**Culture as a Driving Force for Research and Technology Development: A Decade's Experience of Canada's NRC 3D Technology**

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July 2002

* published in Proceedings of the EVA2002 London (Electronic Imaging and the Visual Arts) Conference, Farnborough, England, July 25 2002, ISBN 0-9 543146-1-1, pp. 4.1-4.13. NRC 44936.



Canada

# Culture as a Driving Force for Research & Technology Development: A Decade's Experience of Canada's NRC 3D Technology

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**Keywords:** 3D imaging, digitization, laser scanner, cultural heritage, recording

**Abstract:**
In 1981, the National Research Council of Canada (NRC) commenced research on the development of 3D laser scanner imaging technology. Initially it was thought that development would be driven primarily by industrial applications. However, in the past decade, the cultural sector has become one of the main driving forces. The purpose of this paper is to present an overview of some of the cultural applications developed during the past decade that has helped drive the development of the technology.

## 1. Introduction:

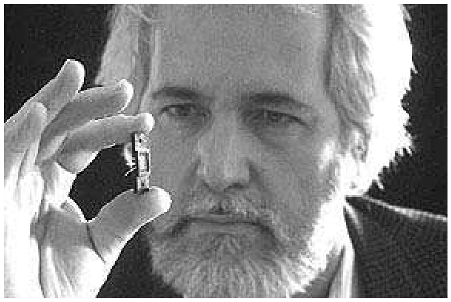
The idea that led to the invention of NRC's 3D digital imaging technology started as a result of scientific curiosity. It was triggered by a little device called a "lateral effect photodiode" (Figure 1). It is a small photosensor, which converts the position of an incident light beam to an electrical signal. Marc Rioux initially bought it around 1980 for its functionality.

> "It combined my three main scientific interests, physics, light and geometry. The physics of the photoelectric effect that converts photon to electron. The use of light - especially the laser light to produce an extremely small focused beam and the geometry associated with its function of giving the beam position on its surface. The device was not used for at least a year, but I knew that it would be useful someday" [1].

A year later, in 1981, he thought of the idea of using it as the sensor in a 3D camera for robot vision applications. Subsequently, with his colleagues at the National Research Council, he designed, patented and developed NRC's first laser scanner.

In the early stages of development in the mid 1980's, although the museum sector was identified as one of several areas of potential application, it was thought that the development of the technology would primarily be driven by industrial applications.

These applications included robot vision systems, inspection, and rapid prototyping as well as medical and anthropometrical applications.



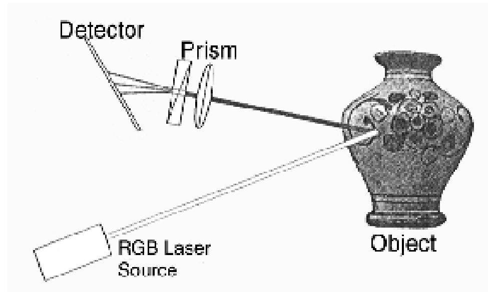



**Figure 1**. Marc Rioux and the lateral effect diode, which led to the invention of NRC's 3D imaging technology. The diagram on the right illustrates the principle of the 3D technology. A RGB (red, green and blue) laser source projects a small 50-micron white light laser spot on the object. The light beam reflected back to the camera is separated into its red, green and blue components and converted into an electronic signal by the detector. The position on the detector is a function of the position (x,y,z measurement) of the spot on the object. Significantly, the shape and color measurement are recorded simultaneously. The complete object is recorded by scanning the spot over the entire object.

However, following presentations at several international conferences in the early 1990's, including EVA '92 in London [2], our attention became increasingly drawn to cultural applications. We started to receive application inquiries not only from Canadian institutions but also from international museums and cultural organizations in the UK, France, Italy, U.S.A., Israel, China and South Africa. In addition to scanning traditional museum objects, these inquiries included scanning archaeological sites, paintings, sculptures, architectural elements, replication as well as VR theatre and web display applications. Very seldom were two inquiries the same.

Significantly, each inquiry brought with it not only a new application, but also the requirement to develop and test a new aspect of the technology. For documenting features such as brush stroke details on paintings or tool mark details on sculpture, a high-resolution system was needed. A portable system was needed for archaeological and architectural site recording. A large volume camera was required for large sculptures. The ability to measure surface reflectance along with the shape of an object opened new possibilities in condition monitoring. New and improved software programs were needed for each scanning application as well as for new display technologies including interactive/immersive 3D VR theatres and web productions. As time went on and the inquiries kept coming in, we recognized that the cultural applications were driving the development of the technology.

