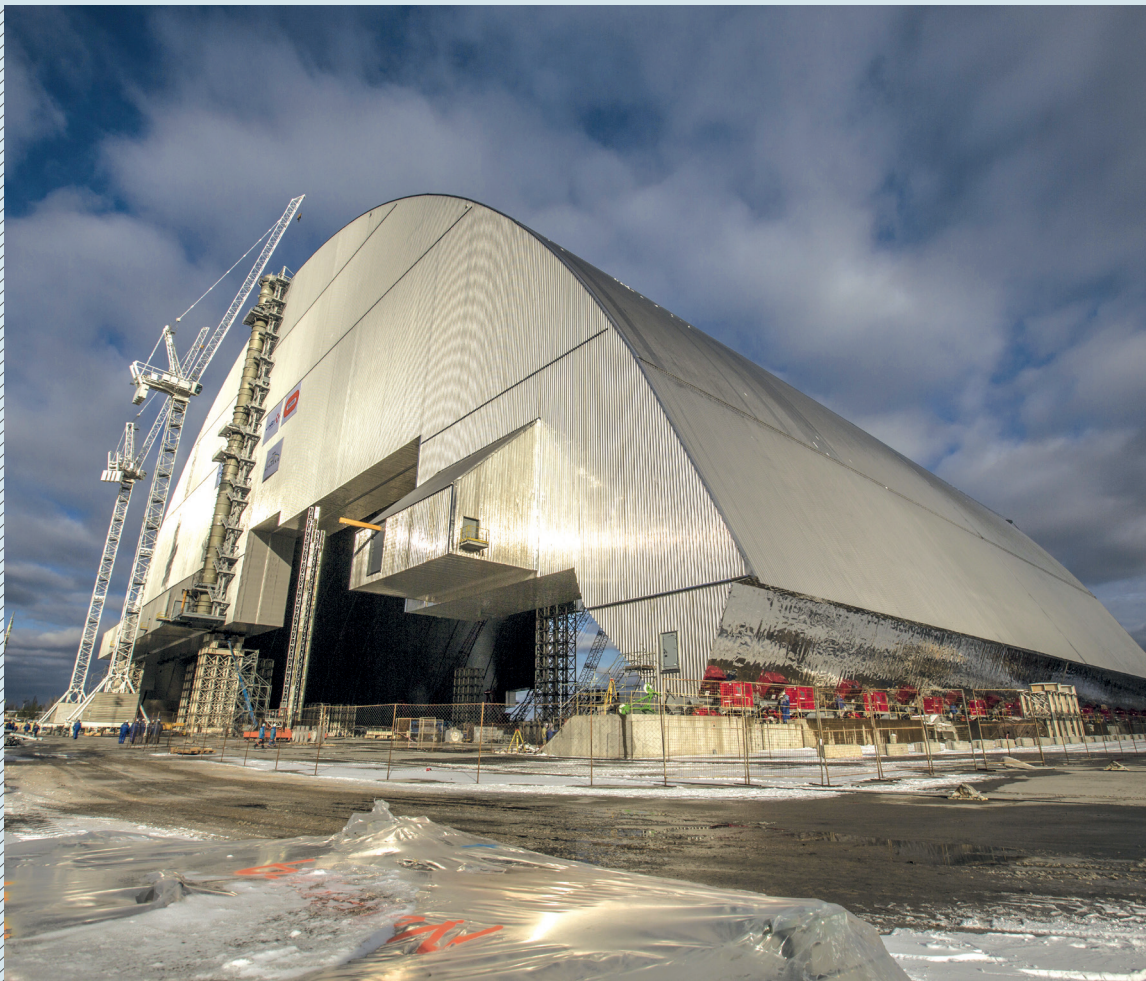


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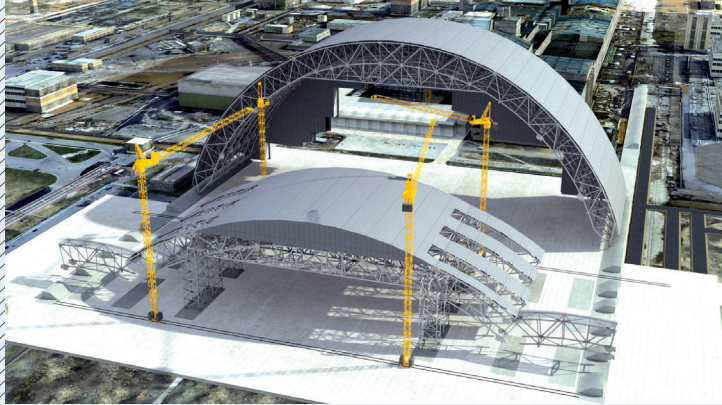
November 29th 2016 press conference,  
Chernobyl, Ukraine

# Chernobyl New Safe Confinement: a one-of-a-kind project



#chernobyl

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## Editorial

# “Transforming Chernobyl”

**Nicolas Caille**, head of the Novarka project

The new arch confining Chernobyl is unrivalled worldwide. VINCI Construction and Bouygues Construction joined forces and pooled their expertise in the Novarka consortium to fulfil their mandate from Ukrainian authorities.

10,000 men and women from almost 30 countries have spent part of their lives making this feat possible, imagining and designing a smart metal arch to secure and dismantle the damaged reactor, building it, equipping it and now pushing it into its final position. This unbelievable challenge forced us to push our limits day after day. We have spent 25 million hours engineering, designing and building this arch here.

Employee health and safety were naturally at the centre of every decision we made and our goal was to make sure we had zero radiological accidents.

In a year's time, the last technical components will have been fitted and tested, and we will deliver a structure that will keep Ukraine safe for the next 100 years.

Many people teamed up with Novarka to put us where we are today. Our partner suppliers and subcontractors, Ukrainian authorities, ChNPP (Chernobyl Nuclear Power Plant), PMU (Project Management Unit) and EBRD (European Bank for Reconstruction and Development) employees and donor country representatives all worked together with us to bring hope back to Chernobyl.

**Suma Chakrabarti**, EBRD president

The works to transform Chernobyl with the construction of the New Safe Confinement (NSC) are nearing conclusion. This year, we are witnessing a crucial milestone – the New Safe Confinement slid into its final position over the Chernobyl shelter. This gives us confidence that the project will be finished by November 2017 as scheduled.

The Chernobyl project would not have been possible without the active involvement and generous contributions of the international community and Ukraine.

To date more than 40 countries and organisations have provided close to €2 billion of which the European Bank for

Reconstruction and Development (EBRD)'s contribution for the NSC is €500 million. The progress on the ground gives us a sound basis to believe that the total costs for the Shelter Implementation Plan – the strategy to transform the site into a safe state, of which the New Safe Confinement is the most prominent element – will remain within the planned €2.1 billion.

Our engagement in Chernobyl has always been guided by the need to overcome the legacy of the 1986 accident through a joint effort. As we approach the final stage our commitment must not falter and we must bring our effort to a successful conclusion.

# 1. Project overview

## 30 years of international cooperation serving an outstanding project

### 1986 #accident

The 1986 nuclear accident at the Chernobyl power plant left behind a dangerous, difficult and costly legacy. A first shelter was built from May to October 1986, intended to last no more than 30 years.

### 1992 #competition for ideas

In 1992, Ukraine initiated a competition for ideas to design a confinement following the explosion of Unit 4. The European “Resolution” consortium led by **Campeon Bernard SGE** (that later became **VINCI Construction Grands Projets**) was declared the winner.

