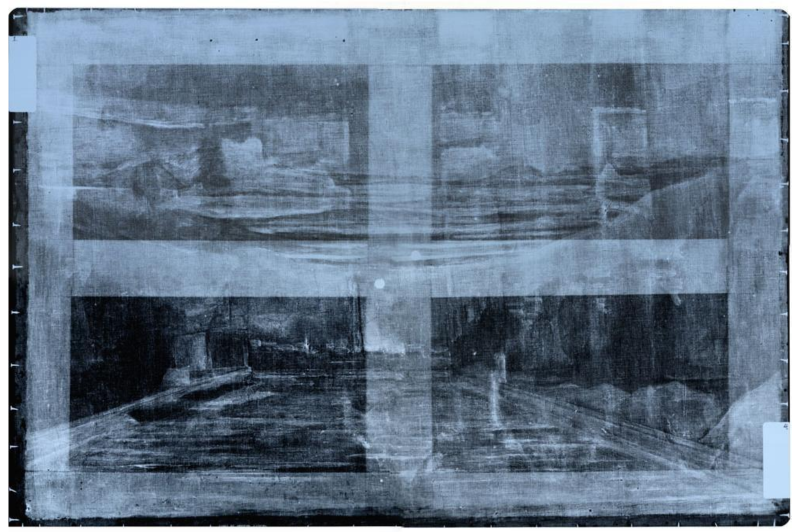
Examination Using X-rays

The previously discussed methods of visual examination are non-destructive, meaning they do not change the artwork in any way and no sample material is removed from the object. Another way to perform non-destructive analysis is by using various x-ray techniques, particularly x-ray radiography and x-ray fluorescence spectroscopy (XRF). **X-ray radiography** is similar to other imaging techniques in that it still requires taking a picture of the piece of art. **X-ray fluorescence spectroscopy** (see next page) is an analytical technique that identifies elements on the surface and slightly below the surface of a painting (or other art object).

X-ray Radiography: Materials Determine the Image

X-ray radiographic imaging of an artwork differs from medical uses because exposure times can be longer (usually several minutes instead of fractions of a second) and the energy of the radiation is adjusted to penetrate a wide variety of materials depending on what piece of art is being examined. In medical x-ray radiography the doctor is always trying to penetrate the same material, the human body. Materials in a painting vary in their interaction with x-rays. Areas that absorb x-rays will appear white in developed radiographs. More transparent areas or materials in or on the art object will range from gray to black. Pigments containing lead, for example, strongly absorb x-rays and prevent the x-rays from passing through the painting to exposure the sensitive x-ray film. Therefore, pigments containing lead would appear white on the developed radiograph. Many other pigments, especially those containing elements with low atomic numbers, like carbon, are quite transparent to x-rays.

Henri Rousseau, *The Eiffel Tower*, c. 1898. Oil on canvas. 20 5/8 x 30 3/8 in. The MFAH, Gift of Audrey Jones Beck



Above: Henri Rousseau, *The Eiffel Tower*, c. 1898, Overall X-Radiograph

X-rays Reveal Painting Supports

A painting is made of many layers, from the support to the ground to various layers of paint. In a radiograph the information from all these layers is conflated or on top of one another, making it challenging to distinguish features belonging to different layers. Some details in radiographs are easily interpreted, such as the metal nails seen along the edges of Rousseau's *The Eiffel Tower* which secure the canvas to the stretcher (pictured above right). Other details are more subtle and require experience to interpret. Paint layers rarely block x-rays completely and this allows x-ray radiography to reveal the structure of the support underneath the painting, like the stretcher bars in *The Eiffel Tower* that make a white cross on the image.

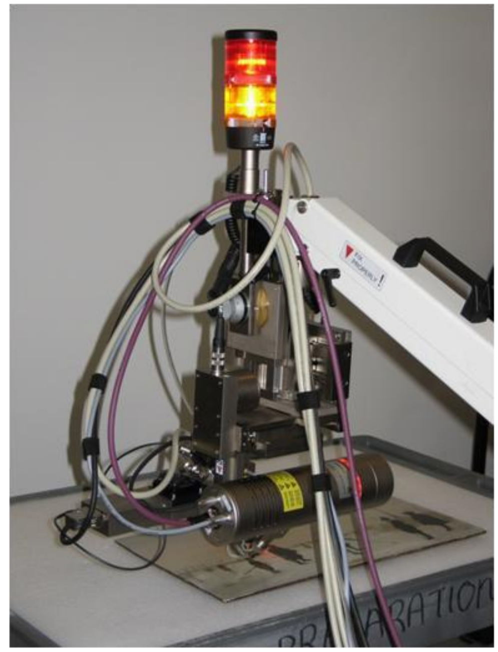
Similarly, x-ray radiography can make visible the seams, folds, tears or holes in canvases that may be less noticeable on the surface when covered with paint. The technique is also very helpful to determine if a painting on a wooden panel has been altered through time. If the original back of a panel is not visible, an x-radiograph can reveal where and how different pieces of wood are joined together, or if there is an addition with a wood grain that does not match the rest.

