A SunCam online continuing education course

Ethics Case Study on Notre-Dame Cathedral Fire

by

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Course Outline:

Professional Ethics
NSPE Code of Ethics for Engineers
Notre-Dame Cathedral Fire Overview
Timeline of Events
Lack of Fire Suppression System
Risk Ranking
Fire Protection in Cathedral Renovation
Lessons Learned
Helpful References
Examination

Professional Ethics

Ethics is concerned with moral principles and appropriate conduct. For example, doing the right thing, considering others before oneself, and behaving in accordance with agreed principles.

Professional ethics are standards of behavior for working professionals. For example, the Hippocratic Oath has been taken by physicians since the fourth century BCE. The oath established several principles of medical ethics still in use around the world, including medical confidentiality and non-maleficence (not harming a patient). Another historic example is the Teacher's Oath, which includes a commitment to respecting students, improving teaching skills, and teaching for the good of the students.

Today, professional behavior standards are set and enforced by:

- Employers, such as corporations,
- Professional organizations (NSPE, etc.), and
- Federal, state, or local regulations (government).

For example, Apple promotes conducting business ethically and has the following ethics statement on their website:

Ethics and Compliance

Apple conducts business ethically, honestly, and in full compliance with the law. We believe that how we conduct ourselves is as critical to Apple's success as making the best products in the world. Our Compliance and Business Conduct policies are foundational to how we do business and how we put our values into practice every day.

"We do the right thing, even when it's not easy."

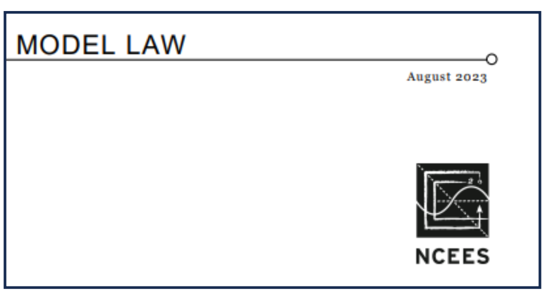
Tim Cook

Federal government employees (including government engineers) are subject to the ethical standards in Code of Federal Regulations:

> *5 CFR 2635.101 Basic obligation of public service.*
> *(a) Public service is a public trust. Each employee has a responsibility to the United States Government and its citizens to place loyalty to the Constitution, laws, and ethical principles above private gain. To ensure that every citizen can have complete confidence in the integrity of the Federal Government, each employee must respect and adhere to the principles of ethical conduct set forth in this section, as well as the implementing standards contained in this part and in supplemental agency regulations.*

<u>Engineering Ethics</u>
For the engineering profession, there are several behavioral standards specific to engineers. In the United States, a popular standard is the “Code of Ethics for Engineers” by the National Society of Professional Engineers (NSPE).

The National Council of Examiners for Engineering (NCEES) manages “model law” and “model rules” which include behavioral standards (cover pages below). Most states have laws and rules that are based on these model documents. Each time the model documents are updated, the NCEES and NSPE encourage all states to adopt the new standards.



Each state has rules for professional conduct specific to engineers. These rules are usually located in the state administrative code in the chapter/section for engineering. These state rules are enforceable with disciplinary consequences. An example rule is that a person shall not offer or perform engineering services unless he or she is licensed as a professional engineer.

NSPE Code of Ethics for Engineers

This is the most widely accepted document for engineering ethics in the United States is the “Code of Ethics for Engineers” by the National Society of Professional Engineers (NSPE).

The main statements are copied here:

I. Fundamental Canons

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. Rules of Practice

1. Engineers shall hold paramount the safety, health, and welfare of the public.
2. Engineers shall perform services only in the areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act for each employer or client as faithful agents or trustees.
5. Engineers shall avoid deceptive acts.

III. Professional Obligations

1. Engineers shall be guided in all their relations by the highest standards of honesty and integrity.
2. Engineers shall at all times strive to serve the public interest.
3. Engineers shall avoid all conduct or practice that deceives the public.
4. Engineers shall not disclose, without consent, confidential information concerning the business affairs or technical processes of any present or former client or employer, or public body on which they serve.
5. Engineers shall not be influenced in their professional duties by conflicting interests.
6. Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by other improper or questionable methods.
7. Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.
8. Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising out of their practice for other than gross negligence, where the engineer's interests cannot otherwise be protected.
9. Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others.

Notre-Dame Cathedral Fire Overview

The roof of the Notre-Dame Cathedral caught fire and burned down on April 15, 2019. Construction of the grand cathedral started in the 12th century and took centuries to build. The cathedral stands as the symbolic center of Paris and had 12 million visitors per year before the fire. Although no one died, seeing the fire caused great sadness in many people around the world. The cathedral was recently restored at a cost of approximately $900 million dollars, or 840 million euros.

Figure 1: Cathedral roof and bell tower ablaze on April 15, 2019.
Source: commons.wikimedia.org/wiki/File:Notre-Dame_en_feu,_20h06.jpg, GodefroyParis, CC-BY-SA-4.0

The cause of the fire was determined to be either an electrical fault or a discarded cigarette. The roof space (attic) was made of uncoated wooden framework which burned quickly. The attic had no active fire suppression system (i.e. no sprinklers). The design of the tall stone structure contained the fire to the top portion of the structure, thus saving the lower portion of the cathedral, the alter, most of the stained glass, relics, and rooms.

Figure 2: Cathedral before and after the fire showing the loss of the entire roof structure.
Source: commons.wikimedia.org/wiki/File:Cath%C3%A9drale_Notre-Dame_de_Paris_16_avril_2019.jpg, Louis H. G.

