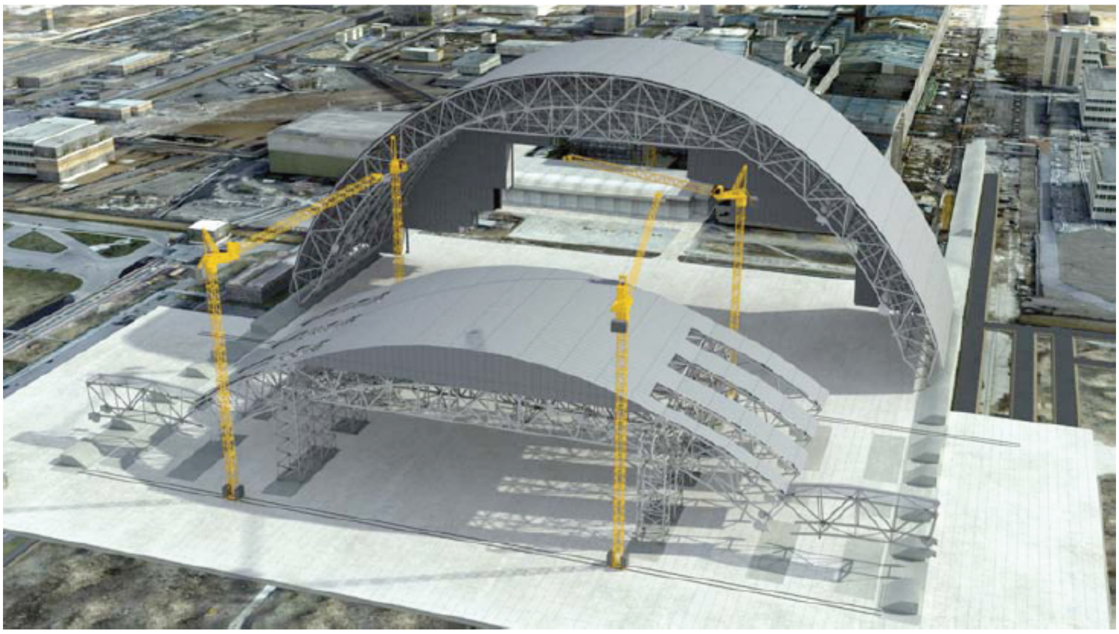
PRESS KIT

Confinement shelter for the Chernobyl sarcophagus

Design, construction and commissioning



Update: February 2016

Contents

1- Dual French engineering for an exceptional project

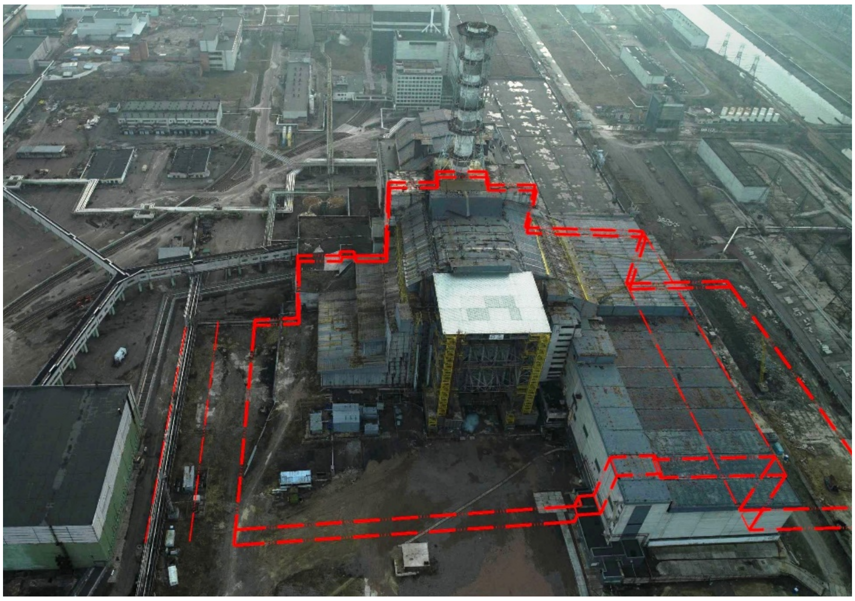
NOVARKA, a 50/50 joint venture formed by VINCI Construction Grands Projets (leader) and Bouygues Travaux Publics, is currently building a new safe confinement over the Unit 4 reactor at Chernobyl, which exploded on 26 April 1986.

This unparalleled project comprises the design and construction of a confinement shelter in the form of an arch that will cover the current object shelter, or sarcophagus, built in 1986 just after the accident. Standing on two concrete beams, the metal arch will be assembled in an area to the west of the damaged reactor and slid into place above the existing object shelter.

The purpose of the new structure is to contain the radioactive materials and protect the existing shelter from weather damage. Ultimately, it will allow work to begin on deconstruction of Unit 4 of the Chernobyl power plant.

Two French construction groups have joined forces to carry out the outsized project, with each group providing its specific expertise.

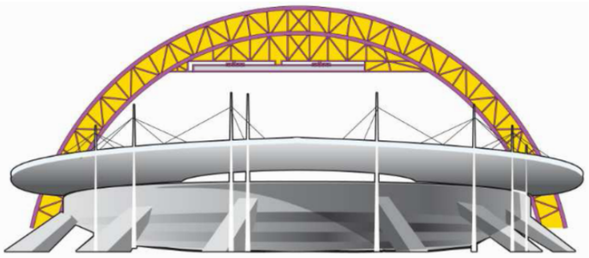
Area covered by the new safe confinement



© NOVARKA

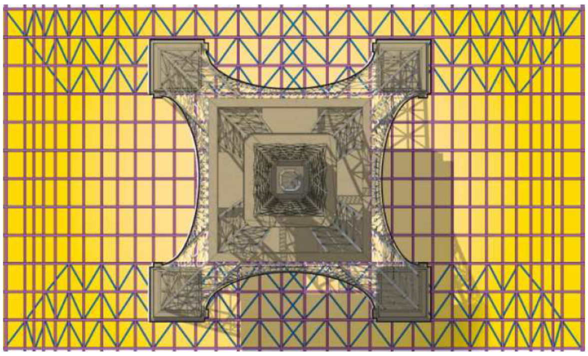
2- An unprecedented project

The arch-shaped confinement is made up of a 25,000 tonne (36,000 tonnes equipped) metal structure. With its 108-metre height, 162-metre length and 257-metre span, the outsized arch is large enough to enclose the Stade de France, the Statue of Liberty, or the footprint of the Eiffel Tower. It is as tall as a 30-storey building.