### 1994 #feasibility study

In 1994, the European Union financed a feasibility study on securing the existing shelter. The Alliance consortium was formed for this purpose, bringing together six European companies: **Campeon Bernard SGE (leader)** – France, **AEA Technology** – UK, **Bouygues** – France, **SGN** – France, **Taywood Engineering** – UK and **Walter Bau** – Germany. During this phase the consortium proposed a New Safe Confinement shaped like an arch.

### 1995 #Memorandum of Understanding

In December 1995, Ukraine signed a Memorandum of Understanding with the G7 and EU which provided for the establishment of dedicated donor fund at the **EBRD** to support the country in overcoming the challenges it faces in Chernobyl.

### 2000 #last operational reactor shut down

In December 2000, the last operational reactor at Chernobyl was shut down.

### 2001 #conceptualization

Agreement on the concept of the New Safe Confinement has been reached in 2001 and the preliminary design was approved in 2004.

### 2004/2005 #tender

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 shelter. The **NOVARKA 50/50** consortium made up of **VINCI Construction Grands Projets (leader)** and **Bouygues Travaux Publics** has been 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.

### 2007 #contract's signature

The contract was signed on 17 September 2007 in Kiev.

### 2010/2012 #beginning of construction

Phased regulatory approvals allowed the civil construction work to start in 2010 and the assembly of the arch-shaped construction began in 2012.

### 2016 #sliding operations

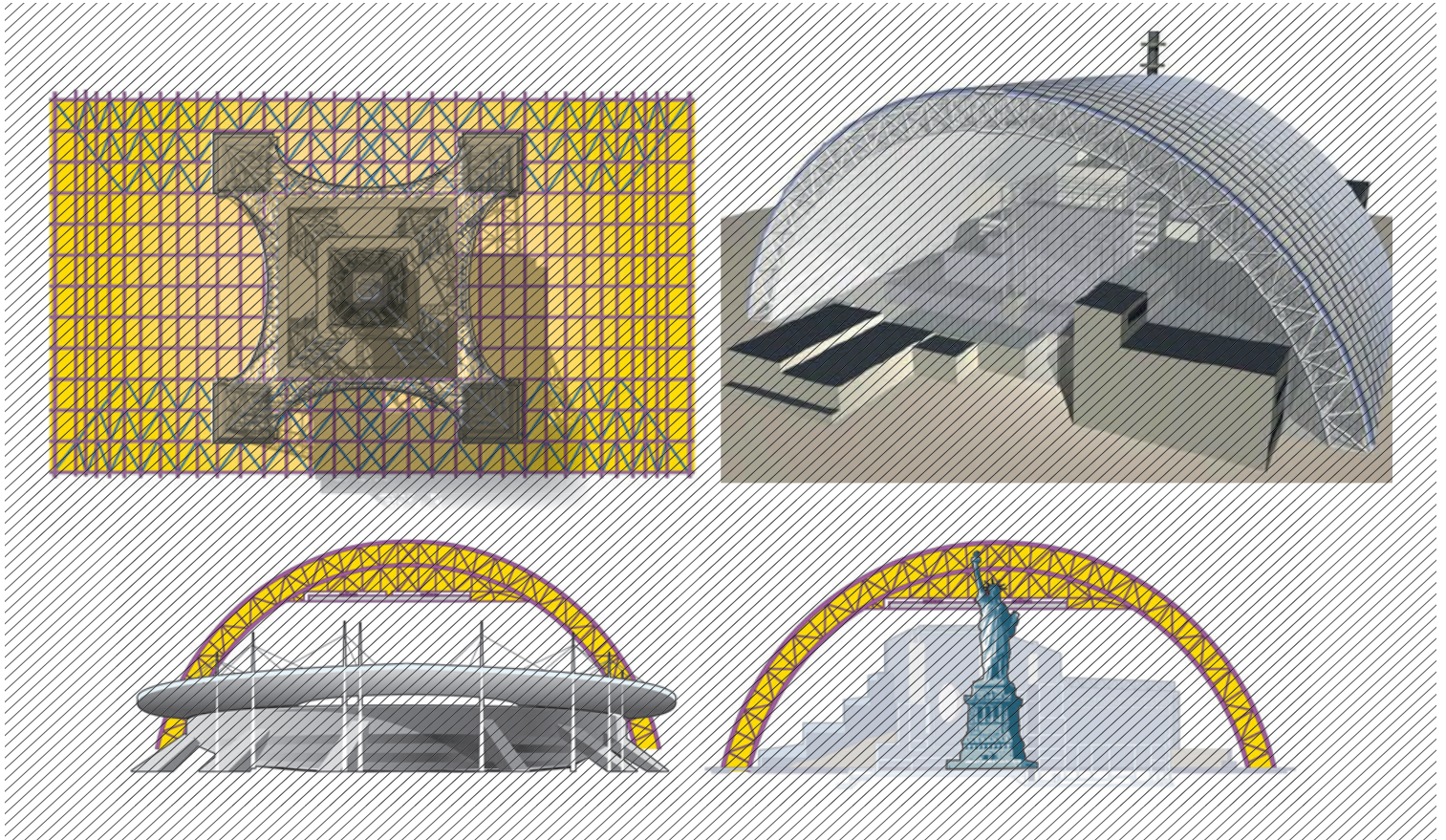
The gigantic structure, equipped to support the operation of the confinement and dismantling, has been slid into its final position over the current Chernobyl shelter in November 2016.

### 2017 #end of works and implementation

In 2017, work will continue on the final installation of equipment, testing and commissioning in advance of project completion in November of that year.



## The biggest mobile metal structure in the world



The arch-shaped confinement is made up of a 25,000 tonnes (36,000 tonnes when 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. It is the biggest mobile metal structure in the world.

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

- protect the environment from the instable shelter
- contain large masses of radioactive material still inside
- create conditions for future dismantling.

It has been 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.

# The Shelter Implementation Plan

The New Safe Confinement has been built under the framework of the Shelter Implementation Plan, a blueprint developed by Western and Ukrainian experts and funded by the European Commission and the United States of America. The plan sets out a step-by-step approach to the search of solutions for the Chernobyl problems and defines over 300 sub-tasks, most of which have been delivered to date.

## Infrastructure

Creating the necessary infrastructure was a prerequisite for the construction of the New Safe Confinement. This included the construction of road and rail connections as well as the refurbishment of power, water, drains and communications services and supplies. In addition, a new changing facility for workers provided medical and radiation protection facilities and ambulances.

## Stabilisation

The roof and the western wall of the Chernobyl shelter hastily built in 1986 were successfully stabilised during the period 2004/08. Eighty per cent of the roof load was transferred to a new external support structure. Inside the shelter, extremely challenging tasks were carried out, such as the installation of new structural supports in the “de-areator stack”, reducing the risk of collapse.

## Workers' protection and safety

A radiological protection strategy, a programme for workers and an emergency plan for accidents were developed and implemented. State-of-the-art biomedical protection and screening programmes as well as radiation protection equipment were introduced and a new safety culture implemented.

## Monitoring

Detailed studies were carried out to assess the site's risks. The probability of criticality incidents was examined and assessed as virtually non-existent. Today, an integrated monitoring system is in place.

## Additional decommissioning works in Chernobyl

Reactor 4 is not the only challenge donor funds are addressing in Chernobyl. Urgent, early safety and security upgrades in Chernobyl's unit 3 were completed. After the completion of urgent, early safety and security upgrades in Chernobyl's unit 3, the EBRD-managed Nuclear Safety Account finances two projects:

### The Interim Spent Fuel Storage Facility-2 (ISF-2)

The Interim Storage Facility will provide safe and secure storage of the spent nuclear fuel generated during the operation of units 1-3. It is currently in the final phase of construction. The facility will process, dry and cut more than 20,000 fuel assemblies, which will be placed in metal casks to be enclosed in concrete modules on site. The spent fuel will then be stored safely and securely for a minimum period of 100 years.