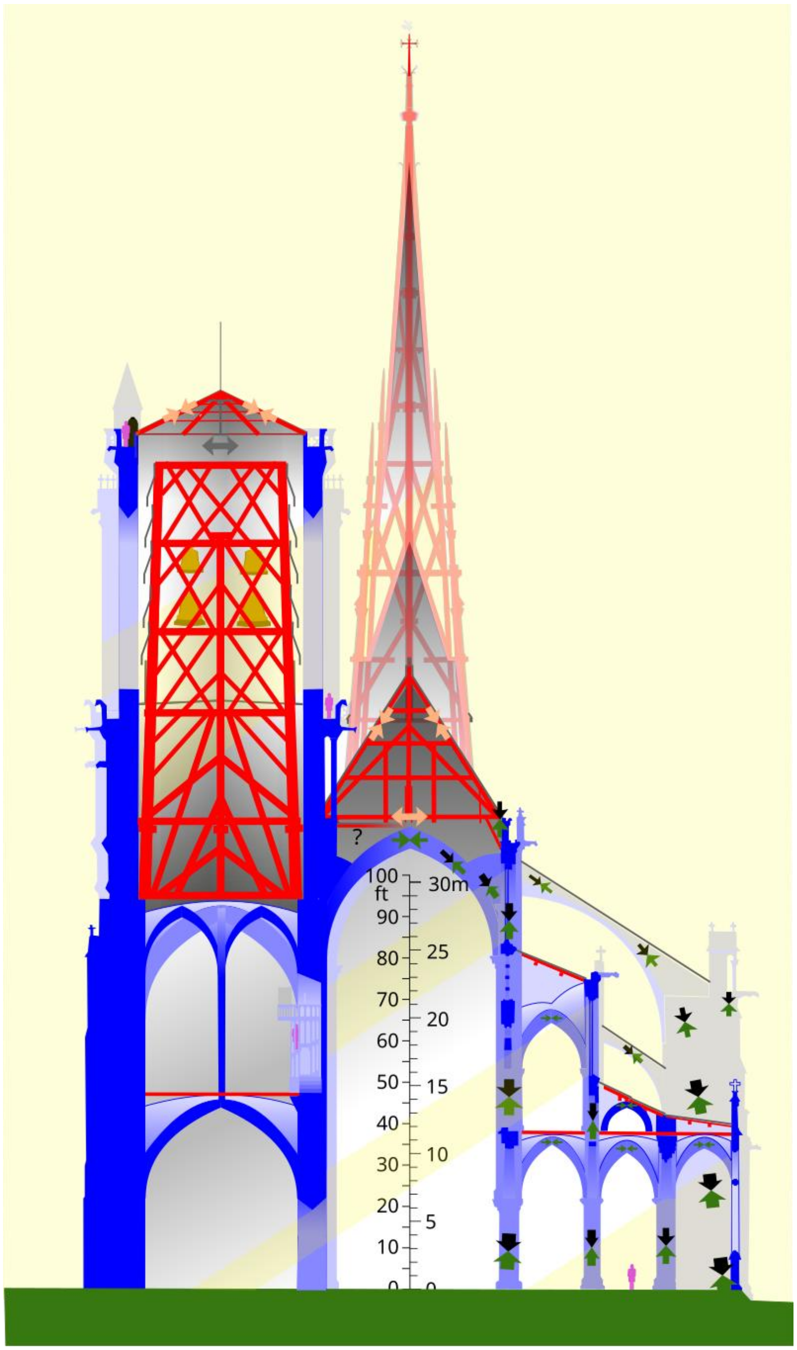


Figure 3: Section of the Notre-Dame Cathedral showing a bell tower on the left (one of two shown for convenience) and flying buttresses on the right. Timber that burned is in **red** while stone that stayed intact is in **blue**.
Source: commons.wikimedia.org/wiki/File:Notre-Dame_de_Paris_composite_transverse_section.svg

Figure 4: Attic of the Notre-Dame Cathedral with wooden frames and no fire sprinkler system.
Source: commons.wikimedia.org/wiki/File:Charpentes_Notre_Dame_2018_6.jpg, Bernard Hasquenoph, CC-BY-SA-4.0

A roof and spire restoration project was ongoing near the location where the fire spread, leading to speculation that construction activities were at least partially to blame. Renovation presents a fire risk from sparks, short circuits, heat from welding, and cigarette butts. No permanent electrical wiring was present in the attic because of the fire risk. The roof framing was made of very dry timber that was reported to be powdery when touched due to age. Temporary wiring was allowed at the scaffolding, roof, and spire for construction purposes.

The restoration firm Europe Echafaudage had a team working on the roof and spire on the day of the fire. The company claimed that no soldering or welding had occurred in the period just before the fire. The scaffolding had electrical wiring for temporary elevators and lighting.

The roofing company Le Bras Frères claimed that it had followed procedure and that none of its personnel were on site when the fire began. Le Bras Frères confirmed that some its workers had smoked cigarettes during work, contrary to regulations, but denied that a cigarette butt could have started the fire since no workers were present when the fire started. Investigators determined the fire "to have been started by either a cigarette or a short circuit in the electrical system".

Security guards were in charge of monitoring the fire alarm system along with various security systems. The guard on that dreadful day was new on the job and working a second eight-hour shift because his relief had not arrived. The fire alarm system gave an early warning of the fire however it was labelled in a confusing manner so the guard had to physically check multiple areas before finally visually confirming the fire location and intensity. It took the guards 30 minutes between hearing the alarm and calling the fire brigade.