© Agence Idé

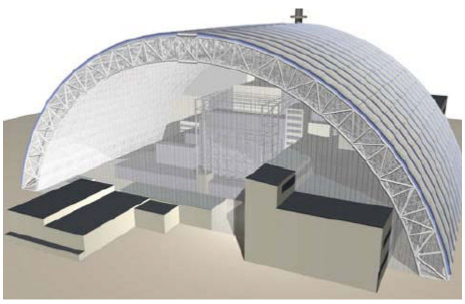
© Agence Idé



© Agence Idé

Standing on two concrete beams, the arch has been assembled to the west of the damaged reactor and will be slid into position over the existing object shelter, built in 1986 just after the accident. The purpose of the new arch, designed and built by NOVARKA, is to:

- **contain radioactive materials**
- **protect workers** at the site
- **protect the existing object shelter** against weather damage.



© NOVARKA

It will be fitted with equipment and facilities to allow work to begin on deconstruction of Unit 4 under the safest and most flexible conditions possible, keeping human intervention to the strict minimum.

Project status in February 2016

Work has progressed steadily since NOVARKA and the Ukrainian authorities signed the contract in September 2007:

- Between October 2007 and the summer of 2009: 1st planning and design studies phase
- From the summer of 2009 to early 2011: 2nd planning and design studies phase
- Early 2009: worksite installation and preliminary activities (geotechnical investigations, etc.)
- Early 2010: clearing and clean-up of the assembly area
- April 2010: start of earthworks in the assembly area for the concrete beams on which the arch will be slid over the damaged reactor
- May 2010: NOVARKA awards the contract to manufacture the arch elements to Cimolai (Italy). Main crane system contract awarded to PaR Systems (U.S.A.)
- August 2010: approval of the temporary structures and start of work on the foundations of the lift towers and the metal piles for the longitudinal beams in the assembly area
- November 2011: approval of the structural design and the crane systems
- April 2012: start of frame assembly
- October 2012: start of cladding
- November 2012: first arch lifting operation
- April 2013: first approval of systems design (ventilation, auxiliary building, power supply, monitoring and control) and start of associated procurement (by call for tender).
- June 2013: second arch lifting operation
- September 2013: third lifting operation for first half of the arch
- April 2014: sliding of the first half of the arch towards the holding area (4 April) and first lifting operation for second half (26-27 April)
- April 2014: casting of first concrete for foundations of Technological Building and auxiliary buildings
- June 2014: 2 million hours worked without an accident
- August 2014: second lifting operation for second half of the arch
- September 2014: 3 million hours worked without an accident
- October 2014: third and final lifting operation for second half of the arch
- December 2014: adjustment and final connection of the tilting panel 1 (immense sealing door)
- May 2015: 5 million accident-free hours worked
- June 2015: start of electrical and ventilation installation within the confinement
- October 2015: connection of the two halves of the arch
- Octobre 2015: start training for operation personnel
- November 2015: installation of the tilting panel jacks
- November 2015: lift the first overhead bridge crane inside the arch
- December 2015: start installing the special doors (fire doors, anti-tornado, sealed and armoured)

Key figures

Manpower

- 1,220 Ukrainian workers present at the site during peak periods (x 2 => 2,000 total, since the teams alternate, each spending two weeks at the site, followed by two weeks' leave)
- 200 expatriate employees of 21 different nationalities to supervise the project
- 60 people at the site working exclusively on radiation protection

Technical resources

- Arch span: 257 metres
- Arch height: 108 metres
- Covered length of the arch: 162 metres (nearly two football pitches)
- Metal frame: 25,000 tonnes (nearly 3 times the weight of the Eiffel Tower)
- Total weight of the equipped structure: 36,000 tonnes
- Life span of the confinement shelter: 100 years
- Exterior cladding: 86,000 m²
- Overhead bridge cranes: 2 x 750 tonnes
- Overhead bridge crane girders: 100 metres (equivalent of a football pitch)
- Loads supported by the overhead bridge cranes: 50 tonnes vertical, 1.5 tonnes horizontal
- Final foundations: 20,000 m³ of concrete
- Engineering: 5 million hours
- Construction: 17 million hours