X-rays Reveal Artistic Process

X-ray radiographs can also be extremely useful in showing the ground preparation and initial layers of a painting, usually revealing if an artist has changed his/her mind and painted over something, or left an empty space to add something later. The x-radiograph of *The Eiffel Tower* reveals that Rousseau painted over a different scene, which is almost impossible to distinguish. It is speculated that the roofline of a building is visible in the top left possibly next to a large tree (appearing as a dark vertical shape just above the white horizontal stretcher bar). This x- radiograph also shows large vertical rectangles on the right side which do not belong to or relate to the final composition.

X-ray fluorescence spectroscopy (XRF)

X-ray fluorescence spectroscopy (XRF) is also based on the interaction of x-rays with matter. This technique provides information about the presence and distribution of atomic elements in a painting. XRF instruments, like the one pictured on the right, direct x-rays onto the surface of the artwork. Some of the x-rays are absorbed by atoms and then re-emitted back to the dectector, a phenomenon called fluorescence. The fluorescent x-rays have specific energies that are characteristic of elements in the periodic table of elements. Based on knowledge of the elemental composition of many pigments found in paint, inferences can be made about the various pigment components in paint layers on or slightly below the surface of the painting. XRF can be sensitive enough to detect trace elements, which may help locate the source of a mineral used to make a pigment in some cases.

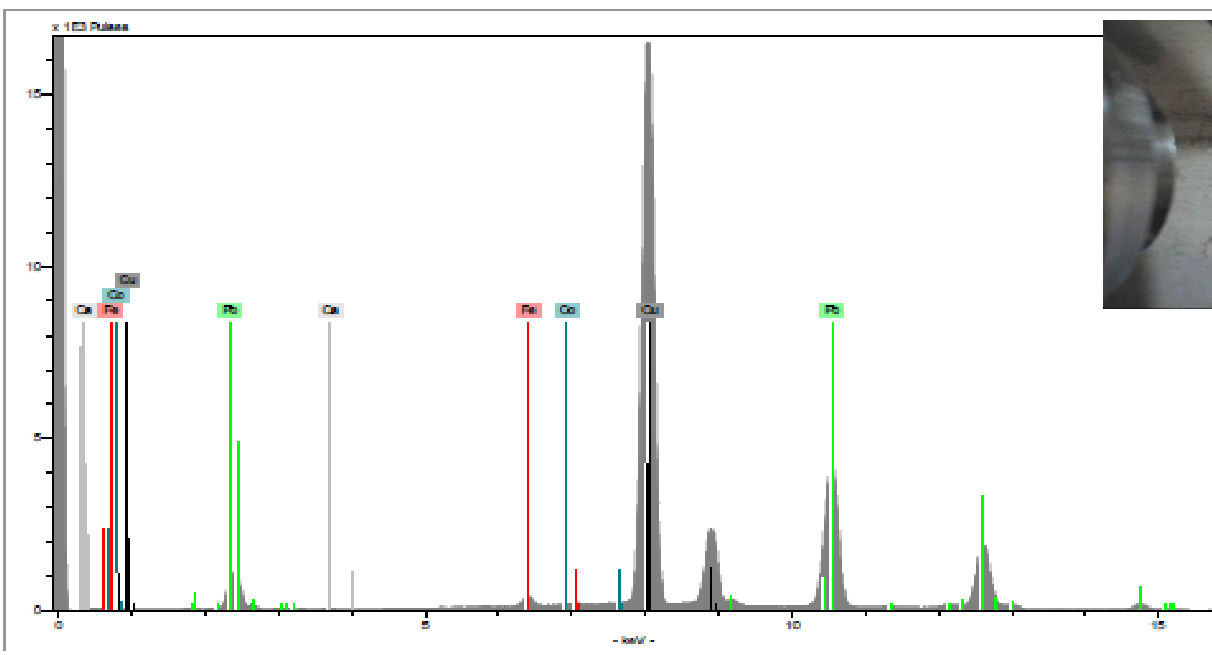


Above: XRF analysis being performed on Hendrick Avercamp's *Ice Scene with Golfers*, 1625

XRF and Classifying Paint Pigments

XRF can also be a quick way to verify the attribution of an artwork to a specific time period based on the earliest dates most pigments were used. For example, the detection of a pigment not available until the 19th century may be suspicious on a much older painting. Most XRF instruments, like x-ray radiography, conflate information from various layers of a painting as well as various mixtures of pigments within one color.

Furthermore, XRF is limited to the characterization of inorganic materials and is not suitable for detecting organic colorants, because the elements in these pigments (like carbon) do not have enough energy to be detected. The absence of elements associated with inorganic pigments of a certain color, however, can help indicate that an artist may have used an organic colorant.



Exact spot of analysis on the Avercamp yielding the spectra shown

XRF Analysis of one blue stroke of paint in Hendrick Avercamp's *Ice Scene with Golfers, 1625*

The spectrum above is an example of how information is displayed from the XRF analysis of one blue stroke of paint in Avercamp's *Ice Scene with Golfers,* 1625. Elements are identified based on the specific energy of each peak and then labeled. In this case, the detection of intense copper peaks (marked Cu) suggest the blue paint stroke being analyzed from the Avercamp painting is copper-based, probably azurite or its man-made version, called blue verditer.