At the present time, ten Canadian companies have licensed various segments of the technology and it is used for a wide range of applications – not only in the cultural sector, but also for industrial, space, modeling and display applications. The purpose of this paper is to present a summary some of the more significant cultural applications which have driven the development the technology. Several of these have been reported in more detail at past EVA Conferences as well as in other forums.

## 2. NRC 3D Imaging Technology:

Three high-resolution 3D imaging systems, the ***High Resolution Laser Scanner***, the ***Biris 3D Laser Camera*** and the ***Large Volume Laser Scanner*** (Figure 2), each designed for different imaging applications, have been applied to a variety of cultural recording projects [3-6]. The High Resolution Laser Scanner simultaneously digitizes the 3D shape and color of traditional museum objects and provides a maximum depth resolution of 10 microns [7-10]. The Biris system is a portable 3D monochrome imaging system and is ideally suited for field recording applications [11-13]. It provides an accuracy of 80 microns at a range of 0.3m. The Large Volume Scanner is a research prototype system for high-resolution monochrome 3D digitization of large structures at a standoff distance from 50 cm to 10 m [14,15]. At a standoff of 50 cm, it provides a resolution of 70 microns.

These systems use a low power non-damaging laser light to digitize sequential overlapping images from multiple points of view over the surface of an object or site. Once scanned, data modeling and display software is used to integrate the multiple view data sets into a seamless archival quality high-resolution 3D digital model of the object [16,17]. The software also enables the data to be used for a variety of heritage applications.

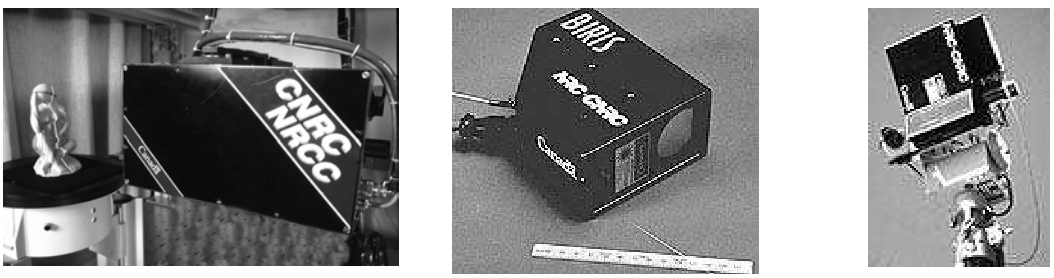



**Figure 2**. The High Resolution Laser Scanner (left), shown scanning a ceramic figurine. The Biris 3D Laser Camera (middle) can be mounted on either a conventional tripod or on a linear translation stage for scanning. The Large Volume Laser Scanner (right) can be mounted on a telescoping tripod and raised to a height of 10 m to scan large objects such as outdoor sculpture.

## 3.0 Cultural Applications

During the research and development phase of the technology, as noted above, we have collaborated on a number of projects to test and demonstrate the cultural applications with several Canadian and international museums and cultural agencies. The following is a summary of some of these projects for interactive display, archival recording and replication applications.

### *3.1 Interactive Display Applications:*

A unique feature of this technology is that the scanner digitizes details of objects at high-resolution and in perfect registration. This enables the rendering of very accurate “high fidelity” 3D models for interactive display on high-end information kiosks or in 3D VR theatres within a museum or at a remote site connected with high-speed communications systems. One of the primary “driving force” applications has been unique interactive displays for museum exhibitions as well as for web based virtual museums. For example, high-resolution 3D digital models of museum objects can be transmitted to remote locations using modern communication systems for interactive manipulation in information kiosks and home computers. Similarly, archaeological sites can be digitized and interactively displayed in 3D VR theatres. In addition, compact 3D models, which retain excellent model to object fidelity can be used for interactive web exhibitions.