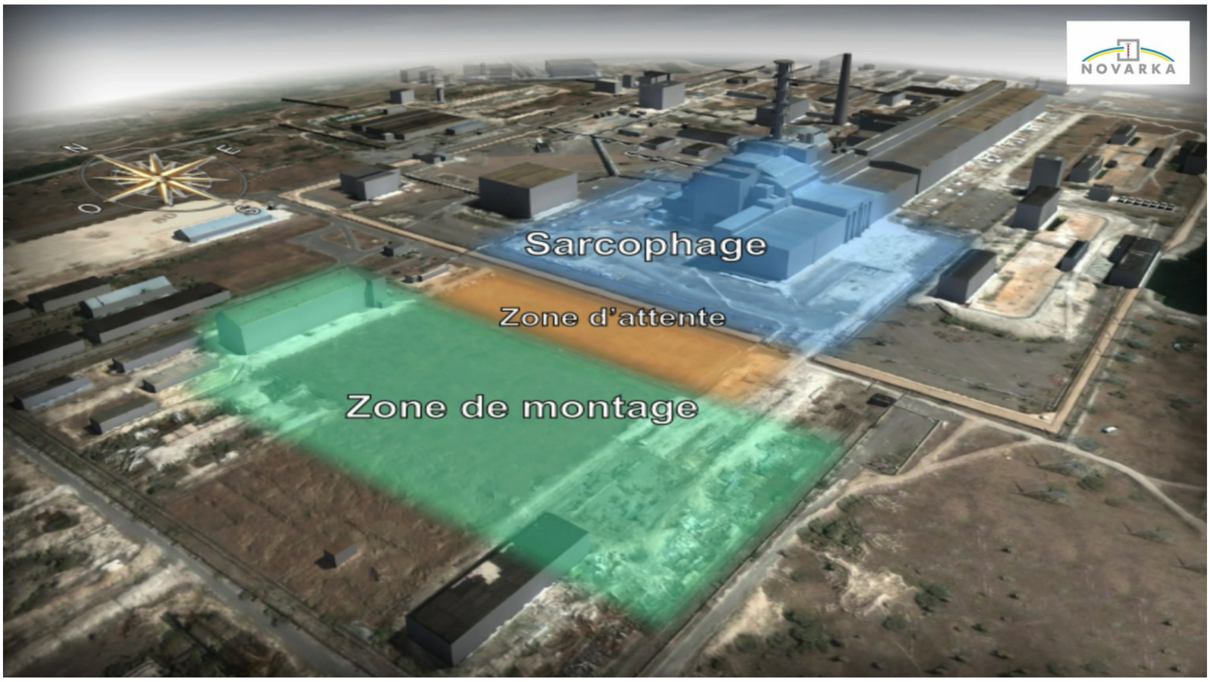
The confinement must withstand:

- temperatures ranging from -43°C to +45°C
- a class 3 (1,000,000 year) tornado
- an earthquake reaching a maximum intensity of 6 on the Mercalli scale (10,000 year earthquake). Ukraine is a low seismic risk zone. The design earthquake epicentre is in Romania, 300 km away, and has a magnitude of about 7 on the Richter scale.

Construction timeline

The arch has been assembled to the west of the site in a specially developed area away from the damaged reactor, and then will be slid into position to cover the existing object shelter.

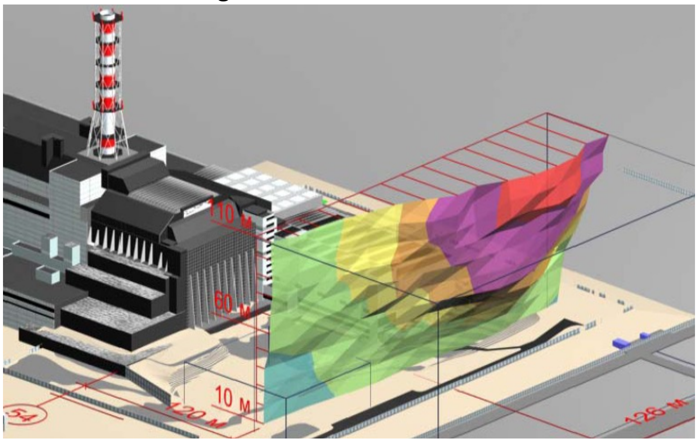
The worksite is divided into three areas: the existing object shelter (sarcophagus), the assembly area and the holding area.



© NOVARKA

Top priority has been given to protecting the environment and the population and to ensuring the safety of personnel. The site will be constantly monitored (radioactivity and air contamination) throughout the construction process.

The assembly area was selected to avoid the risk of radiation. The intensity of radiation at a distance of 60 metres from the damaged reactor depending on position – from the lowest (blue) to the highest (red) exposure – is shown below. The assembly area is 300 metres from the reactor, i.e. in an area protected from radiation. The structure has been assembled on the ground, since radiation increases with height.