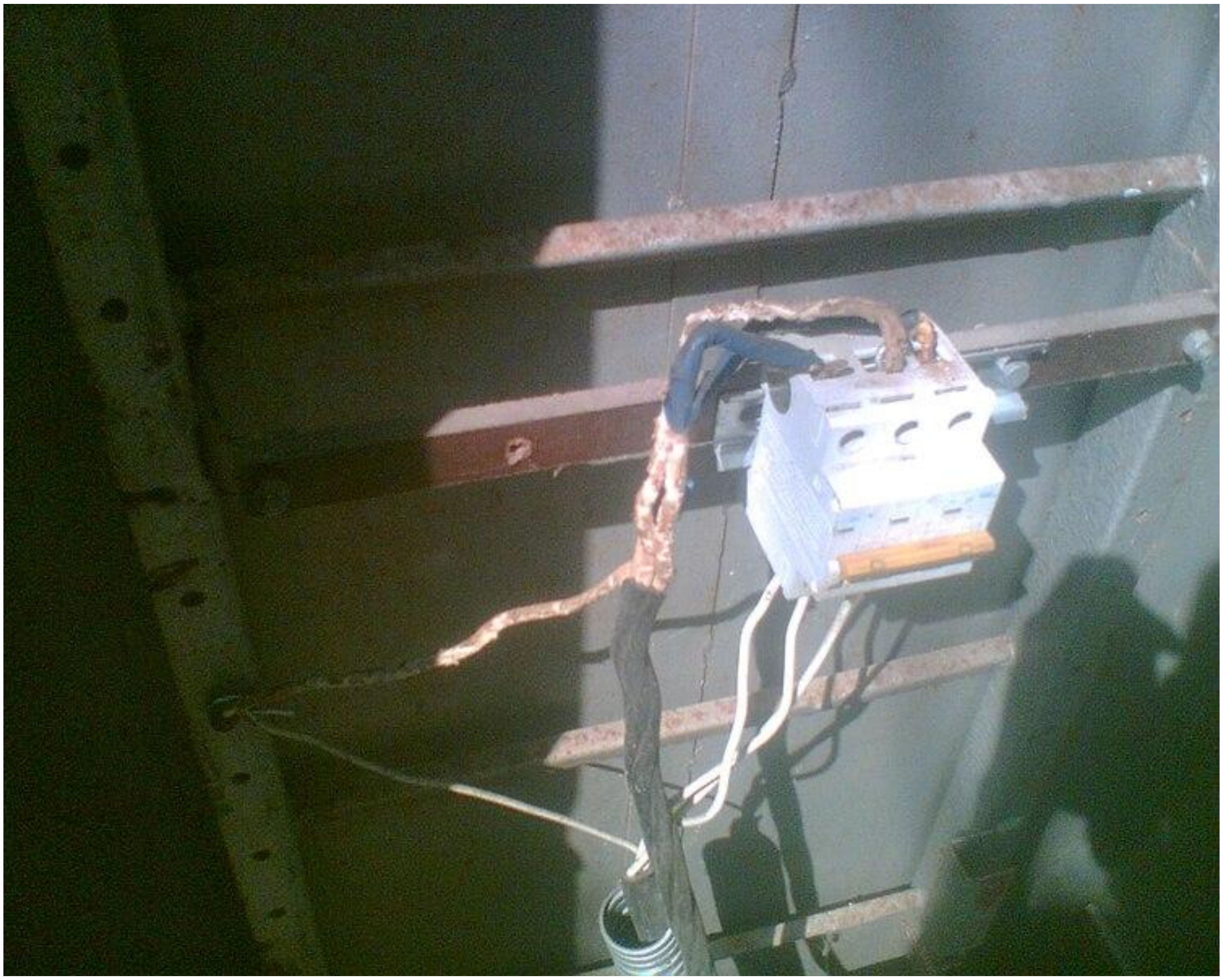
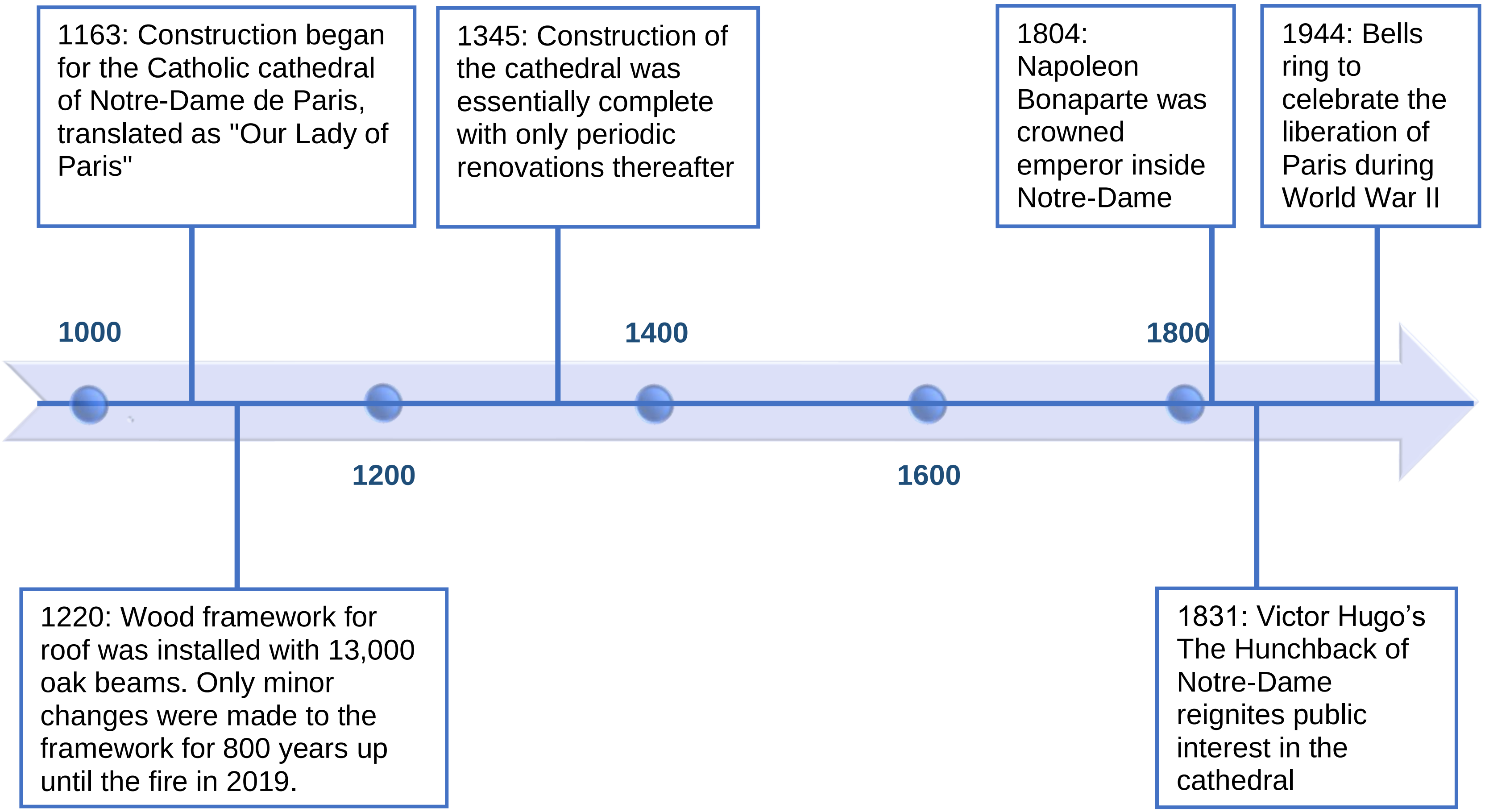
