Notre-Dame de Paris scientific action - CNRS/Ministry of Culture

Towards a cathedral of data & knowledge in heritage science

Livio De Luca, MAP UMR 3495 CNRS/MC

Web3D 2022, 2-4 November, Evry, France

Web3D technologies for the Notre-Dame de Paris scientific action

- **Livio De Luca** (CNRS-MAP) : the role of the Digital Data Working Group in the general scientific action, the potential of co-creation, sharing and semantic annotation of 3D resources in multidisciplinary collaborative studies.

- **Roxane Roussel** (CNRS-MAP): an approach to build a complete digital report of the cathedral (after fire) with the AIOLI 3D annotation platform.

- **Marco Callieri** (CNR-ISTI): the 3DHOP-based visualization and analysis application to interact with specific artifacts (the rib stones).

- **Anaïs Guillem** (LRMH): a collaborative work on the digital-physical anastylosis of the nave arch.

- **Violette Abergel** (CNRS-MAP): multimodal exploration of semantically-enriched data.

- Q&A

Notre-Dame
Fire of 15 April 2019
A new (painful) page on its history

- A challenge
> a site of global, interdisciplinary, diachronic and heuristic studies
   - The recovery of knowledge about architectural elements and materials before fire;
   - The extraction of information contained in the preserved materials
   - Introduction of new physicochemical proxies to understand the evolution of the climate
   - The coupling of modelling systems for geometric, structural and acoustic studies
   - The capture and the analysis of a common heritage that arouses emotions in society

- An asset
> a privileged moment for the observation and study
   - Access to materials and technical details
   - Working with a rare past-present-future dialectic

National scientific site "Notre-Dame" coordinated by CNRS and Ministry of Culture
> 175 research staff , +50 research units, 9 working groups :
> Wood, Metal, Stone, Glass, Decors, Structure, Acoustics, Heritage Emotions, and Digital Data