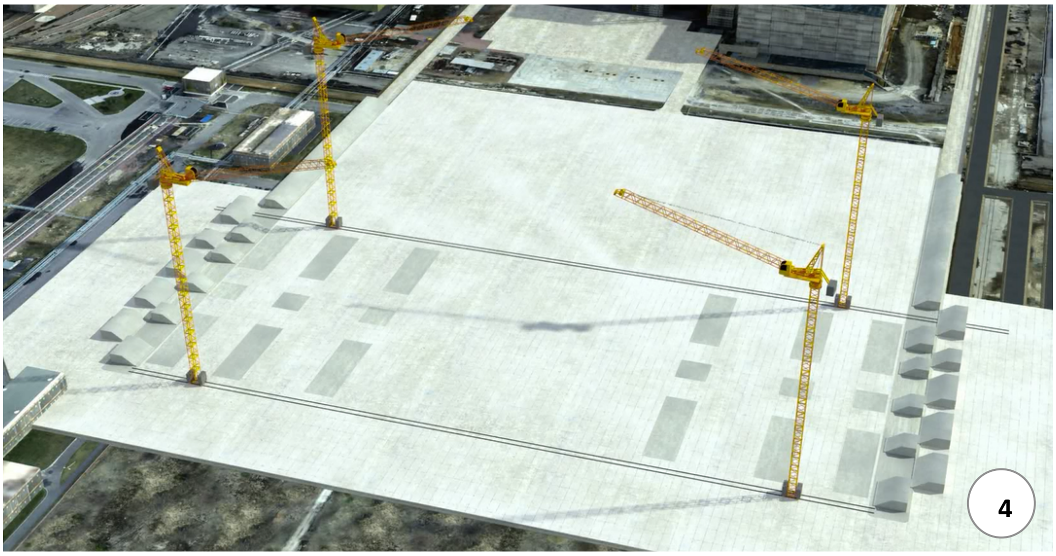


© NOVARKA

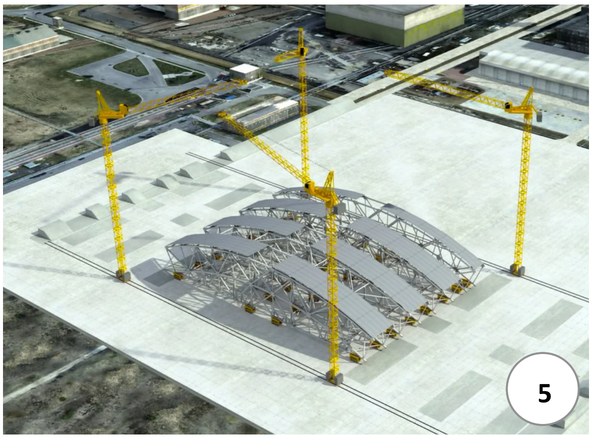
1 - The work began with cleaning and clearing the assembly area and dismantling the empty buildings. Excavation in the assembly area was kept to a minimum to avoid generating waste whenever possible. Two wide trenches were dug on either side of the reactor to prepare the ground for the longitudinal beams that serve as arch foundations. In the centre, solid blocks were built to support the towers designed to lift and assemble the structure.

2 - Roads were built specifically to serve the assembly area; the civil engineering works began with the placement of blinding concrete.

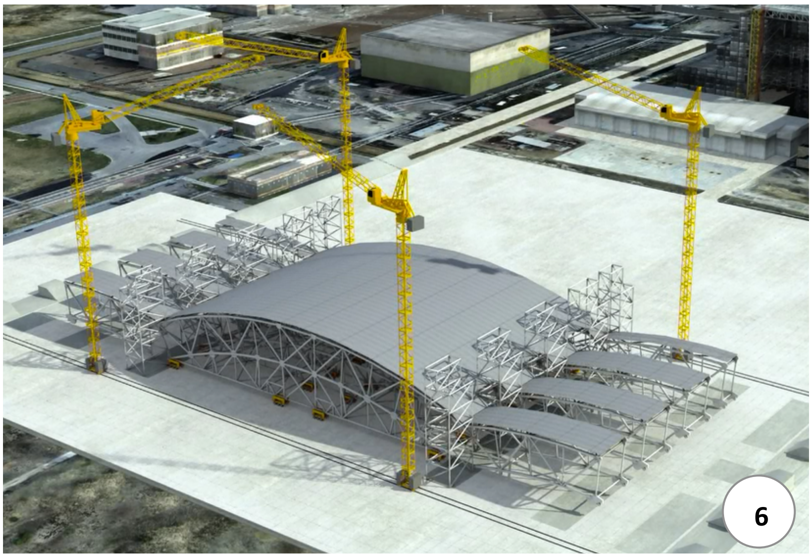
3 - Meanwhile, deep foundation works were undertaken in the trenches. In the assembly area, this involved driven metal piles. They are 1 metre in diameter, driven to an average depth of 25 metres.



4 – In the assembly area, the reinforcements were installed and the concrete cast for the foundation blocks of the lifting towers. To protect workers, the assembly area (some 90,000 m²) was backfilled, using clean filler, to an average height of one metre, and then partially covered with concrete slabs. These slabs form a work surface and provide protection from any radiation coming from the ground.



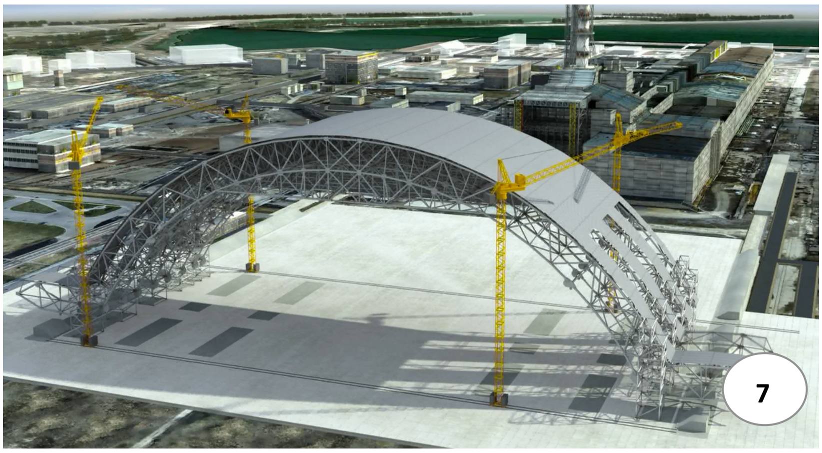
5 – It was then a question of building the arch. The first segments of the arch structure were pre-assembled on the ground in the assembly area. The construction of the arch began with the upper section. The segments were interconnected with bracing before the cladding was fitted on the central section.



6 - The secondary arch elements were then connected to the central section using a hinge system.