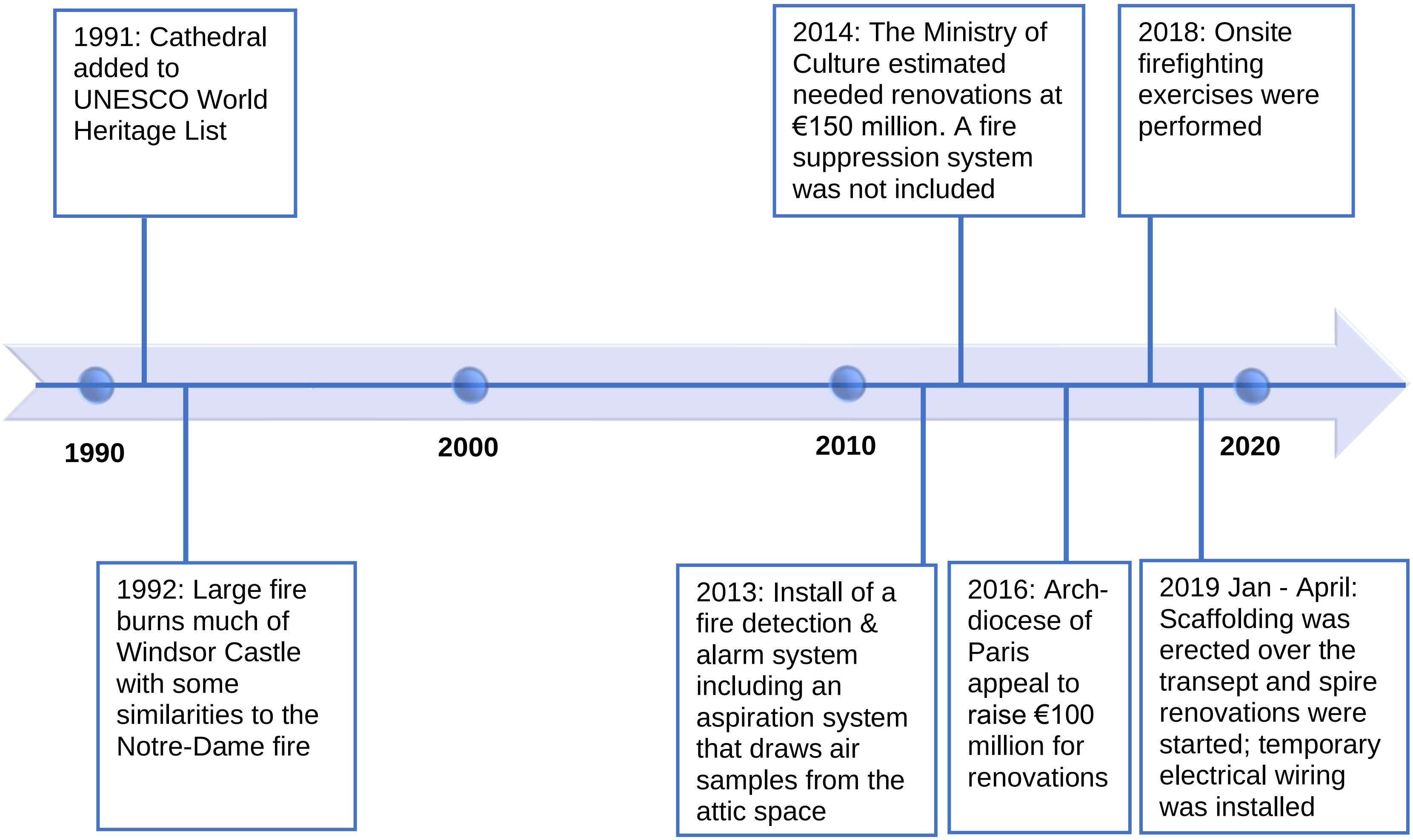
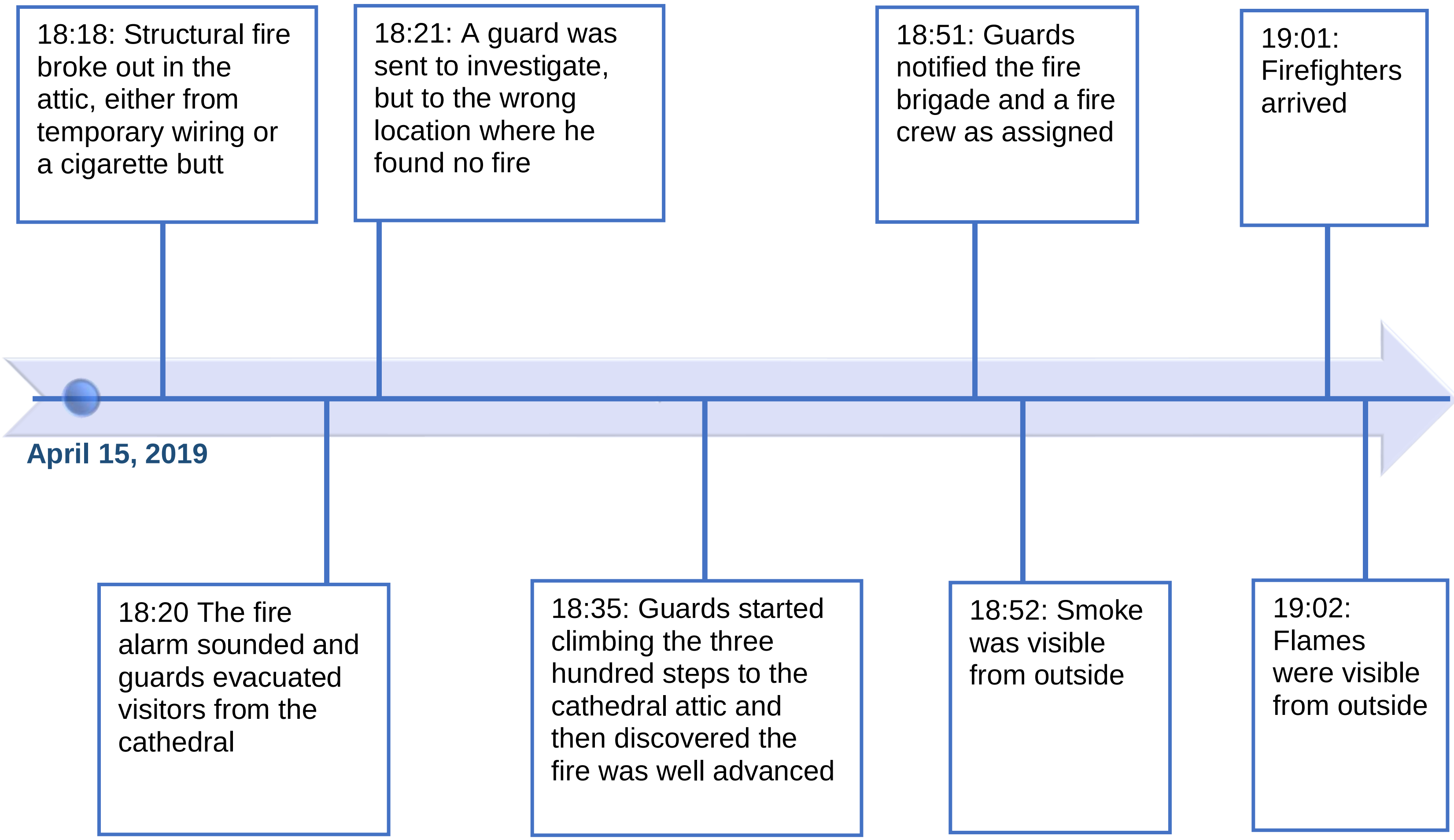