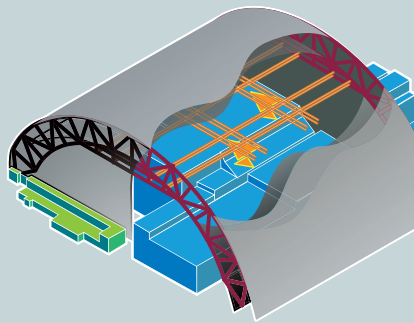
### The Liquid Radioactive Waste Treatment Plant (LRTP)

The plant retrieves highly active liquids, processes them into a solid state and moves them to containers for long-term storage. The facility was awarded its operating licence in December 2014.



### 3. Key figures of the project

Located two hours drive north of the Ukrainian capital Kiev, the accident at Chernobyl spread radioactive dust across Europe and poisoned the surrounding area.



Watch the NSC take shape  
<http://bit.ly/1Fe9Pjc>

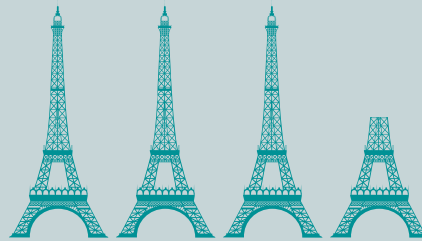
#### Built to last

Huge doesn't begin to describe this structure  
The metal frame alone weighs...

25,000  
tonnes



... 3.5 times the weight of the Eiffel Tower



And at

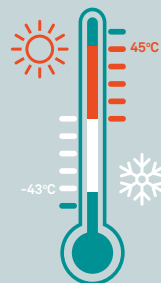
108 metres

is tall enough to cover Notre-Dame de Paris

Total equipped weight

36,000 tonnes

The majority of the steel structure has been fabricated in Italy



#### The test of time

With an expected minimum lifetime of 100 years the NSC will need to deal with all climate changes. The confinement is built to withstand temperatures ranging from -43°C to +45°C...

...and a category-3 tornado  
(wind speeds of 254–332km/h)



## Big and smart

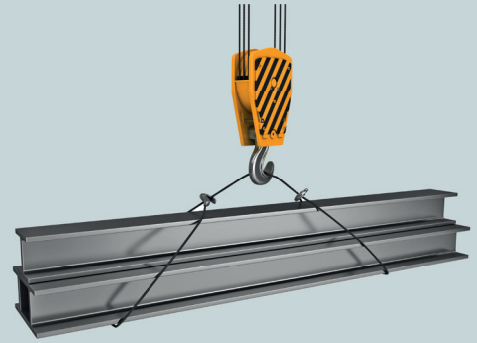
Vaguely similar to an aircraft hangar the total length of the NSC is:

162 metres...  
... or longer than  
two jumbo jets



2x

remotely operated cranes will allow workers to dismantle and remove highly radioactive material without entering the danger zone.



Each crane girder is  
100 metres long...  
... and supports  
50 tonnes

## Human resources



1,200 workers  
on site every day  
during the construction

To ensure that workers on the NSC are safe from excessive exposure to radiation, strict dose limits are observed. Dose rates in the main arch construction area are:

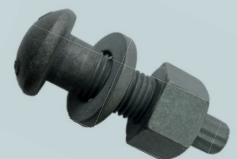


0.0075 mSv/hr  
An average dental x-ray is  
0.014 mSv

Safety is paramount. The project has an excellent safety record with first class safety procedures in place.

An international workforce of over  
30 nationalities

Workers have had to fit over  
500,000  
specially  
manufactured  
bolts





## Moving heaven and earth

Once joined and fitted with cranes the NSC has been slid the final 327 metres and begin final commissioning.

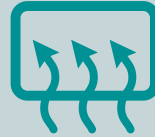
The foundations contain

20,000 m<sup>3</sup> of concrete



equivalent to

3,200  
truckfuls of concrete



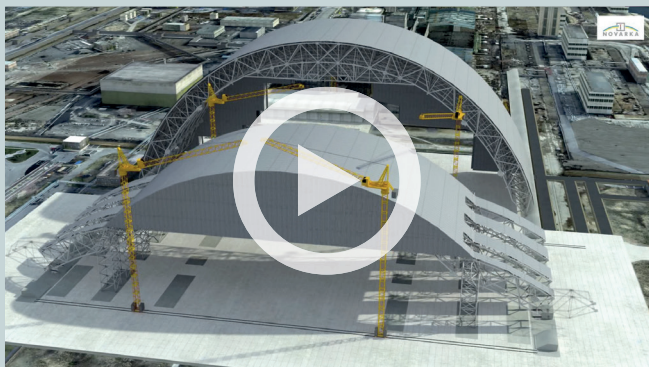
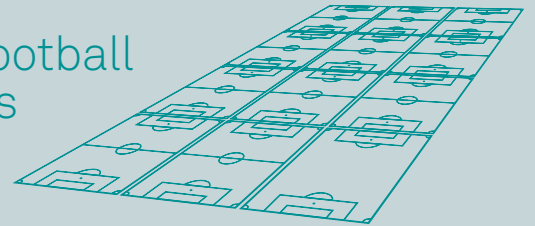
A sophisticated ventilation system will minimise the risk of corrosion, ensuring that there is no need to replace the coating.

