundred-year challenge during the 20th century – Skyscrapers (5/5) – Traffic increase

View of traffic on Fifth Avenue at 42nd Street in New York City, 1932 (credits: New York State Archives. Education Dept. Division of Visual Instruction. Instructional lantern slides, 1911-1925, A3045-78, Lantern slide DnNC62)

Katy Freeway in Texas, 2015 (credits: Wikipedia, Aliciak3yz)



Due to development of cities and construction of skyscrapers, traffic on roads increases enormously.

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A hundred-year challenge after 1990 – Skyscrapers (1/3) – Some design and research issues on wind actions

At the end of the nineteenth century we have new skyscrapers design issues. Wind tunnel tests are the starting point to find solutions. The structural measures implemented in these new and extremely tall buildings are studied to reduce the effects of external loads, first of all the one of the wind. Here are some of those issues.

1) plan shape: no more sharp edges – Example: Hong Kong, Central Plaza (Dennis Lau & Ng Chun Man Architects & Engineers, 1992, credits: Wikipedia, Wing1990hk)

2) top shape: an irregular top shape reduces wind actions – Example: Miami, Southest Financial Center (Skidmore, Owings & Merrill, 1992, credits: Wikipedia, Jedi94)

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A hundred-year challenge after 1990 – Skyscrapers (2/3) – Some design and research issues

3) variable section over the height: it breaks the regularity with which dangerous wind vortices generate – Example: Hong Kong, Bank of China Tower (I.M. Pei & Partners, 1990, credits: Wikipedia, WiNG)

4) structures coupling: two buildings can protect each other from wind actions – Example: Kuala Lumpur, Petronas (César Pelli, 1998, credits: Wikipedia, Someformofhuman)

5) structural openings – Example: Shanghai, World Financial Center (Kohn Pedersen Fox, 2008, credits: Wikipedia, GG001213)

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A hundred-year challenge after 1990 – Skyscrapers (3/3) – Some design and research issues – Brâncuşi's *Endless Column*: a prophecy from 1938

Many of the structural solutions adopted in high-rise buildings can be found in a work of art created by the Romanian artist Constantin Brâncuşi with a structural engineer, Stefan Georgescu Gorjan: the Endless Column. Since the Column dates back to 1938, it can be considered a prophecy of how skyscrapers would have been in the future.
In fact, after being studied in wind tunnel, the artwork turned out to be the ideal structure to endure strong wind actions. We do not know whether the artist and the engineer were aware of that, anyway the Endless Column is a masterpiece of both art and wind engineering!

Constantin Brâncuşi, *Endless Column*, 1938, Târgu Jiu (credits: Flickr, Alin B.)

A hundred-year challenge in the future: utopia – “Horizontal” skyscrapers (1/4)

Research and design of the last years allowed the construction of higher and higher skyscrapers. In the future there will be not only a further increase in tallness, but also the creation of horizontal links between different skyscrapers. This is already happening and creating new ways of moving between buildings and around cities.

Chongqing, Raffles City Chongqing (Moshe Safdie, 2019, credits: www.safdiearchitects.com/projects/raffles-city-chongqing)

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A hundred-year challenge in the future: utopia – “Horizontal” skyscrapers (2/4)

Singapore, Marina Bay Sands (Moshe Safdie, 2010, credits: Wikipedia, Someformofhuman)

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A hundred-year challenge in the future: utopia – “Horizontal” skyscrapers (3/4)

The Squall Tower is going to be both a skyscraper and a wind turbine, combining architecture with sustainability.

Dubai, Squall Tower (Hayri Atak, to be built, credits: www.en.futuroprossimo.it)