### *3.1.1 Remote Interactive 3D Display:*

In the 1997 exhibition *The 3rd Dimension: A New Way of Seeing in Cyberspace*, at the Canadian Museum of Civilization, one of NRC's industrial partners, Hymarc, developed a COLORSCAN system (Figure 3) for digitizing objects from the Museum's collection [18]. Two interactive display stations were used for stereo image display – one at the Museum and the second "remote site" at the Royal British Columbia Museum in Victoria. Visitors could select an object from a menu, examine it and access associated text information. Stereo viewing glasses were provided for viewing the images in stereo. In addition to rotating the object, visitors could zoom in and examine specific details of interest.

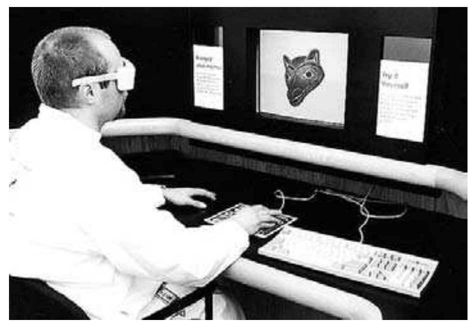


**Figure 3.** The Hymarc COLORSCAN system (left) at the Canadian Museum of Civilization scanning an object from the Museum's collection during the exhibition *The 3rd Dimension: A New Way of Seeing in Cyberspace*. Stereo images were displayed in a interactive display station (right) at the Museum and at Royal British Columbia Museum in Victoria.

### *3.1.2 Interactive 3D Virtualized Reality:*

Interactive 3D Virtualized Reality Systems are increasingly being used for museum display and heritage site interpretation applications. In a virtualized reality display, the simulation models are created from 3D imaging data recorded directly from the site or object [19]. The systems provide a real-time interaction with the models in a display that gives the user 3D immersion in the model world and direct manipulation of objects. These systems offer the potential of accurate "digital reconstruction" of archaeological and historic sites as well as "digital repatriation" of models of artifacts, which have been removed to distant museums, back into the virtualized model of the original site.

In May 1998, the exhibition, Mysteries of Egypt opened at the Canadian Museum of Civilization in conjunction with the world première of the IMAX movie *Mysteries of Egypt*. With an attendance of nearly 700,000, it was the most popular exhibition presented by the Museum and the second all-time highest attendance generator for a temporary exhibition in Canada.

As a new feature, the Museum collaborated with NRC and several industrial partners, on the construction of a Virtual Reality 3D Theatre and on the production of a VR Tour of the Tomb Tutankhamun [20]**.** The Tutankhamun tour featured a virtual visit into the burial chamber. Visitors to the actual tomb can enter only the first undecorated antechamber; a railing prevents entry into the burial chamber. The 3D model of the tomb (Figure 4) was prepared from survey data provided by the Theban Mapping Project using a CAD program. Texture maps of the paintings in the burial chamber were mapped on the 3D model using detailed color slides provided by the Getty Conservation Institute. Permission to use the survey data and slides was granted by the Supreme Council of Antiquities in Egypt.

To illustrate the concept of "digital repatriation", a 3D model of a replica of Tutankhamun's funeral mask was integrated into the 3D model of the tomb. The replica was scanned using the Colorscan system. The mask model was placed inside the sarcophagus where it was found and was introduced into the display at the conclusion of the Tour to demonstrate how models of objects, which are originally associated with a site, can be reintegrated into a digital reconstruction.

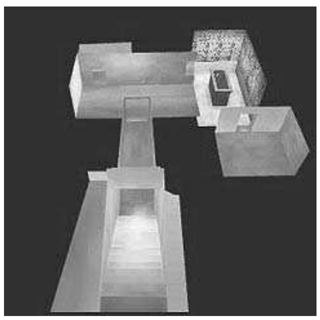


**Figure 4.** For the Tour of Tutankhamun's Tomb a 3D model of the tomb (left) was prepared using ArchiCAD from survey data provided by the Theban Mapping Project. Texture maps of the paintings in the burial chamber from detailed color slides by the Getty Conservation Institute were mapped on the 3D model. The tour featured a virtual visit into the burial chamber (right), which is closed, to the public.

***3.1.3 Interactive Web Display:***

In April 2001, the Canadian Heritage Information Network (CHIN) launched the new Virtual Museum of Canada (VMC) [21]. During the planning stages for the VMC, CHIN conducted a survey of focus groups with an interest in museums and culture across Canada [22]. One of the results noted in the report was:

> "In each session, a portion of the participants had clear expectations of a three dimensional tour of one or many museums. Some of these participants clearly explained how the website user would be able to control their path through a museum, allowing them to pivot and view any section of the museum and objects in the museum in 3-D".