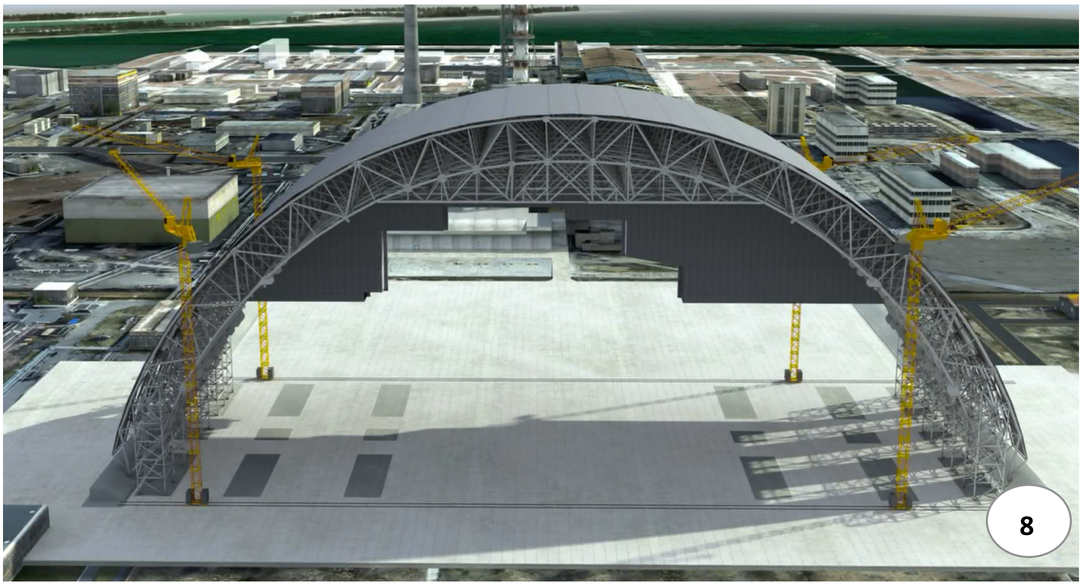
The first lifting operation was now undertaken, using towers designed to lift loads of more than one thousand tonnes.

The structure was gradually completed with the addition of its remaining components.



© NOVARKA

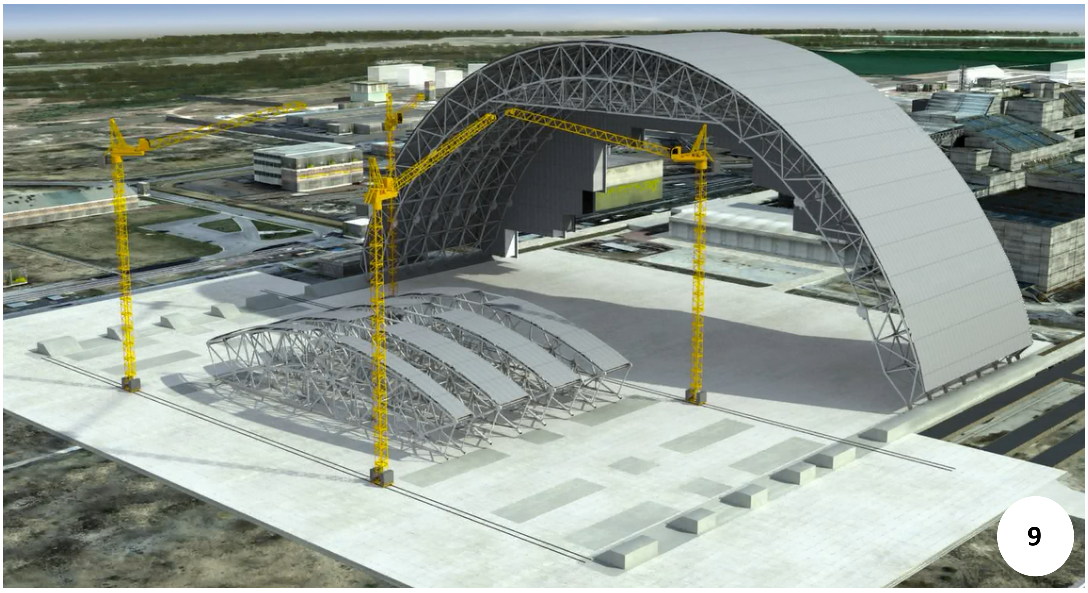
7 - The lifting towers were moved to their final position as the last components, corresponding to the feet of the arch, were brought in.



© NOVARKA

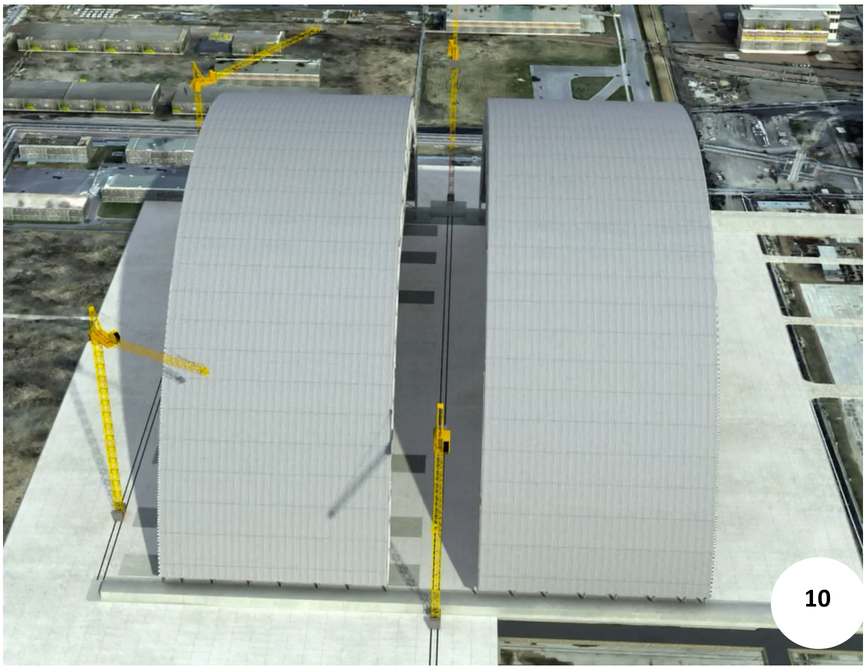
8 - The east side wall was installed and the pushing equipment moved into place to slide the now completed first half into its waiting position (holding area) and clear the assembly area. The second half of the arch was then assembled in the same way.

In parallel with the construction of the arch, civil engineering continues with the concrete beams of the transfer area and then the foundations of the service area. The concrete piles in the service area are constructed with the continuous flight auger method (in which the auger is drilled into the ground, concrete is pumped in as the auger is withdrawn and the reinforcement cage is placed immediately after withdrawal of the auger in the fresh concrete). This technique makes it possible to avoid generating vibrations near the sarcophagus. Construction work is also started on the auxiliary building at the foot of the sarcophagus, which will serve as the future control centre for the dismantling and confinement systems built into the arch.