Exterior cladding

86,000 m<sup>2</sup>

equivalent to

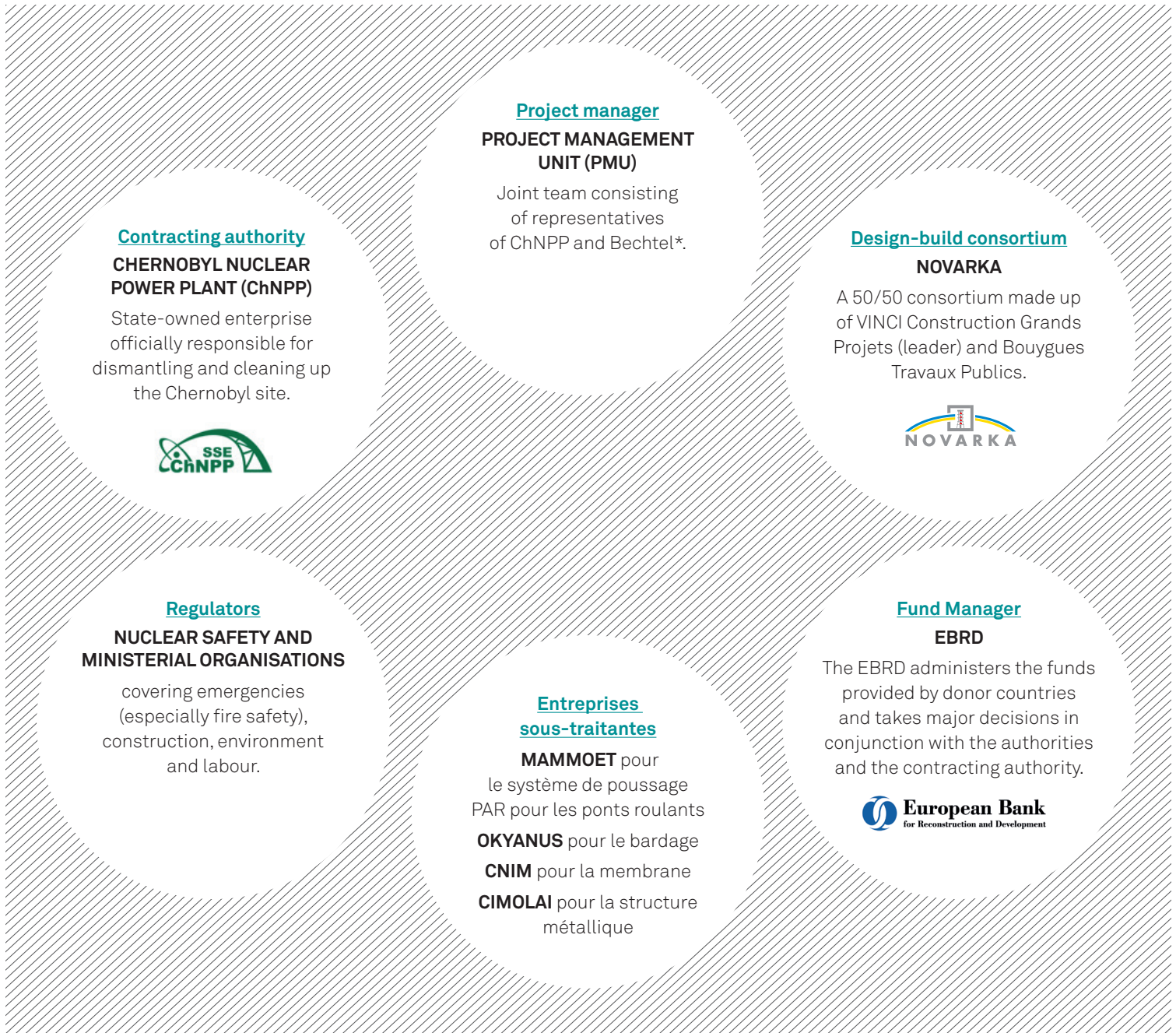
12 football  
pitches



Watch an animation of the construction  
<http://bit.ly/1MtWzqN>

### 3. Experienced stakeholders to transform Chernobyl

#### The project stakeholders



\* 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.



## Two French engineering giants serving Ukrainian and international aims

**NOVARKA**, a 50/50 joint venture formed by **VINCI Construction Grands Projets (the consortium leader)** and **Bouygues Travaux Publics**, has built the New Safe Confinement over the Unit 4 reactor at Chernobyl, which exploded on 26 April 1986.

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



### Staffing

68,000 employees



### 2015 turnover

€14.5 billion



### Staffing

53,500 employees



### 2015 turnover

€12 billion

### VINCI Construction

VINCI Construction is a subsidiary of the VINCI Group, a global player in concessions and construction, which employs more than 185,000 people in some 100 countries. VINCI Construction, a European construction leader, operates on five continents, with more than 68,000 employees and almost 800 companies generating 2015 revenue of €14.5 billion.

### Bouygues Construction

As a global player in construction and services, Bouygues Construction designs, builds and operates buildings and structures which improve the quality of people's living and working environment: public and private buildings, transport infrastructures and energy and communications networks. A leader in sustainable construction, the Group and its 53,500 employees have a long-term commitment to helping their customers shape a better life. In 2015, Bouygues Construction generated €12 billion in revenue.

**VINCI Construction et Bouygues Construction,  
a winning alliance on other major projects**



The Cairo metro



The new coast road, La Réunion

**The Cairo metro since 30 years**

VINCI Construction Grands Projets and Bouygues Travaux Publics have been working together with their Egyptian partners to build the Cairo metro since 1981. With the latest contract for Phase 3 of Line 3, signed on 17 April 2016, the metro system built over the past 35 years now comprises three lines covering more than 90 km with 70 stations. This project is of crucial importance to North Africa's largest urban area. It carries more than 9 million passengers daily.



The Cairo metro, january 2016

**An outstanding civil engineering project in La Réunion**

On Reunion Island, VINCI Construction subsidiaries VINCI Construction Grands Projets and Dodin Campenon Bernard are working with Bouygues Travaux Publics and Demathieu Bard on the design-build construction of the offshore New Coastal Highway. The exceptional 5,400 metre engineering structure running along the coast will be France's longest viaduct. It will link Saint-Denis (the administrative centre of Reunion Island) and La Grande Chaloupe, replacing the current coastal road, which is exposed to rock fall and flooding by heavy seas and storm surges. The technical solution used to build the offshore viaduct was to precast 95% of the sections on land and install them offshore by seagoing equipment, notably the Zourite self-elevating, self-propelled barge for which a prototype was specially designed and built for the project. The Zourite began installing the sections in September 2016.

## 4. Large-scale international funding

### Donors and funding

The EBRD manages two donor funds on behalf of the international community which finance Chernobyl projects – the Nuclear Safety Account and the Chernobyl Shelter Fund (CSF). In addition, the Bank has become the largest contributor with total commitments from its own resources of €715 million. As fund manager the Bank works closely with the government of Ukraine to help ensure that projects are implemented efficiently. The Bank enters into grant agreements with the recipient organisations and disburses funds to contractors. All contracts are awarded in compliance with EBRD Procurement Policies and Rules.

### The Chernobyl Shelter Fund (CSF)

The CSF was established at the EBRD in 1997 and finances the activities under the Shelter Implementation Plan.

The fund's activities are directly supervised by the donors. All contributors are represented in the assembly, which meets twice a year as the highest-decision making body. The following contributors are members of the CSF: Austria, Belgium, Canada, China, the Czech Republic, Denmark, the European Community, Finland, France, Germany, Greece, Ireland, Italy, Japan, Kazakhstan, Kuwait, Luxembourg, the Netherlands, Norway, Poland, Russia, Saudi Arabia, Spain, Sweden, Switzerland, Ukraine, the United Kingdom, and the United States of America.

The following countries have made donations: Argentina, Australia, Azerbaijan, Croatia, Estonia, Hungary, Iceland, India, Israel, Korea, Liechtenstein, Lithuania, Portugal, Romania, the Slovak Republic, Slovenia and Turkey.

As of November 2016 the CSF has received close to €2 billion in total. The EBRD to date has provided €500 million of its own resources to support the New Safe Confinement.

### The Nuclear Safety Account (NSA)

Established in 1993, the Nuclear Safety Account (NSA) is the EBRD's oldest nuclear safety donor fund. Today, it finances the ISF-2 and the LRTP. To date, the Fund has received €390 million from 18 donor countries and institutions. A significant part of the EBRD contribution to the Chernobyl projects was allocated to ISF-2. The EBRD has indeed provided €217 million of its own resources for the ISF-2 project.

The following contributors are members of the NSA: Belgium, Canada, Denmark, the European Community, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Russia, Sweden, Switzerland, the United Kingdom, Ukraine and the United States of America. Azerbaijan has made a donation. As of November 2016, the NSA has received some €390 million.

### The EBRD and nuclear safety

Transforming Chernobyl is the biggest, but not the only task the EBRD Nuclear Safety Department is facing. Financed by the international community the EBRD is currently managing seven nuclear safety funds to assist tackling the nuclear legacy in eastern Europe and the former Soviet Union. In addition to the NSA and the CSF the EBRD also manages three International Decommissioning Funds for nuclear power plants in Jaslovské Bohunice, Slovak Republic; Ignalina, Lithuania; and Kozloduy, Bulgaria. The three countries committed to close their first generation Soviet-designed nuclear power plants in the context of their EU accession. These funds have also taken a leading role in the promotion of energy efficiency projects in these countries which faced the loss of generating capacity with the closure of nuclear power stations.



## Others projects

The Northern Dimension Environmental Partnership Support Fund was established at the EBRD in 2002 for the improvement of the environment in north-west Russia. The programme's "Nuclear Window" provides funding for projects that mitigate the legacy of the operation of nuclear-powered ships and submarines of the Northern fleet in Russia that have been decommissioned.