Figure 5: Example electrical device with frayed insultation, exposed power wires and aluminum wire twisted with copper on the main grounding busbar, all of which can cause a fire.
Source: commons.wikimedia.org/wiki/File:Very_nice_fuse_box_ever.JPG, Peps, CC-BY-SA-3.0

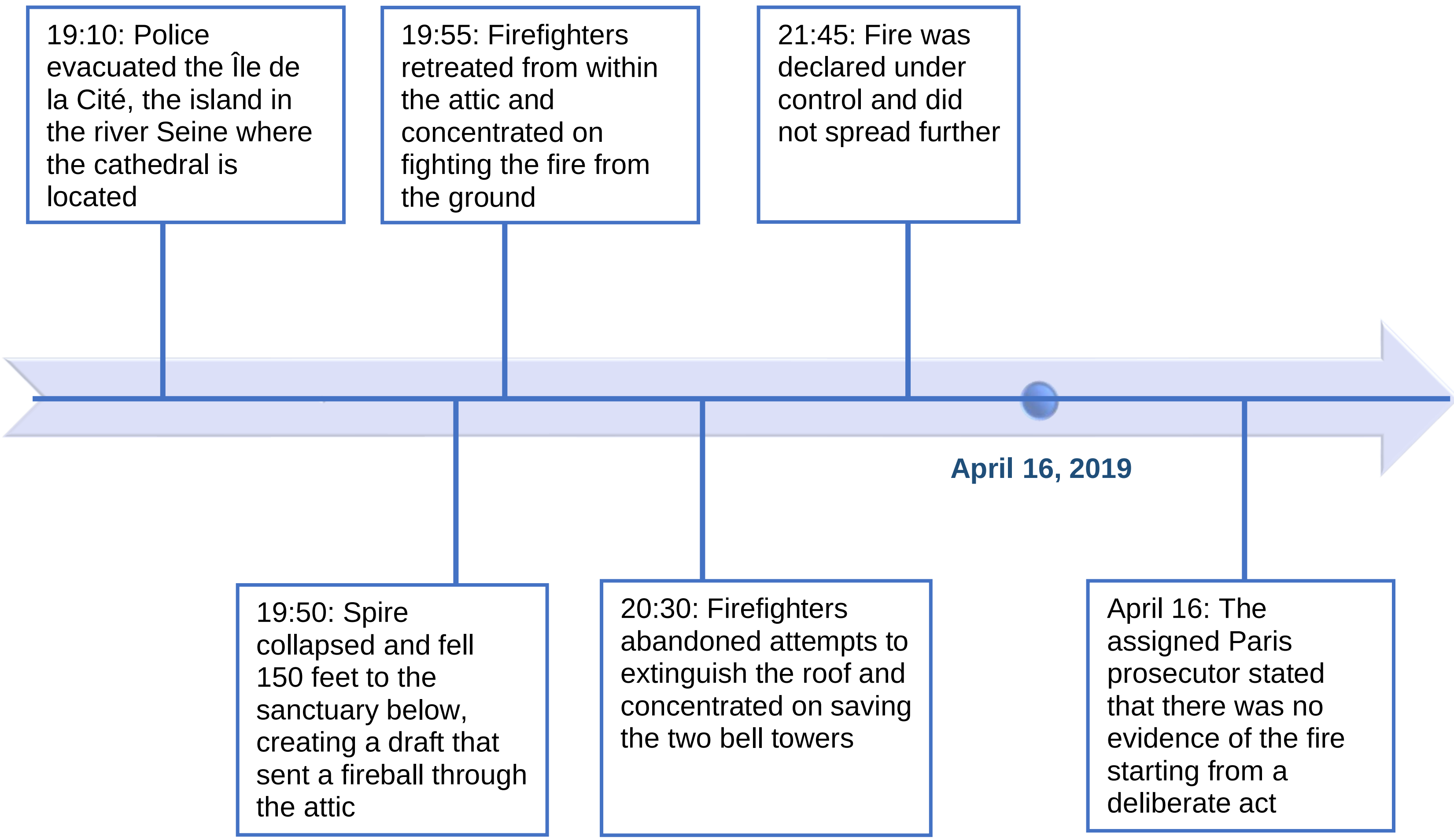
Timeline of Events

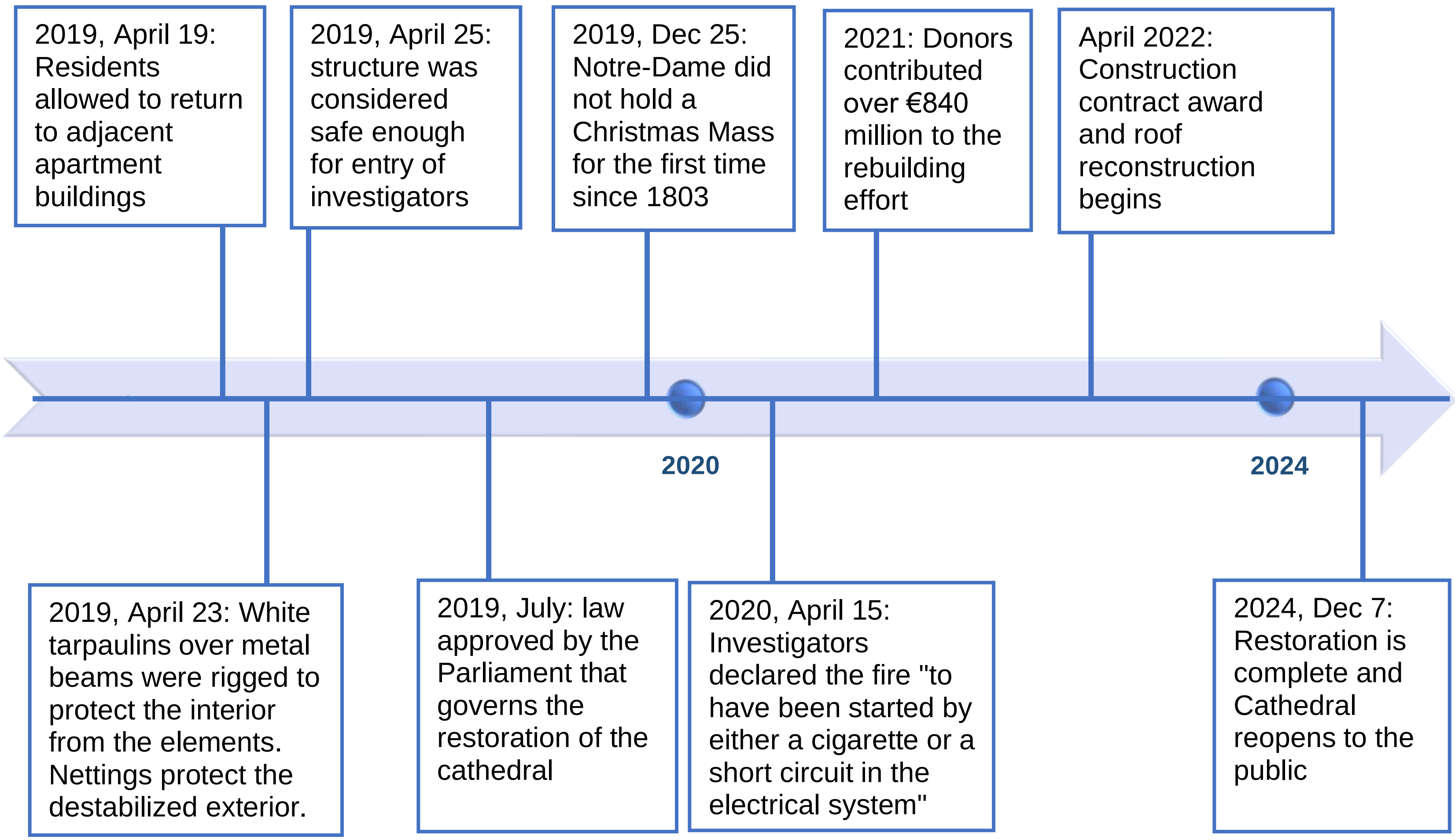



1991: Cathedral added to UNESCO World Heritage List
2014: The Ministry of Culture estimated needed renovations at €150 million. A fire suppression system was not included
2018: Onsite firefighting exercises were performed
1990
2000
2010
2020
1992: Large fire burns much of Windsor Castle with some similarities to the Notre-Dame fire
2013: Install of a fire detection & alarm system including an aspiration system that draws air samples from the attic space
2016: Arch-diocese of Paris appeal to raise €100 million for renovations
2019 Jan - April: Scaffolding was erected over the transept and spire renovations were started; temporary electrical wiring was installed



All times are Paris local time (CEST), military


19:10: Police evacuated the Île de la Cité, the island in the river Seine where the cathedral is located
19:55: Firefighters retreated from within the attic and concentrated on fighting the fire from the ground
21:45: Fire was declared under control and did not spread further
April 16, 2019
19:50: Spire collapsed and fell 150 feet to the sanctuary below, creating a draft that sent a fireball through the attic
20:30: Firefighters abandoned attempts to extinguish the roof and concentrated on saving the two bell towers
April 16: The assigned Paris prosecutor stated that there was no evidence of the fire starting from a deliberate act


2019, April 19: Residents allowed to return to adjacent apartment buildings
2019, April 25: structure was considered safe enough for entry of investigators
2019, Dec 25: Notre-Dame did not hold a Christmas Mass for the first time since 1803
2021: Donors contributed over €840 million to the rebuilding effort
April 2022: Construction contract award and roof reconstruction begins
2020
2024
2019, April 23: White tarpaulins over metal beams were rigged to protect the interior from the elements. Nettings protect the destabilized exterior.
2019, July: law approved by the Parliament that governs the restoration of the cathedral
2020, April 15: Investigators declared the fire "to have been started by either a cigarette or a short circuit in the electrical system"
2024, Dec 7: Restoration is complete and Cathedral reopens to the public

Lack of Fire Suppression System

Although the fire was deemed an accident, the magnitude of the disaster makes it worth considering how it could have been prevented or the damage minimized, and thus how similar incidents may be prevented in the future.