A central challenge
> restauration worksite <> scientific worksite
> temporalities: urgency of the site <> the long period of research
> new ways of working on the same object
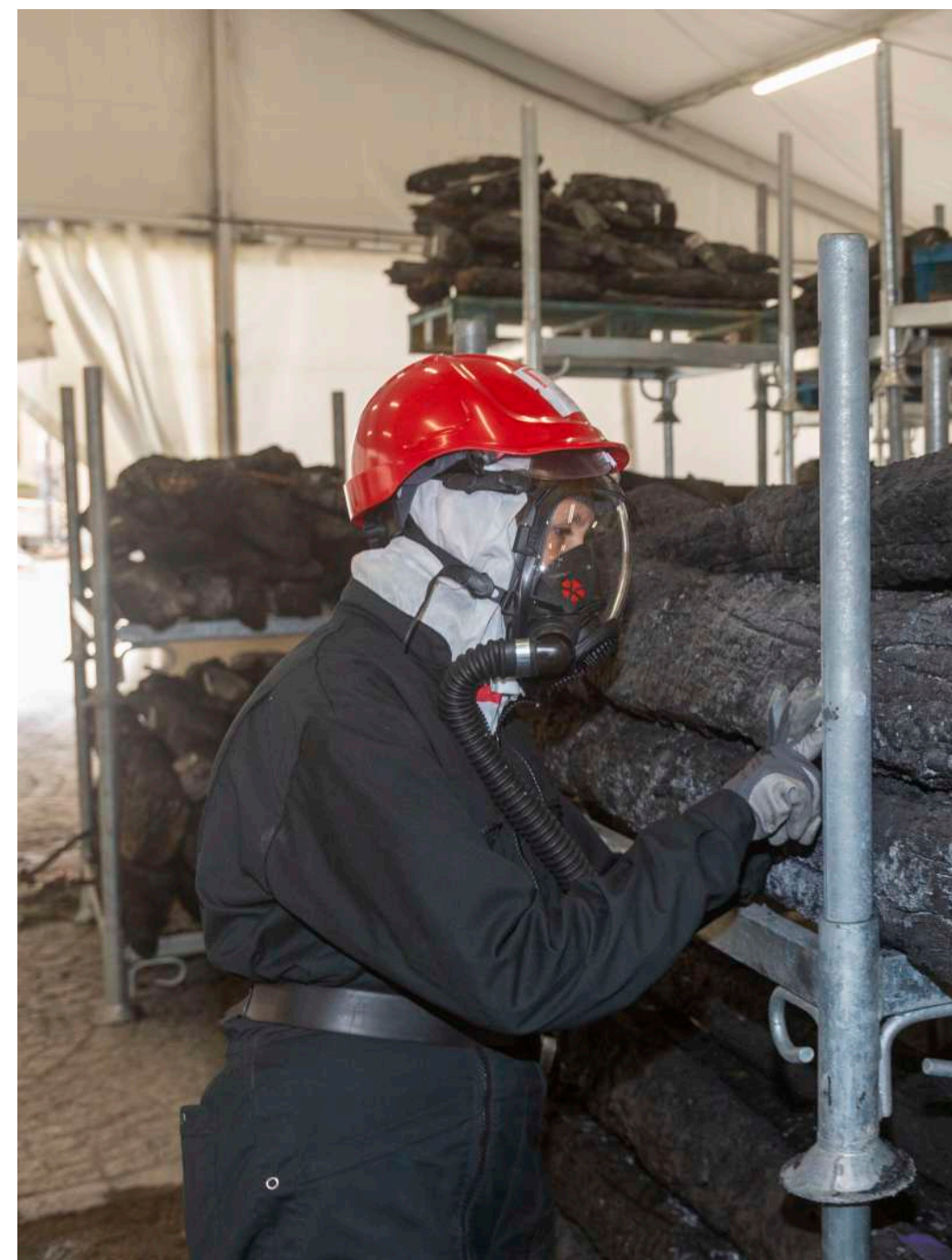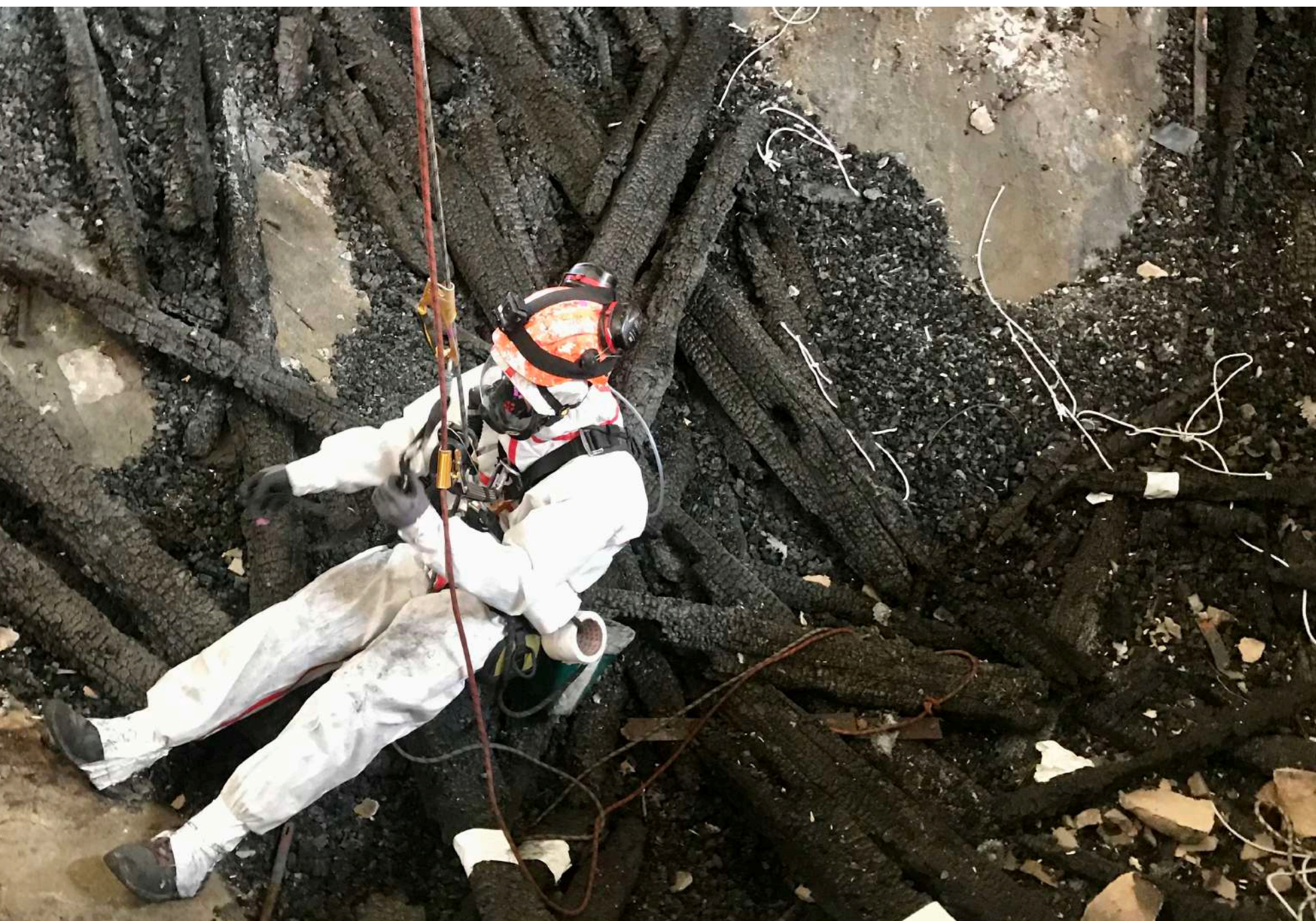
Background and state of the art in computational modelling and digitisation