The recently established Environmental Remediation Account will deal with the legacy of uranium mining in Central Asia. All funds are managed by the EBRD Nuclear Safety Department on behalf of the contributing countries. The department, in cooperation with specialised services of the Bank, is responsible for all technical, financial, administrative and legal aspects of fund management and compliance with EBRD policies and rules, particularly with respect to procurement, environmental protection and public information.

Each Nuclear Safety Fund is governed by fund rules agreed by the respective assembly of contributors (donors) to the fund and approved by the EBRD Board of Directors. The assembly approves and oversees fund management, work programmes and financial statements and decides on the financing of individual projects.

In addition to managing nuclear safety grant funds, the EBRD Nuclear Safety Department also plays an important role in EBRD projects to upgrade nuclear safety levels in existing power plants. The EBRD can finance nuclear waste management decommissioning and safety upgrade projects with loans and signed a loan agreement, together with Euratom, with Ukraine in 2013 for a €600 million safety upgrade of operating nuclear reactors in the country.



## 5. An original and complex project Numerous technical innovations

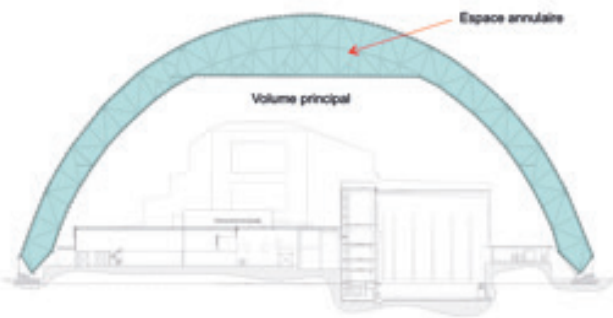


fig. 1



fig. 2

### A confinement using lightweight metal cladding

The creation of an annular space kept at a slight positive pressure over the main volume, which is kept at a slight negative pressure, lightens the structure (*figure 1*).

The external and internal cladding is made up of multiple layers, each of which has a specific function. It has undergone a large number of laboratory tests to validate its negative pressure resistance, impact and fatigue strength and airtightness.

Functions of the external cladding:

- Resistance to wind, tornados (up to 13 kN/m<sup>2</sup> negative pressure)
- Static and dynamic resistance to snow load
- Resistance to local impact
- Airtight and watertight sealing
- Durability (100 years) with minimum maintenance

Functions of the internal cladding:

- Radioactive dust containment
- Airtight sealing
- Decontamination capacity (ability to be decontaminated)
- Fire resistance
- Durability (100 years) with minimum maintenance

In addition, the outside arch walls are made of stainless steel to ensure durability and strength.

### Large scale tilting panels

To slide the confinement over the existing shelter and connect it with the existing structure, tilting panels with a height of up to 30 metres have been provided. They will be lowered into position after the arch is transferred.

Some features of the existing shelter protrude above the permanent structures. To clear them, it was necessary to include components in the Eastern wall that can be raised during the sliding operation and then lowered into position after the arch has reached final location. These "tilting panels" (*figure 2*) are made of the same structure as the walls, to which they are attached by sealing membranes. They are tilted by winches and jacks and then locked into position by means of special jacks equipped with a separate hydraulic circuit.

### Multipurpose ventilation

The ventilation system ensures both confinement and durability of the structure by controlling humidity. To ensure semi-dynamic confinement, an annular space was created in which a slight positive pressure will be maintained. It has a volume of about one million m<sup>3</sup> and forms a barrier preventing radioactive dust from escaping to the outside. The air within it is also kept at 40% relative humidity to ensure the long-term and even very long-term durability of the metal frame of the arch. All electrical and mechanical equipment for the ventilation system is supported by the Western wall and is easily accessible for maintenance purposes.

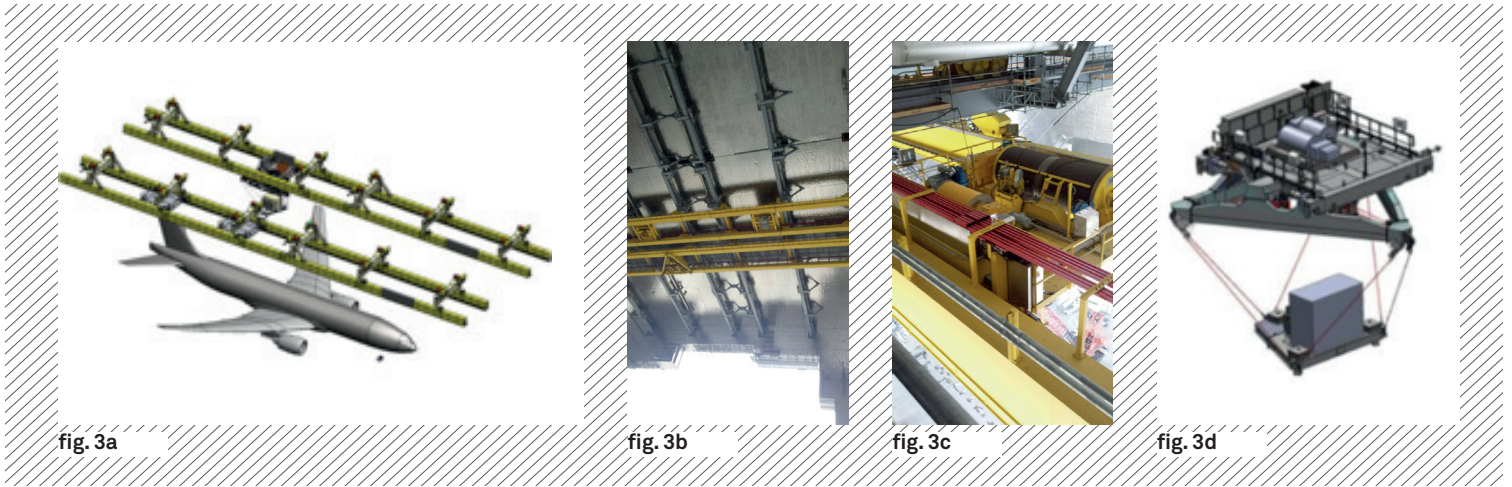


fig. 3a

fig. 3b

fig. 3c

fig. 3d

The air is dehumidified by low-energy dessicant wheels. A slight negative pressure is maintained in the main volume of about 1.4 million m<sup>3</sup>. The air passes through HEPA filters that remove virtually all radioactive particles before it is discharged through the stainless steel stack suspended from the arch. The main-volume ventilation equipment is housed in the waste treatment building and is accessible for maintenance purposes. Nearly 4 km of ducts are installed in the annular space and the main volume.

### Outsized bridge cranes

To limit risks during deconstruction, remotely operated bridge cranes with a length of almost 100 metres span the width of the area covered.

Remotely operated dual-girder bridge cranes (*figures 3a & 3b*) span the entire width of the area in which dismantling will take place

In the first phase, several types of secure carriages will be suspended from these “quadrilaterals” to deconstruct large components (*figure 3c*). A cable trolley with 6 degrees of freedom will then transfer deconstruction tools into the workspace and support vertical and horizontal loads (*figure 3d*). Trolley maintenance will take place in a suspended garage, which will be protected from radiation and ventilated with clean air under slight positive pressure compared to the main volume.

### Customised sealing membranes

Special sealing membranes were designed to accommodate major movements of the arch end walls and reduce the load transmitted by the arch to existing structures.

The membranes (*figure 4*) that seal the arch to the existing structure must meet a number of requirements. They must be durable and repairable, withstand large relative movements of 1m in all directions, drastically limit loads to avoid destabilising fragile existing structures and prevent propagation of tears in a T3 tornado.

The material selected, based on a special polyurethane, has undergone extensive laboratory and factory testing. To manufacture it, a robot is used to spray the material on a mould. The patented chevron pattern limits deformation.