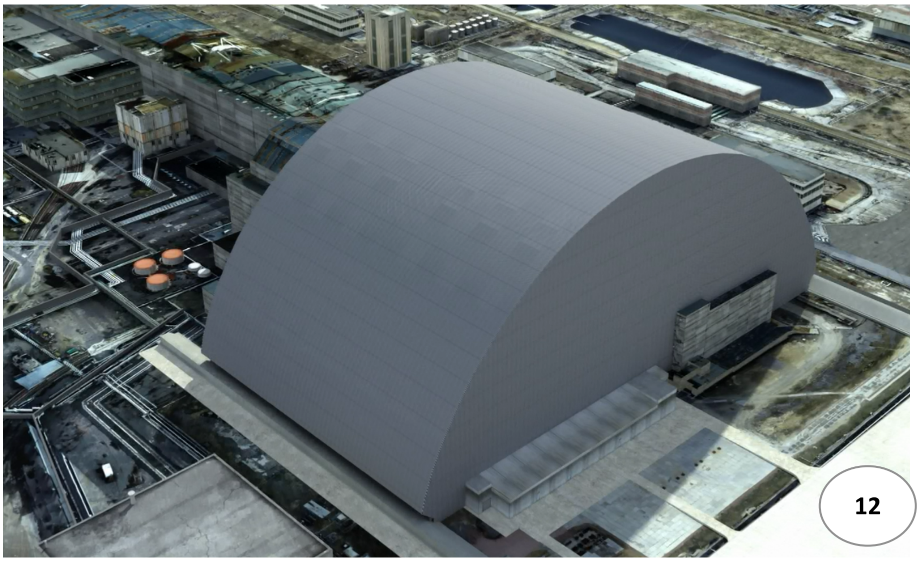
9 –All structural elements are pre-assembled in a designated area outside the site, where as many components as possible – including electrical and mechanical equipment, ducting, piping and walkways – are mounted before being brought to the assembly area, to reduce the number of operations performed in the immediate vicinity of the object shelter.

The cladding is designed to protect the existing shelter from external hazards and to protect the population and the environment from any radioactive release. A complex ventilation system is installed to control the atmosphere inside the arch, regulate the ambient temperature and humidity conditions inside the confinement structure and limit release to the atmosphere.



10 - Once the second half of the arch has been completed, the first half is moved back to the westwards to connect to the second half, forming the complete arch. The bracing and metal cladding connections are then completed.

11 - The arch is equipped with overhead bridge cranes designed for dismantling the existing shelter and the damaged reactor unit. They are assembled on the ground and then lifted using cabled actuators secured to the arch structure 85 metres above.



12 - After the finishing works and testing have been completed, hydraulic jacks will slide the arch 300 metres into its final position. Once it has been positioned above the object shelter, the arch and its side walls will be connected to the existing structures. The damaged reactor will then then be completely isolated from the outside world.

Project participants

Contracting authority	**Chernobyl Nuclear Power Plant (ChNPP)** State-owned enterprise officially responsible for dismantling and cleaning up the Chernobyl site

Project manager	**Project Management Unit (PMU)** Joint team consisting of representatives of ChNPP and Bechtel [1]. [1] *Bechtel is a global engineering, construction and project management firm. The private company is headquartered in San Francisco and has offices all over the world.*

Design-build consortium	**NOVARKA** A 50/50 consortium made up of VINCI Construction Grands Projets (leader) and Bouygues Travaux Publics.

Regulators	**SNRIU** (nuclear safety) and ministerial organisations covering emergencies (especially fire safety), construction, environment and labour.

Bank	**EBRD** The bank administers the funds provided by donor countries and takes major decisions in conjunction with the Authorities and the Contracting Authority.

3- Safety of personnel, a constant priority

NOVARKA's top priority is to protect the population and personnel.

The site is monitored (radiation and atmospheric pollution) at all times throughout the project. Workers are also constantly monitored. A dedicated team of 60 duly qualified radiation protection specialists is tasked with ensuring site safety.

Design and construction methods are governed by the "ALARA" (As Low As Reasonably Achievable) principle applying throughout the nuclear industry. During the planning and design phase, this consists in examining a range of solutions to a given problem and calculating the "committed dose budget" for each one(1). Unannounced evacuation drills are regularly held throughout the project.

All personnel working in the area are outfitted with appropriate personal protective equipment (coveralls, masks, boots, helmets, gloves) and two dosimeters. The legal dosimeter records monthly doses received. The operational dosimeter monitors the actual radiation dose in real time and compares it with the predicted calculated dose. The recorded data is checked twice daily by NOVARKA radiation protection technicians at the site and analysed by the contracting authority's laboratory.

If the budget is exceeded (which is in principle impossible, given the prevention procedures), personnel may be refused access to the work zone. Additional specific protocols include such procedures as systematic analysis of the data by a radioprotection specialist.

For certain types of work, notably in areas near the object shelter (foundation beams, for example), personnel work behind concrete or lead screens.
The radiation protection measures and rules applying at the site are the same for all workers expatriate NOVARKA workers, Ukrainian NOVARKA workers and NOVARKA subcontractors alike.

At the arch assembly site, where the area has been cleaned up and doses are low, the procedure is less stringent. Workers keep their masks with them but wear them only in case of an alert.

(1) *Maximum annual authorised dose: 14 mSv/year (the standard set by the French nuclear authorities is 20 mSv/year)*

Hiring and human resources management

Hiring is extremely selective and includes a very comprehensive medical examination, which will be the decisive criterion for recruitment. Personnel hired to work at the site undergo the particularly stringent Ukrainian legal medical examination (called BIOMED), and due to this screening only two applicants out of three are hired on average. Personnel undergo prior safety training to learn how to behave in a radioactive environment. Regular medical monitoring - financed by the EBRD - is carried out by BIOMED in Kiev for all personnel working at the site (every year and every three months for those working in the industrial zone). A team of two physicians is present at the site at all times.