The cathedral was regularly assessed by architects, structural engineers, and fire protection engineers. Significant attention had been given to the risk of fire at the cathedral. Efforts taken included:

- The Paris Fire Brigade drilled regularly to prepare for emergencies at the cathedral. In 2018, the brigade performed on-site exercises to practice putting out a fire.
- A firefighter was assigned to the cathedral each day for faster response.
- Fire wardens checked conditions beneath the roof three times a day. Appears a visual check was done some hours before the fire started.
- A fire alarm system was installed and a security guard assigned to keep watch over the alarm display panel. The guard was confused by the display labels on the day of the fire.
- A manual dry standpipe system was installed for a fire truck to connect to at street and with connections for firefighting at the roof level. The pipes had leaks which greatly reduced pressure during firefighting. Also, by the time a fire truck was able to connect, most of the roof was already in uncontrollable flames.

After the fire, the architect responsible for fire safety at the cathedral acknowledged that the fire spread much faster than had been estimated. It appears the architect, and others responsible for the structure, assumed the alarm would provide the fire location and the fire brigade would respond fast enough to control the fire.

Fire protection experts have criticized the lack of modern fire protection features in the cathedral before the fire. However, to be fair, very few historic churches have a fire sprinkler system or even smoke alarms. A study of churches with fires found that only 35% had smoke alarms and only 4% had a sprinkler system. Note that a sprinkler system is the most common form of fire suppression, but several alternative systems exist.

Some of the reasons most historic structures and sacred spaces don't have a sprinkler system include:

- Sprinklers are expensive to add as a retrofit
- Sprinklers can cause water damage (alternative systems are available)
- Visible piping systems diminish aesthetic value and historic heritage
- Ignorance of fire risk and impact
- Regulations only require sprinklers on new construction
- Insurance policy does not require sprinklers and discount offered is marginal

For the Notre-Dame Cathedral, the main reason for not installing sprinklers was the view that doing so would significantly alter the building's historic character. The roof framing was an elaborate web of 800 year old timber, as shown in Figure 6. The attic was referred to as "the forest" and was considered a key feature of the cathedral's historic heritage. Visitors were not normally allowed to see the attic.

Figure 6: Views of "the forest" (attic) of the Notre-Dame Cathedral before the fire.
Source: commons.wikimedia.org/wiki/File:Notre-Dame_de_Paris_059.jpg, Harmonia Amanda, CC-BY-SA-3.0

Looking back, adding fire sprinkler pipes would not have significantly altered the historic heritage of the attic space. It seems that architects and engineers involved in the assessment of the fire protection system did not adequately convey the risk of a fire and the fact that a fire could quickly spread and result in a complete loss of the historic heritage of the roof.

<u>Risk Ranking</u>

Engineers are often asked to perform risk assessments, including risks for a structural failure, power failure, life and safety issue, fire, vehicle accident, terrorism, and vandalism. One approach for a risk assessment is a numerical ranking of components from lowest to highest risk. This is called a “Risk Ranking”. High risk components should be prioritized for improvement projects that will reduce the risk.

The risk ranking approach typically entails assigning a likelihood of failure (LOF) and consequence of failure (COF) to each potential failure (or incident). See Figure 7 for an example plot of COF versus LOF, called a risk matrix.

Consequence of Failure

Likelihood of Failure	Very Low	Low	Moderate	High	Very High
Very High					
High		Lightning Strike	Power Failure		
Moderate		Vandalism	Theft of Relics		
Low		Construction Accident	Fire at Ground Level	Fire in Tower	Fire on Roof
Very Low					

Figure 7: A high-level risk matrix for a historic monument.
Items in red are considered highest priority, followed by yellow, then green.
Source: Author

Typically the COF is considered of more importance than the LOF. This can be seen in Figure 7 as there are more red boxes in the very high column of COF. To account for this, an importance factor (IF) can be used when calculating the total risk, per this formula:

Total Risk = IF * COF + LOF

Fire Protection in Cathedral Renovation

The roof was reconstructed in 2024 with the following major fire safety improvements, (depicted in Figure 8):

1. Fire Suppression System. A misting sprinkler system was installed in the roof space that activates when the temperature exceeds 500 degrees. The system can quickly reduce the temperature and extinguish flames with very little water damage to cathedral elements.

2. Fire Cut Off Beams. Two sections of fire cut off beams (a type of fire wall) were installed in the roof space to divide the roof into three distinct areas and limit the spread of fire. The beam will rotate and fall away during a fire which prevents a fire from spreading to adjoining areas.

3. Standpipes with Fire Pumps. Two new dry standpipe systems with pumps were installed. One is located at the bell towers, and the second near the middle of the cathedral with outlets at the floor level and roof space level. The pumps supply water from the Seine River.

4. Advanced Fire Monitoring and Alarm System. The renovated cathedral has a state-of-the-art air monitoring system, thermal imaging cameras, and a fire alarm integration system. These new systems cover the entire structure including all significant concealed spaces. A fire safety control room was added with more user-friendly interfaces. The alarm system also automatically informs the fire brigade of a potential fire.