To meet this objective, NRC collaborated with the Canadian Museum of Civilization on the production of Inuit 3D, one of six inaugural VMC exhibitions. Inuit 3D is an interactive exhibition in which visitors navigate through three exhibition halls and interactively examine twelve 3D models of Inuit objects from the Museum's collection [23].

Within the constraints of a web exhibition, a primary objective was the display of 3D models of the objects which represented the shape, subtle color variations, material characteristics (ivory, bone, stone, metal) and features such as tool mark details as closely as possible to the actual object. In short, the *fidelity* of the 3D models to the actual objects was a priority.

As noted above, the High Resolution Laser Scanner records high-resolution models of objects that can be used for the display of accurate *"high fidelity"* 3D on high-end information kiosks. For Inuit 3D, the PolyWorks [24] software suite was used to prepare lower resolution models, which retained excellent object-model fidelity for web display. In compressing the high-resolution models, the software computes a texture mapped compressed triangular mesh. The algorithm for the automatic generation of the texture map is coupled to the mesh vertex removal compression. When the tessellated texture map is applied to the compressed model, it generates a 3D appearance that approximates the appearance of the full resolution colored model (Figure 5).

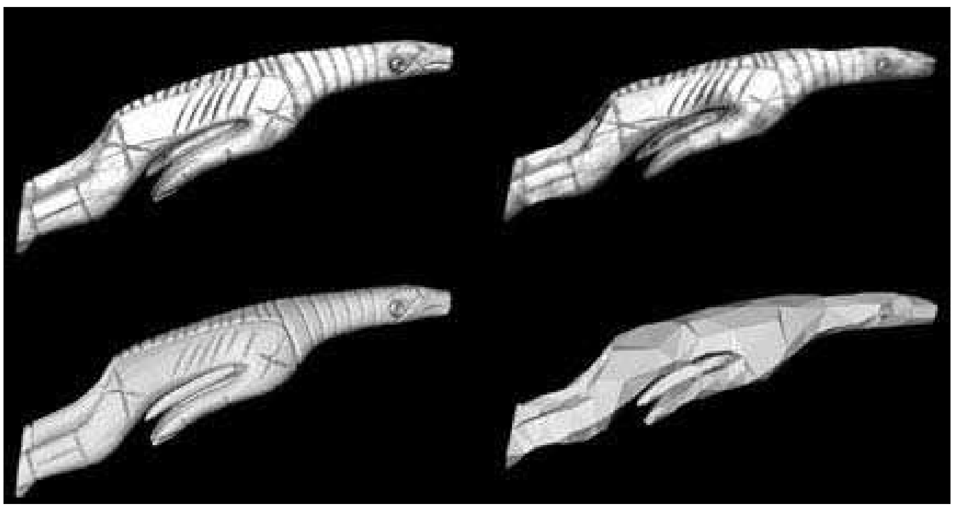


**Figure 5**: The upper and lower images of the Flying Bear on the left illustrate the high-resolution model while those on the right illustrate the compressed model used in Inuit 3D. The high-resolution model contains 443,628 polygons of shape information (lower left) in an 11.8 MB file. This model is the archival quality model. The compressed model contains 1000 polygons of shape detail (lower right) in a 1.2 K file. When a 512 x 512 texture map is applied to the compressed model (top right), it generates a 3D appearance that approximates the appearance of the full resolution colored model (top left). Thus a close approximation to the fidelity of the high-resolution model is retained in the 3D models used for web applications such as Inuit 3D**.**

### *3.2 Archival Recording*

Another major driving force has been the application of the technology to provide archival quality records or "3D digital models" of important museum objects, architectural elements and heritage sites for cultural institutions. Once the object or site is recorded, the data provides an archival record, which can then be used for a wide variety of applications – including display, research, conservation and replication – without the need to re-digitize the object for each application. Following are some examples.

#### *3.2.1 Archaeological Sites*

As a result of the construction of a hydroelectric dam on the Yangtze River, in the Three

Gorges area of China, an estimated 800-1000 heritage sites will be flooded and lost by 2009. The recording of these sites represents a significant and high priority challenge for the State Administration of Cultural Heritage (SACH). In September 1999, NRC collaborated with the Canadian Foundation for the Preservation of Chinese Cultural and Historical Treasures and Innovision 3D – one of our industrial partners – in a pilot project to demonstrate the application of Biris 3D technology for recording some of these sites.