Living and working conditions

In accordance with Ukrainian legislation, project workers can chose between two schedules:

- A normal 5-day week (37 hours), with weekends off.
- Two weeks at the site followed by two weeks home leave.

Working time is obviously adjusted to ensure that doses remain well below the safety levels set by the nuclear safety authorities. To minimise the risk of contamination, steps are taken to limit the amount of work performed at height.

Workers are housed in apartments in Chernobyl that have been fully decontaminated and renovated. NOVARKA has also built a new canteen in the city of Chernobyl.

The design office is based in Kiev and employees working there are housed nearby.

Lastly, the NOVARKA administrative and functional offices are based in Slavutich (see appended map, page 18). Expatriate NOVARKA employees are housed in the city of Slavutich.

4 - Timeline and financing

Overall project timeline (as of February 2016)

- 2011: Finalisation of the civil engineering work in the assembly area
- 2012/2015: Assembly of the arch
- 2015 /2016: Installation of electro-mechanical equipment (systems)
- End of 2016: Sliding of the arch
- Fin 2017: attach the membrane to completely seal the arch, commissioning tests and equipment handover

Financing

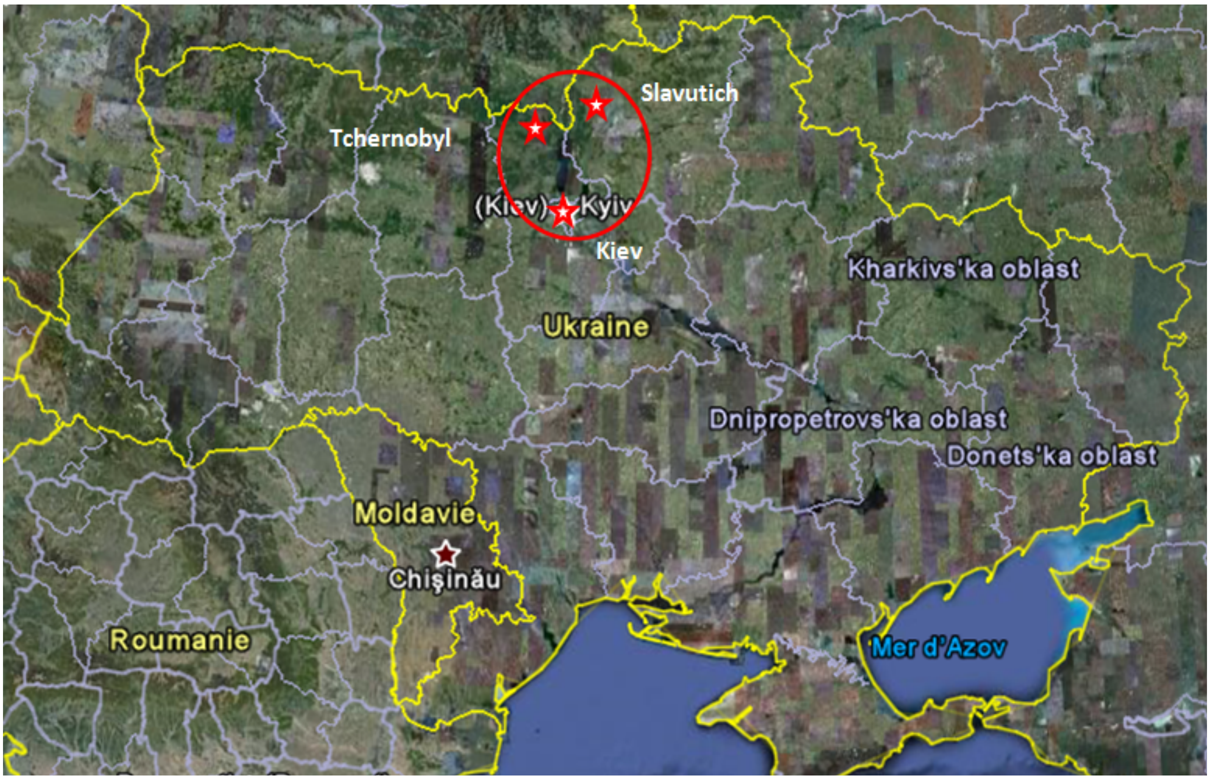
The New Safe Confinement represents about one and a half billion euros, a budget allocated to the Chernobyl Shelter Fund (CSF). This fund is dedicated to the achievement of the Shelter Implementation Plan (SIP), including all projects relating to the confinement of the existing object shelter and the dismantling of the entire power plant, which has now been shut down. The CSF is administered by the European Bank for Reconstruction and Development (EBRD). It was set up in November 1997 at the initiative of the G7 and funded by international grants.

The decision-making body of the Fund is the Assembly of Donors, which comprises 23 European Union countries. Since it was established in 1997, it has been chaired by Hans Blix.

5- Annexes

Map

The project is being implemented at three different Ukrainian sites. Design studies are handled in Kiev, the NOVARKA offices (administrative, functional and project management departments) are located in Slavutich and project offices are located in Chernobyl. All activities are therefore concentrated in a south, north-east, north-west triangle (see map below). The distance between Kiev and Chernobyl is 110 km.



Detailed timeline of the accident on 26 April 1986

Unit 4 of the Chernobyl power plant, commissioned in 1984, is a 1,000 MWe RBMK[1] reactor operating since 1984. It contains 1,681 pressure tubes enclosing the fuel (190 tonnes of enriched uranium oxide) and a graphite stack as moderator. The entire facility is cooled by pressurised water.

The causes of the accident are complex. They are mainly due to design weaknesses and failure to comply with a number of operating procedures.