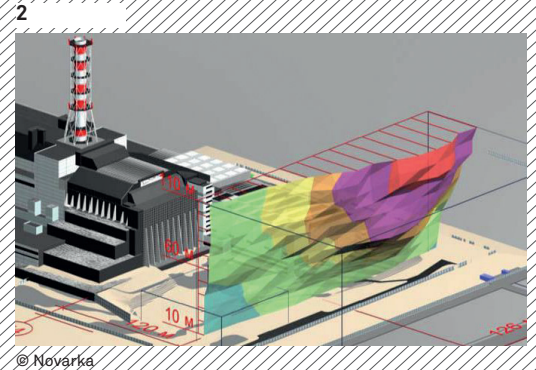
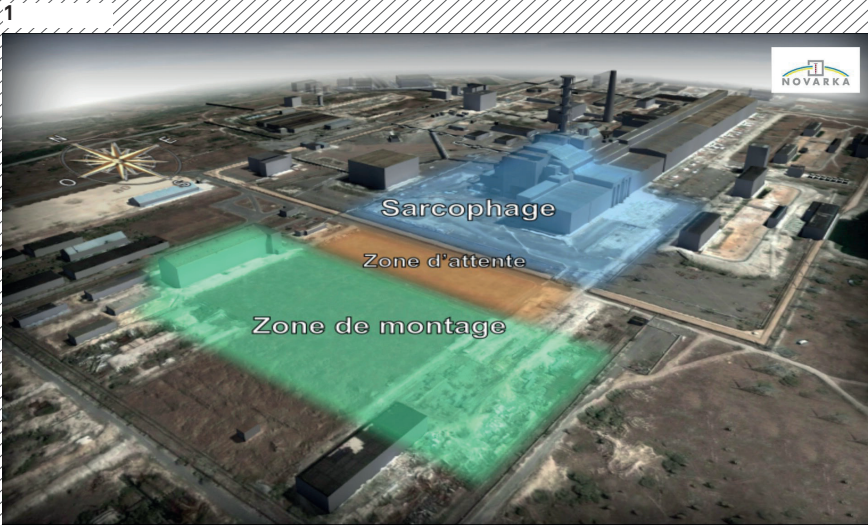
fig. 4

## Construction timeline

The arch was assembled to the west of the site in a specially developed area away from the damaged reactor, and then slid into position to cover the existing shelter. The worksite has been divided into three areas: the existing object shelter (shelter), the assembly area and the holding area.

Top priority has been given to protecting the environment and the population and to ensuring the safety of personnel. The site was 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 was 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.







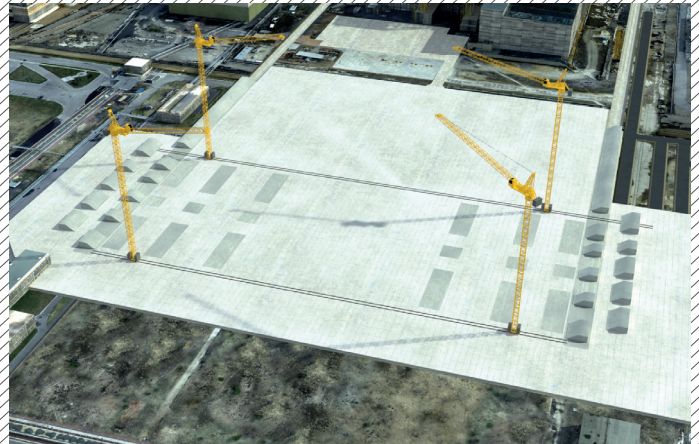
1



2



3



4

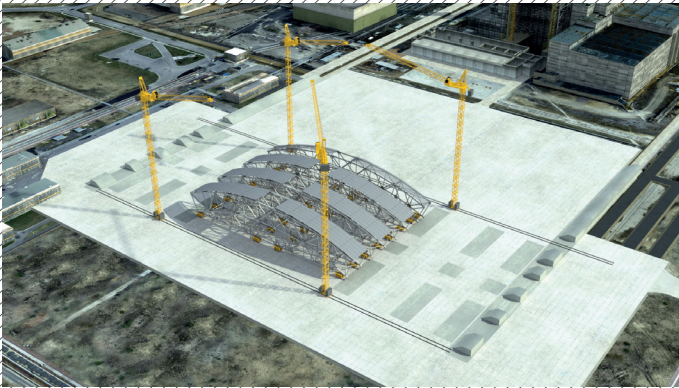
(1) The work began with cleaning and clearing the assembly area and dismantling the empty buildings. Excavation in the assembly area was kept to a minimum to avoid generating waste whenever possible. Two wide trenches were dug on either side of the reactor to prepare the ground for the longitudinal beams 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

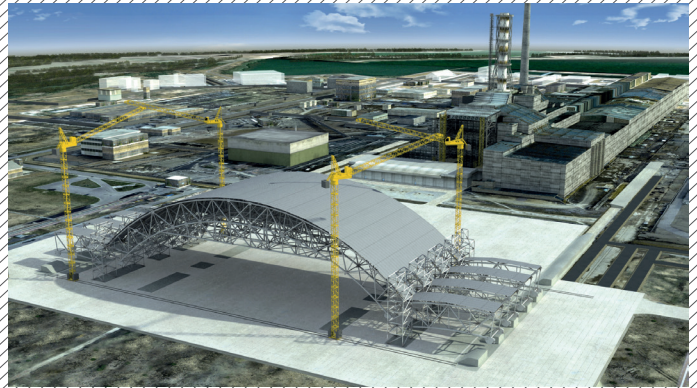
(3) Meanwhile, deep foundation works were undertaken in the trenches. In the assembly area, this involved driven metal piles. They were 1 metre in diameter, driven to an average depth of 25 metres.

(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 m<sup>2</sup>) was backfilled, using clean filler, to an average height of one metre, and then partially covered with concrete slabs. These slabs formed a work surface and provided protection from any radiation coming from the ground.

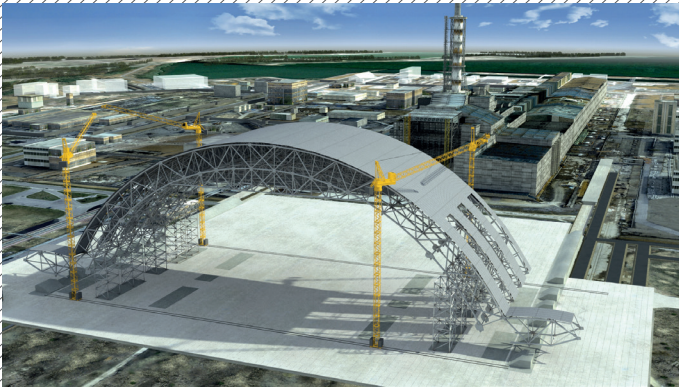




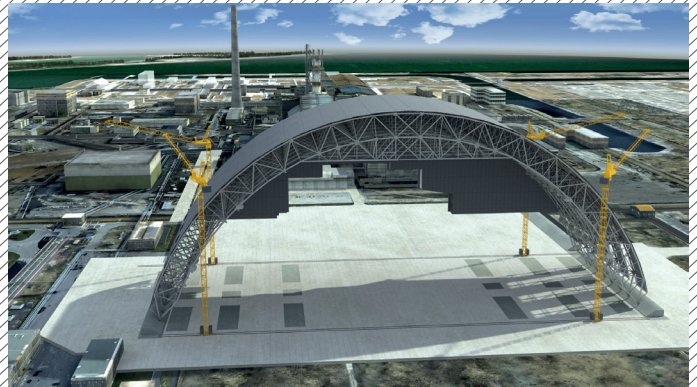
5



6



7



8

**(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.

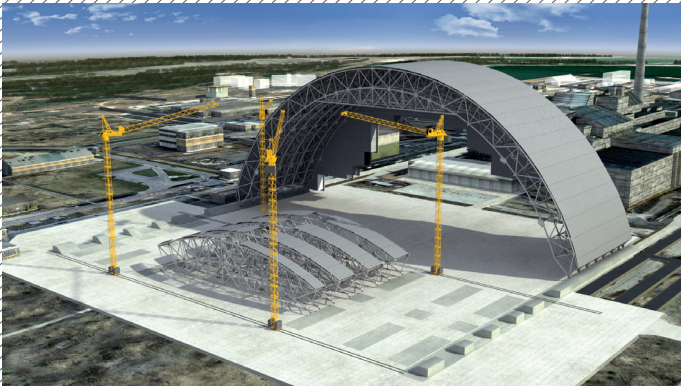
**(6)** The secondary arch elements were then connected to the central section using a hinge system. The first lifting operation was then undertaken, using towers designed to lift loads of more than one thousand tonnes. The structure was gradually completed with the addition of its remaining components.