For the pilot project, a laboratory research prototype system was taken to China and used to scan a rock-carving niche at the ninth century Bei Shan site near Dazu (Figure 6). Subsequently, working with ShapeGrabber Inc. [25], another NRC industrial partner, Innovision designed and built a portable 3D imaging system for use by SACH in recording the sites. Innovision is currently continuing collaboration with Chinese officials on this project.

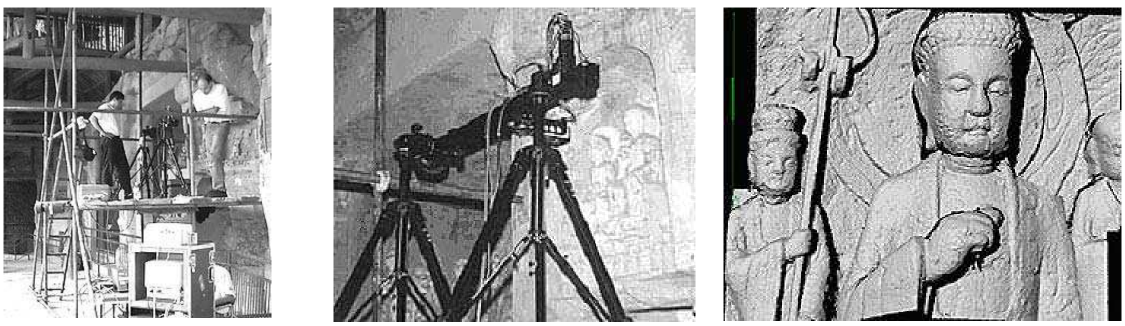


**Figure 6**: The Biris system set up on scaffolding at niche#147 at Bei Shan (left and middle). The archival 3D model recorded by the system is shown on the right.

### *3.2.2 Sculpture and Architectural Building Elements:*

Projects have also been undertaken to demonstrate the applications of 3D scanning systems for archival recording of sculpture and architectural building elements.

To demonstrate the application for recording large outdoor sculpture, the Large Volume System was used to digitize sculpture Mythic Messengers by the artist Bill Reid at the Canadian Museum of Civilization. The sculpture measures 9 m long x 1.2 m wide and is mounted 4 m above ground level on an exterior wall at the Museum. The objective was to prepare an accurate archival 3D digital record of the sculpture, which could be used to prepare an accurate scale replica of the sculpture.

To scan Mythic Messengers, the camera, attached to a remote controlled pan and tilt unit, was mounted on a custom designed telescopic tripod, which enables it to be raised to a height of 10 m (Figure 7). Scans of over 100 different views of the sculpture were recorded at a resolution in the order of 1 mm. The multiple view scans were then merged into a single 3D digital model. This was used to prepare a 2 cm x 10 cm scale replica.

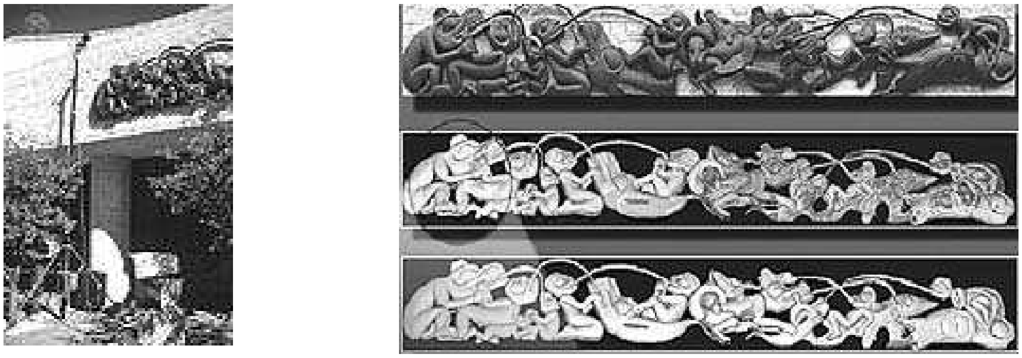


**Figure 7:** The Large Volume camera is shown on (left) mounted on a telescoping tripod to scan the sculpture Mythic Messengers at the Canadian Museum of Civilization. The sculpture, (top right), is mounted 4 m above ground on an exterior wall and measures 9 m long x 1.2 m wide. Over 100 scans were recorded as shown in the colour-coded image (mid right) and merged into a 3D model (lower right).