25 April between 1:00 and 11:00 p.m.

The plant is powered down to achieve the power level used during testing (about 700 MWt). However, at the request of the electricity distribution centre, the reactor is kept at half-power to meet electricity demand. Control rods are progressively retracted from the core to maintain power.

Around 11:00 p.m.

Power reduction is resumed. The control rods are again retracted: the reactor is no longer operating under normal stability conditions

26 April at 1:15 a.m.

Contrary to procedure, operators decide to carry out the planned test and set the automatic trip signals at "low level" and "low pressure" in the steam separators.

1:22

The computer indicates the equivalent of only 6 to 8 control rods inserted in the core, although a trip must be triggered when the level drops to the equivalent of 15. The employees present nevertheless decide to continue the test.

1:23:04

The turbine feed valves are closed to start the actual test, which increases radioactivity (by increasing the void ratio).

1:23:40

The chief operator gives the manual order to rapidly insert the control rods, but due to their design, this begins by increasing radioactivity.

1:23:44

Reactor power peaks. Explosions are followed by fire. In the core, the fuel rods break. Uranium oxide pellets overheat and shatter, reacting with cooling water to produce high pressure that causes the fuel channels to rupture and displace the upper reactor slab (weighing 2,000 tonnes). Burning debris is projected and starts a variety of fires. It takes firemen three hours to put out these fires, during which time reaction continues in the core with combustion of the graphite, which generates a cloud that contaminates Europe. Between 27 April and 10 May, 5,000 tonnes of materials (sand, boron, clay, lead, etc.) are spread by helicopter to cover the reactor.

[1] *The RBMK-1000 (Reaktor Bolshoy Moshchnosti Kanalniy) is a reactor of Soviet design and construction using pressure tubes with graphite moderator and a weakly enriched uranium dioxide fuel (2% 235 U).*

(source : IRSN)

Following the accident at Unit 4

Reactor No. 1, commissioned in September 1977, was shut down in November 1986 (6 months after the disaster). Substantial works would have been required.

Reactor No. 2, commissioned in December 1978, was shut down in 1991 following a fire in one of the machine rooms. The Ukrainian authorities decided in March 1999 to shut it down permanently.

Reactor No. 3, commissioned in 1981, was permanently shut down on 15 December 2000.

The construction of reactors 5 and 6, begun in 1981, was discontinued following the accident.

The current object shelter (sarcophagus)

Immediately after the accident on 26 April 1986, the Russian authorities built a structure called the "sarcophagus" around the damaged reactor under extremely difficult conditions and in the short space of six months.

Erected on walls that had withstood the explosion and over the debris from the Unit 4 building, the sarcophagus was designed to limit dispersal of radioactive materials, prevent ingress of the elements (rain, snow, etc.) into the reactor and make possible the continued operation of Unit 3, adjacent to the damaged reactor. But the extremely difficult conditions under which the work was carried out made it impossible to design the sarcophagus to perfect standards. Roof components had to be installed remotely using cranes. It was not possible to join them in a watertight fashion or to attach them to sound supports. A very large proportion of the 190 tonnes of reactor fuel remains in the sarcophagus. The lower reactor compartments contain water runoff from rainfall and snow. This water is monitored and periodically pumped.

Initial reinforcement work was carried out on the sarcophagus between March and December 1999. This work was designed to stabilise the common ventilation stack shared by Units 3 and 4 and to reinforce the concrete beam structures supporting the sarcophagus roof. Following this, in 2001, additional work was undertaken to reduce runoff water ingress into the sarcophagus and improve physical protection of the nuclear materials. Lastly, a series of works were undertaken in 2005 to consolidate the walls and roof supports. This work was completed in July 2006.

Despite these projects, the current sarcophagus no longer meets safety and security standards, mainly due to:

- the non-negligible risk of sarcophagus collapse,
- the risk of criticality, i.e. of resumption of a chain reaction in the molten fuel due to the presence of water (risk considered very low),
- the risk that radioactive dust from the decomposition of the lava under the reactor could become suspended in the atmosphere.

Moreover, clean-up work cannot take place inside the existing sarcophagus.

History of the New Safe Confinement project

In 1992, Ukraine initiated a competition for ideas to design a confinement following the explosion of Unit 4. The European "Resolution" consortium led by Campenon Bernard SGE (VINCI) was declared the winner. The consortium proposed to confine, sort and store the short half-life debris, to place the waste with no final destination in intermediate storage and to finance the project.

In 1994, the European Union financed a feasibility study on securing the existing sarcophagus. The Alliance consortium was formed for this purpose, bringing together six European companies: Campenon Bernard SGE – France (leader), AEA Technology – UK, Bouygues – France, SGN – France, Taywood Engineering – UK and Walter Bau – Germany.

A first ECU 3 million study contract was signed (between September 1994 and August 1995), followed by a second ECU 500,000 study contract.

In 2004, the New Safe Confinement invitation to tender was issued, covering design, construction and commissioning of a new confinement structure making it possible to subsequently dismantle the existing sarcophagus. The NOVARKA 50/50 consortium made up of VINCI Construction Grands Projets (leader) and Bouygues Travaux Publics was formed. The technical bids were submitted in November 2004 and the financial bids in June 2005.

When the bids were publicly opened, the NOVARKA bid had the lowest cost.

The contract was signed on 17 September 2007 in Kiev.

6- Press contacts and useful links

VINCI Press Office
+33 1 47 16 31 82
media.relations@vinci.com

Mathieu Carré
+33 1 30 60 66 39
m.carre@bouygues-construction.com

NOVARKA's website:
www.novarka.com

VINCI Group corporate site
www.vinci.com/

Bouygues Construction Group corporate site
www.bouygues-construction.com/

A video describing the project timeline is available at:
vimeo.com/156697505

Institut de radioprotection et de sûreté nucléaire (IRSN)
www.irsn.fr/EN/