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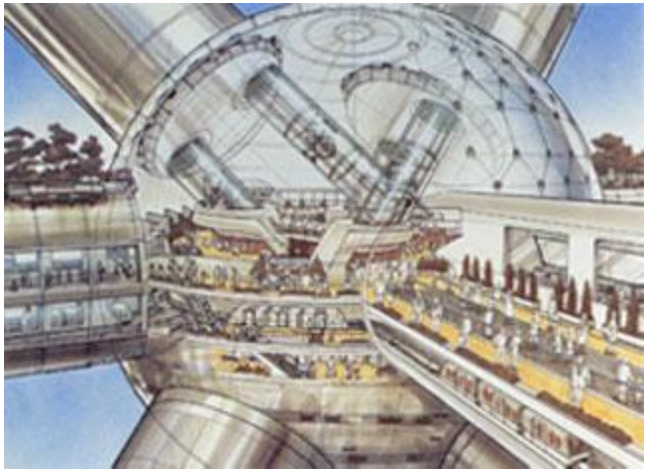
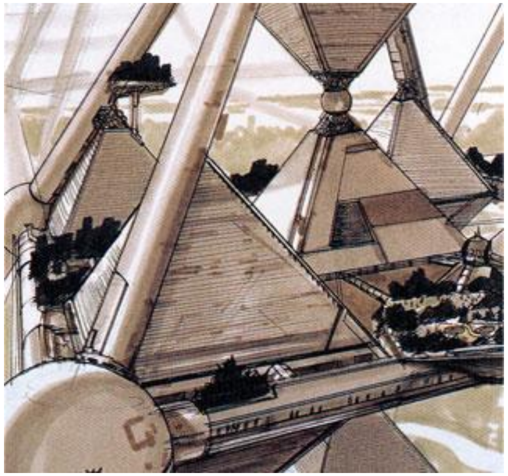
A hundred-year challenge in the future: utopia – “Horizontal” skyscrapers (4/4)

The Mega-City Pyramid is a self-sustaining building designed to float in the air over Tokyo Bay in Japan. Being a city, it will contain all the necessary services for urban life. The structure, 2004 meters high will be able to house 1,000,000 people. Some structural parts are intended to have similar dimensions to that of the Great Pyramid of Giza.

The *Mega-City Pyramid* (Shimizu Corporation, project 2004, credits: www.shimz.co.jp)





A hundred-year challenge in the future: dystopia – Underground masterpieces (1/4)

What if future is a dystopia? The utopia of the slides before will be possible only if we win the challenges of climate change, social inequality, demographic issue, welfare policy, work and road safety. In a word: sustainability. On the contrary, it is possible that we will have to go and live underground. There we could be protected from the UV rays penetrating the atmosphere we are destroying and the pollution of soil and water. Huge cities will grow underground, with roads similar to the ones of the mines, but also ways of transport we do not even imagine. Here are some examples.

Deep Pit Hotel during construction, Shanghai (Martin Jochman, credits: www.china-underground.com)

Deep Pit Hotel, Shanghai (2015, credits: Barcroft images)

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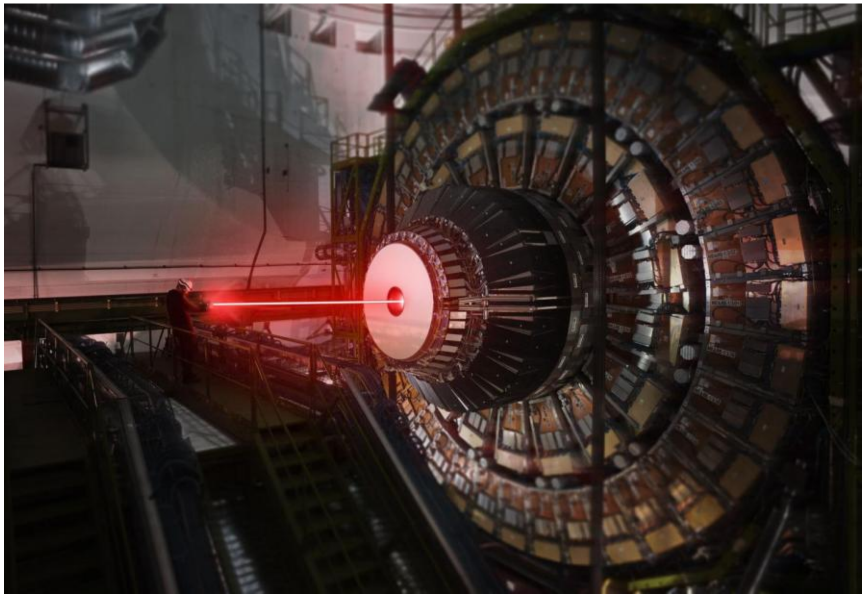
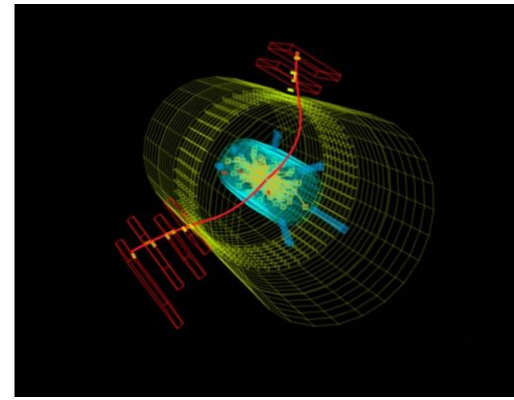
A hundred-year challenge in the future: dystopia – Underground masterpieces (2/4)



CERN, Geneva
(credits:
www.home.cern)



Some of the most outstanding underground structures are CERN’s accelerators and decelerators. They are built up to 100 metres underground and the longest tunnel has a circumference of 27 kilometres. CERN infrastructure is the result of the combination of geotechnical engineering and advanced technologies in many scientific fields.