In 1998, in collaboration with the University of Ferrara in Italy, the Biris system was used to digitize a number of architectural building elements on the facade of the 8th century Abbey of Pomposa, near Ferrara (Figure 8). The building elements included scans of a rosone, a peacock, a column as well as a large 2 m x 6 m area of the façade. For heritage preservation applications, the image data documents the surface condition of features at the time it was digitized. Additional details on this project can be found in references 11, 12 and 26.

**Figure 8:** The Biris camera is shown mounted on a conventional tripod (left) scanning a rosone (middle) on the façade at the 8th century Abbey of Pomposa near Ferrara, Italy. The archival digital model (right) records the surface shape and condition of the object after 1100 years exposure to the elements.

### *3.3 Replication Applications:*

In the museum community, there is substantial economic interest and activity in the replication and sale of objects. The 3D image data can be transferred into CAD models for fabricating accurate 1:1 or scale replicas using modern replication technologies such as stereo lithography. There are four important advantages to this approach for museum and heritage applications:

- Unlike direct casting, the object is not touched or damaged during scanning.
- Scale replicas made using the 3D model data are much closer or truer representations of the shape of the original object than those copied by hand.

- The data can be formatted to machine the replica directly (positive mode) or to make a mold (negative or inverse image).
- Similar to print making, the artist or museum owning rights to the object, can make scale replicas of works for sale as limited edition replicas.

As an example, during the exhibition Mysteries of Egypt, the Canadian Museum of Civilization used the Large Field of View Laser Scanner to scan a model of a sphinx in order to prepare smaller replicas for sale in the Museum shop during the exhibition (Figure 9). This provided a revenue stream both for the Museum and NRC.

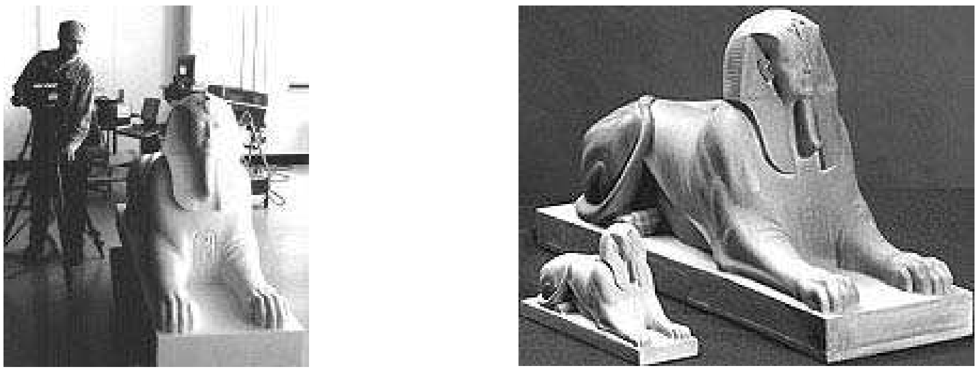


**Figure 9:** For the Mysteries of Egypt exhibition at the Canadian Museum of Civilization, scale replicas (right) of a sphinx were sold in the Museum shop during the exhibition. The replicas were prepared using the 3D model data of a large model of a sphinx scanned using the Large Volume Laser Scanner (left). The original sphinx measured 2 m in length while the scale replicas were 28 cm and 11 cm in length.

Beyond the fabrication of replicas, the same technologies can provide important assistance in the restoration after severe damage. The three-dimensional model could be used in the reconstruction of the works with a controllable level of fidelity to the original.

**4.0 Conclusions:**

As noted in the introduction, the cultural sector applications have become one of the main driving forces in the development of NRC’s 3D technology.  These applications require high quality digitizing systems to record a wide range of sizes, shapes and materials as well as a variety of data processing and display systems to utilize the data for different goals.

The involvement of members of the cultural sector in the early steps of the research on 3D imaging and modeling at NRC proved beneficial to both parties: the researchers obtained valuable feedback on the technology, and new research impetus; museum and curatorial staff were exposed very early to an emerging technology, and were able to steer aspects of its development towards the solution of important problems.

Research that was aimed at heritage applications led to new developments and applications of the technology that was relevant in other sectors, as well as to new business opportunities for our industrial partners.

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