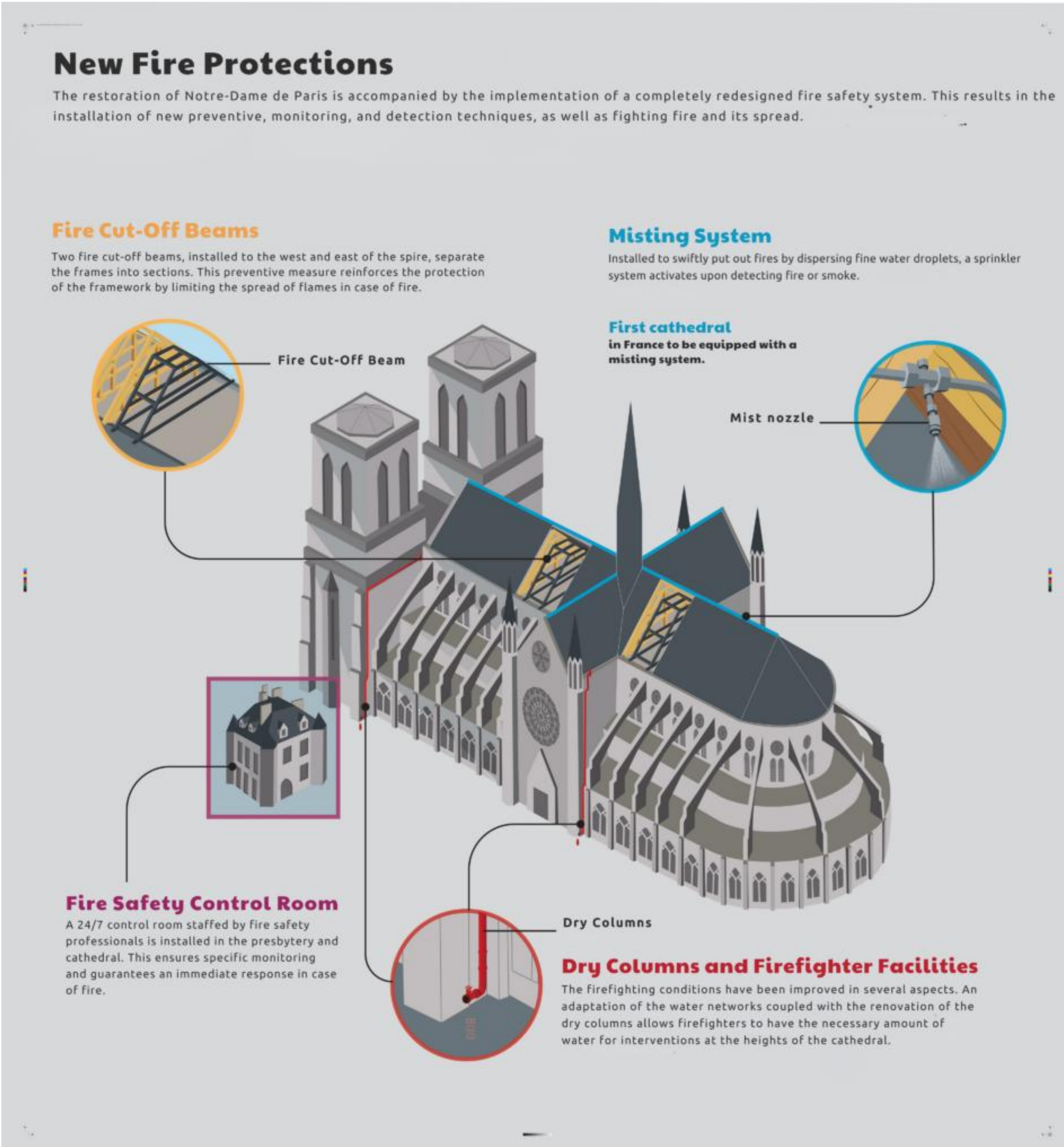


Figure 8: Fire prevention system features added with the 2024 reconstruction.
Source: www.friendsoffdf.org/the-wait-is-over-notre-dame-reopens-its-doors/

Lessons Learned

The following are lessons learned from the Notre-Dame Cathedral Fire as applied to each of the fundamental cannons.

Canon 1: Hold paramount the safety, health, and welfare of the public.

The historic cathedral is considered important to protect for the welfare of the public. A comprehensive risk assessment should have identified that a fire in the roof would be a very high consequence event, which justified additional engineered protections, such as a fire suppression system, fire walls, fire cut off beams, a fire control room with user-friendly features, and an automatic alarm notification to the fire brigade. Risk assessments help show alignment with Canon 1.

Canon 2: Perform services only in areas of their competence.

A registered professional engineer with experience and education in fire protection should be utilized to assess an existing fire protection system, provide recommendations, and design fire protection improvements.

Canon 3: Issue public statements only in an objective and truthful manner.

Very little information was made public on the decisions made to not install a fire suppression system in the attic of the cathedral. It would be helpful to understand more on how the decisions were made and if engineers were involved.

Canon 4: Act for each employer or client as faithful agents or trustees.

The diocese (client) was regularly hiring architects and engineers to make various improvements to the cathedral. The engineers designing the fire protection improvements should have pointed out that an attic fire would likely result in a complete loss of the roof and spire. Although adding a fire suppression system would have added capital cost and impacted untouched areas of the historic attic, it would have save most of the historic attic, potentially saved the spire, and saved the client hundreds of thousands of dollars in restoration costs.

On a positive note, the cathedral was originally engineered so the wood roof was separated from the lower sanctuary and offices by masonry, so the lower portion of the church was protected from a fire at the roof level.

Canon 5: Avoid deceptive acts.

There were no known deceptive acts by engineers.

Canon 6: Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

In general, there appears to have been a general lack of fire protection engineering involvement for such an important cathedral. Engineers should be making themselves available and useful for making assessments and upgrading designs to help prevent such disasters.

Engineers should also learn about technology advances in their field, such as through continuing education. In this case, there are several alternative fire suppression system technologies that would have less impact on the historic attic than a traditional pressurized wet pipe system. If a fire protection engineer would have presented stakeholders with a alterative approach with less impact on the attic, it is possible that a fire suppression system would have been installed prior to the fire and the fire would have been stopped automatically.

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