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A hundred-year challenge in the future: dystopia – Underground masterpieces (3/4)

RÉSO or Underground City, Montréal (credits: Wikipedia, Dickbauch)

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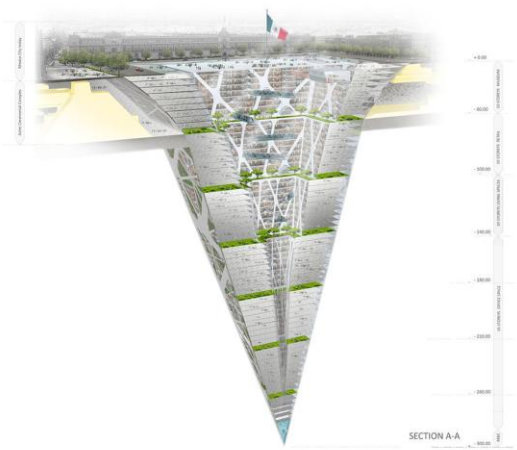
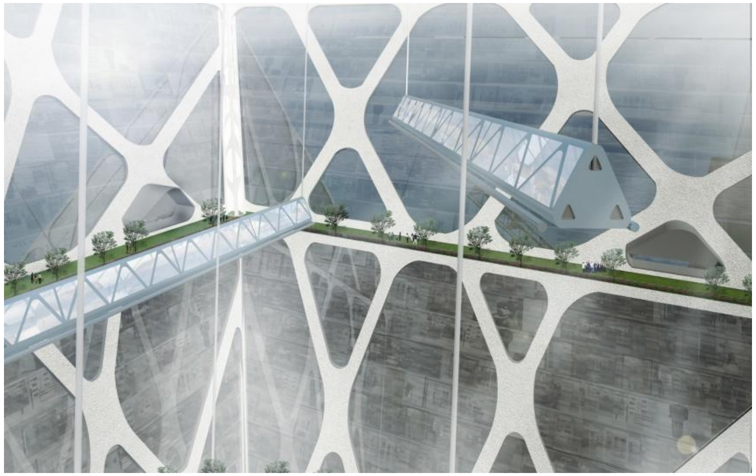
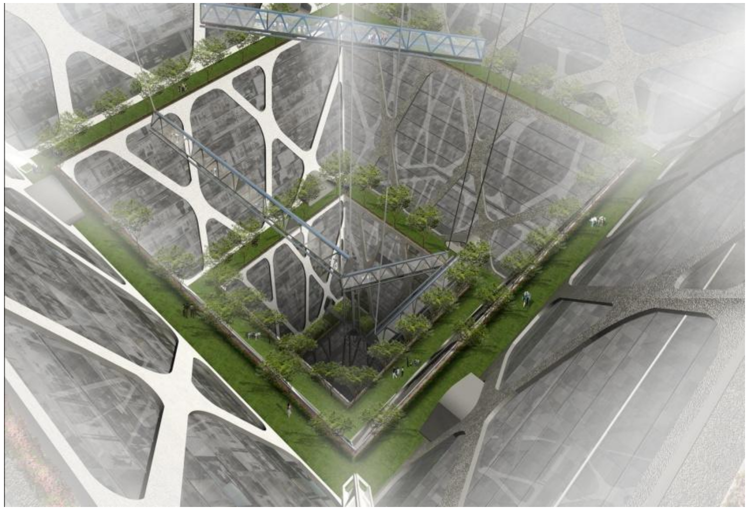
A hundred-year challenge in the future: dystopia – Underground masterpieces (4/4)

The earthscraper: an upside down skyscraper stuck in the ground! It is a sixty-five-story building designed to be placed under the main square of Mexico City. It goes up to 304 meters below the ground surface. It is a futuristic project.







Mexico City, design of the earthscraper *El Zócalo* (BNKR Arquitectura, credits: www.bunkerarquitectura.com)

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Thank you!

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