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

**(8)** The east side wall was installed and the pushing equipment moved into place to slide the 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 continued with the concrete beams of the transfer area and then the foundations of the service area. The concrete piles in the service area were constructed with the continuous flight auger method (in which the auger was drilled into the ground, concrete was pumped in as the auger was withdrawn and the reinforcement cage was placed immediately after withdrawal of the auger in the fresh concrete). This technique makes it possible to avoid generating vibrations near the shelter. Construction work also started on the auxiliary building at the foot of the shelter, which will serve as the future control centre for the dismantling and confinement systems built into the arch.





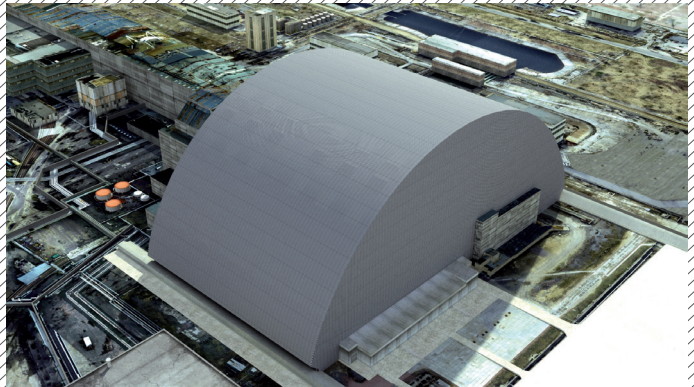
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10



11



12

(9) All structural elements were pre-assembled in a designated area outside the site, where as many components as possible – including electrical and mechanical equipment, ducting, piping and walkways – were 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 was 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 has been 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 were 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 have slide the arch 300 metres into its final position. Once it has been positioned above the object shelter, the arch and its side walls have been connected to the existing structures. The damaged reactor is then completely isolated from the outside world.

## Sliding operations

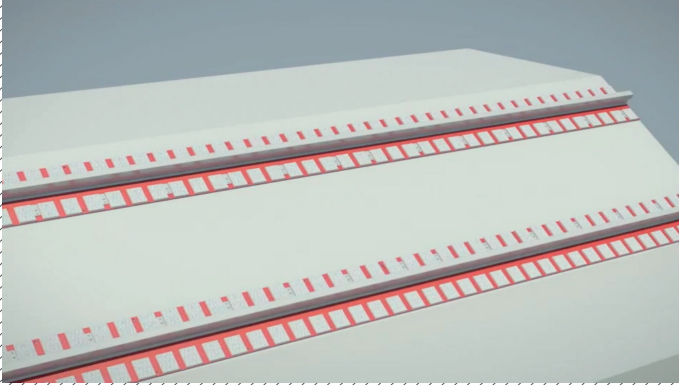


fig. 1

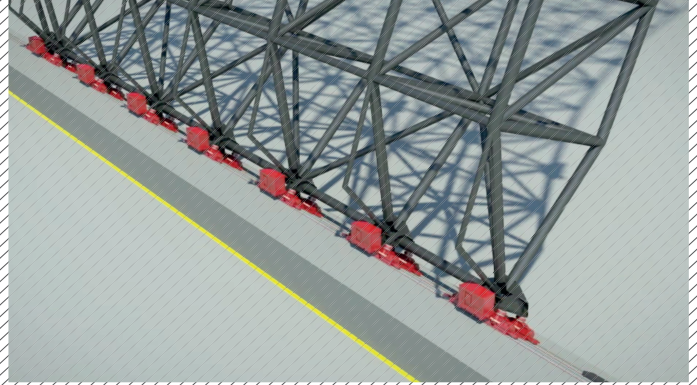


fig. 2

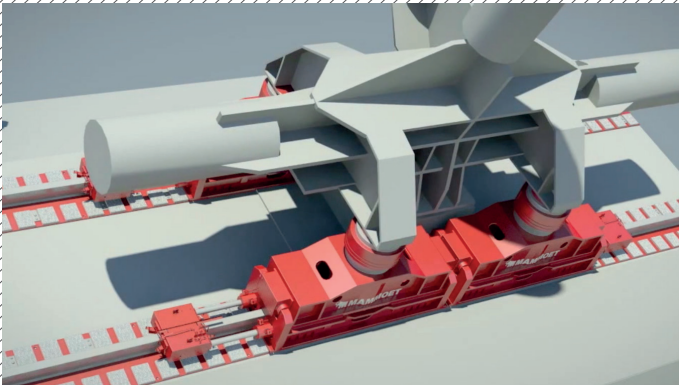


fig. 1

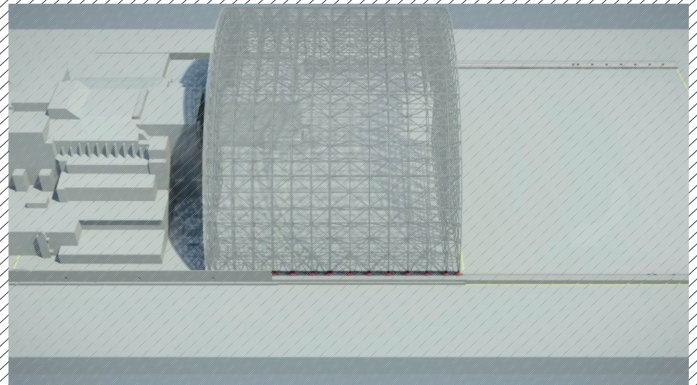


fig. 2

During the project, three previous sliding operations were carried out:

● **April 2014**

the east half of the arch (16,500 tonnes) has been slid 110 metres to make room in the assembly area for the second half.

● **November 2014**

the east half of the arch (17,800 tonnes) has been pushed 25 metres to free up the parking area.

● **July 2015**

the east half of the arch (18,800 tonnes) has been pushed 0.5 metre to connect it with the west half.

● **November 2016**

the fully equipped confinement (36,200 tonnes) has been pushed 327 metres to its final location.

**Figure 1.** Installation of Teflon rails to reduce friction.

**Figure 2.** Introduction of the pushing systems (32 total).

**Figure 3.** Four vertical hydraulic jacks are placed under each foot to support the weight of the arch and four push-pull jacks are used to slide the arch (a total of 116 jacks of each type).

**Figure 4.** Maximum displacement speed: 10 metres per hour.  
Distance to be covered: 327 metres.



## Safety of personnel, a constant priority



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

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

All personnel working in the area were outfitted with appropriate personal protective equipment (coveralls, masks, boots, helmets, gloves) and two dosimeters. The legal dosimeter recorded monthly doses received. The operational dosimeter monitored the actual radiation dose in real time and compared it with the predicted calculated dose.

The recorded data has been checked twice daily by NOVARKA radiation protection technicians at the site and analysed by the contracting authority’s laboratory.



If the budget was exceeded (which is in principle impossible, given the prevention procedures), personnel may have been 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 worked behind concrete or lead screens.

The radiation protection measures and rules applying at the site have been 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 was less stringent. Workers kept their masks with them but wear them only in case of an alert.

### **Hiring and human resources management**

Hiring was extremely selective and included a very comprehensive medical examination, which has been the decisive criterion for recruitment. Personnel hired to work at the site underwent the particularly stringent Ukrainian legal medical examination (called BIOMED), and due to this screening only two applicants out of three were hired on average. Personnel underwent prior safety training to learn how to behave in a radioactive environment. Regular medical monitoring - financed by the EBRD - has been 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 was present at the site at all times.

### **Living and working conditions**

In accordance with Ukrainian legislation, project workers could choose 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 was 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 were taken to limit the amount of work performed at height.

Workers were 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 was based in Kiev and employees working there were housed nearby.

Lastly, the NOVARKA administrative and functional offices were based in Slavutich (see appended map, page 25). Expatriate NOVARKA employees were housed in the city of Slavutich.

## 6. Annexes

### Detail project status in November 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

● **October 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)

● **March 2016:** installation of the last external cladding panel

● **May 2016:** lifting of the second bridge crane (800 tonnes to a height of 82 metres)

● **June 2016:** completion of civil engineering work on the control room building

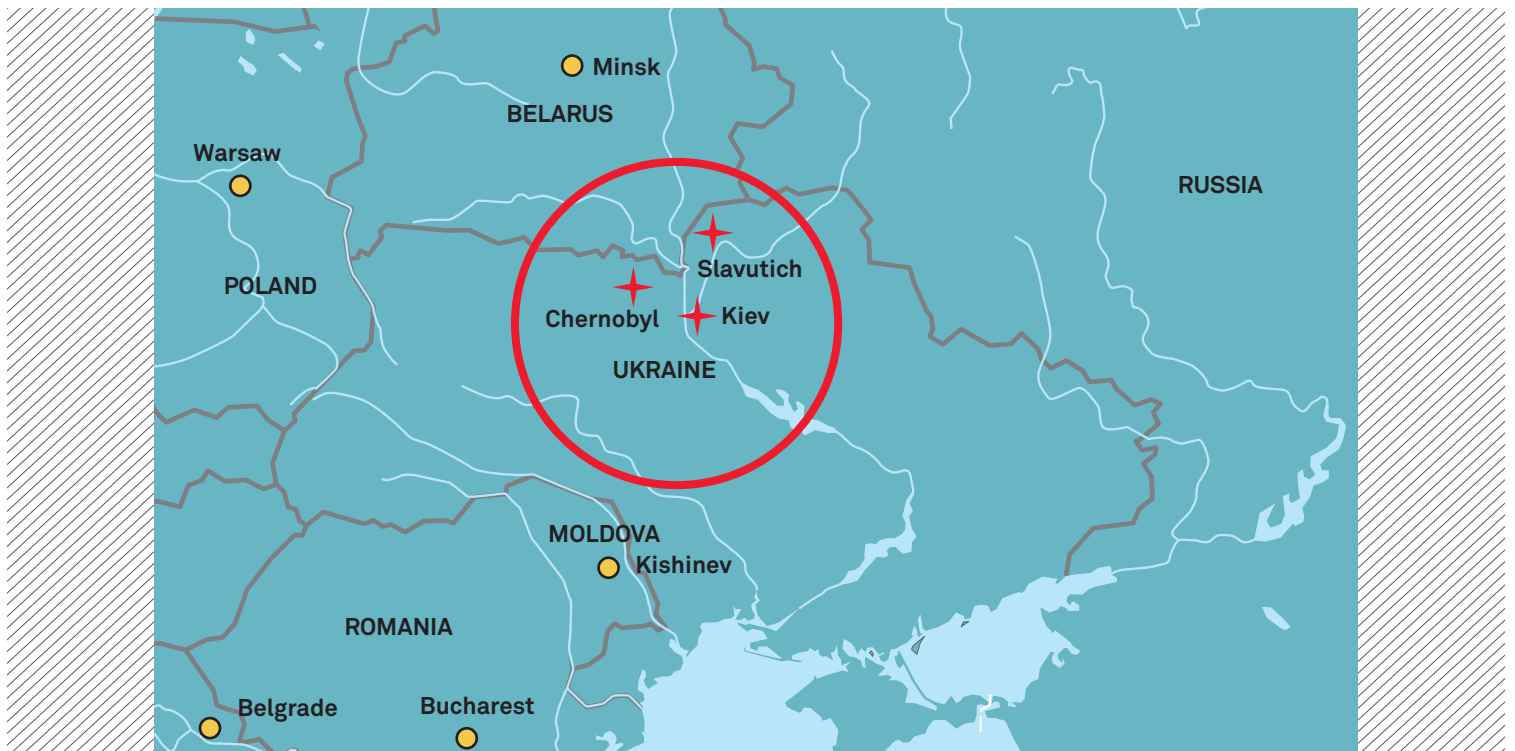
● **September 2016:** installation of the external ventilation system tube (80 metres long, 80 tonnes and 3.5 metres in diameter). Start of installation of anchors on the arch structure to fit the membrane that will seal the structure as a whole

● **November 2016:** sliding of the confinement structure over the damaged reactor and shelter

## Map

The project has been implemented at three different Ukrainian sites. Design studies were handled in Kiev, the **NOVARKA** offices (administrative, functional and project management departments) were located in Slavutich and project offices were located in Chernobyl. All activities were 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, was a 1,000 MWe RBMK\* reactor. It contained 1,681 pressure tubes enclosing the fuel (190 tonnes of enriched uranium oxide) and a graphite stack as moderator. The entire facility has been 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 has been powered down to achieve the power level used during testing (about 700 MWt). However, at the request of the electricity distribution centre, the reactor was kept at half-power to meet electricity demand. Control rods were progressively retracted from the core to maintain power.

### ● Around 11:00 p.m.

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

### ● 26 April at 1:15 a.m.

Contrary to procedure, operators decided 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 indicated 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 decided to continue the test.

### ● 1:23:04

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

### ● 1:23:40

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

### ● 1:23:44

Reactor power peaked. Explosions were followed by fire. In the core, the fuel rods broke. Uranium oxide pellets overheated and shattered, reacting with cooling water to produce high pressure that caused the fuel channels to rupture and displaced the upper reactor slab (weighing 2,000 tonnes). Burning debris were projected and started a variety of fires. It took firemen three hours to put out these fires, during which time reaction continued in the core with combustion of the graphite, which generated a cloud that contaminated Europe. Between 27 April and 10 May, 5,000 tonnes of materials (sand, boron, clay, lead, etc.) has been spread by helicopter to cover the reactor.

Source: IRSN.

\* 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% <sup>235</sup>U).



## 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 initial shelter

Immediately after the accident on 26 April 1986, the Russian authorities built a structure called the shelter 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 shelter 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 shelter 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 shelter. 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 shelter 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 shelter roof. Following this, in 2001, additional work was undertaken to reduce runoff water ingress into the shelter 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 shelter no longer meets safety and security standards, mainly due to:

- the non-negligible risk of shelter 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 shelter.

## Find out more

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## 7. Press contacts and useful links

#chernobyl



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Project website  
[www.novarka.com](http://www.novarka.com)

A video of the project's construction timeline is available here :  
[vimeo.com/156697505](https://vimeo.com/156697505)