"… It is time to introduce what might be called digital humanism, in which archaeologists, anthropologists, architects, historians, philosophers, lawyers, neuroscientists and psychologists work side by side with chemists, physicists and computer scientists to define a new semantics for understanding the complexity of reality…"

Opening ceremony of the first G20 Culture Ministers' Meeting, July 29, 2021

Combining Data and Knowledge to Explore the Complexity of Reality

A semantic gap

Advances in Digitisation : massive but scattered production of digital resources of cultural heritage objects
How to move from the massive production of raw-data to massive production of semantically-enriched data ?

A memory gap
Advances in knowledge engineering for aggregating, interconnecting and explore heterogenous data.
Beyond metadata and paradata and ontologies : how to consider subjective human decisions, non-explicit research protocols, highly individualised skills ?
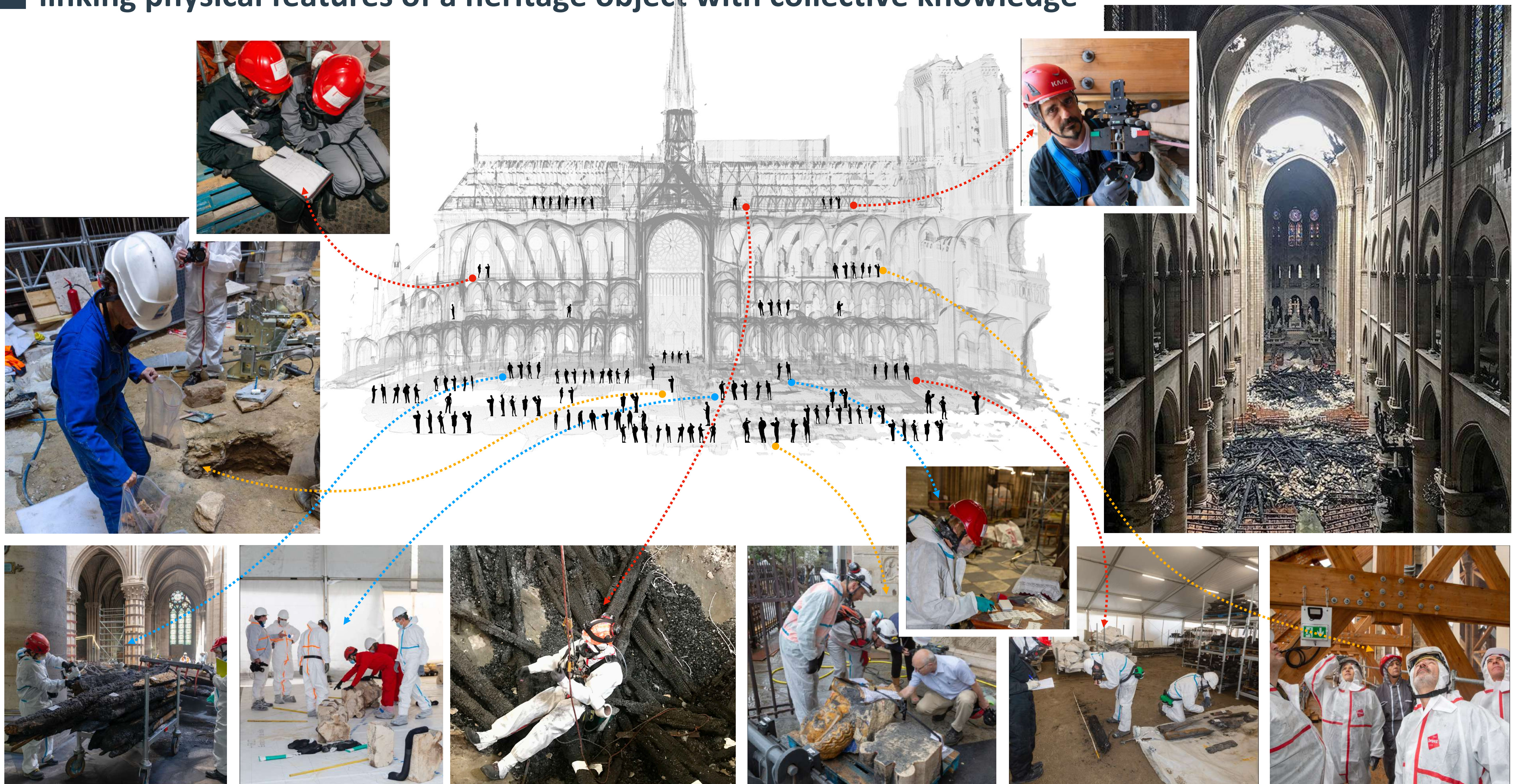
A data correlation gap
Advances in aggregating multi-thematic observations on the multi-dimensional representations. *How to build autonomous mechanisms for correlating data between dimensions and observations ?*

A technological gap
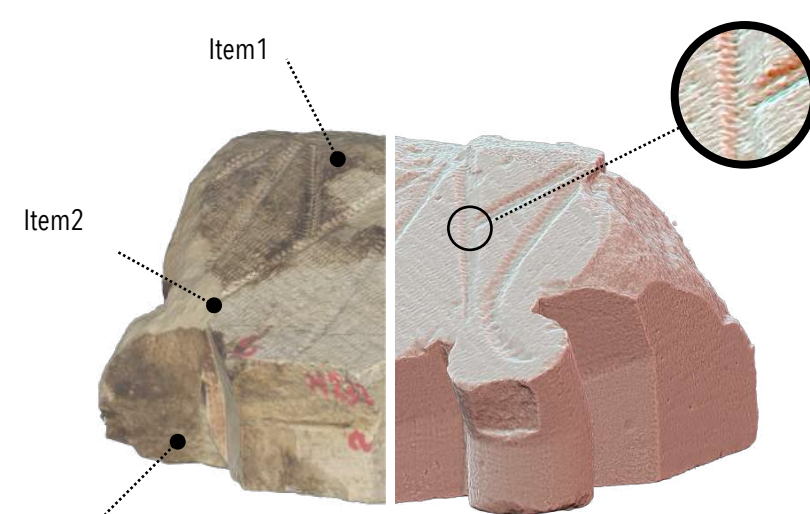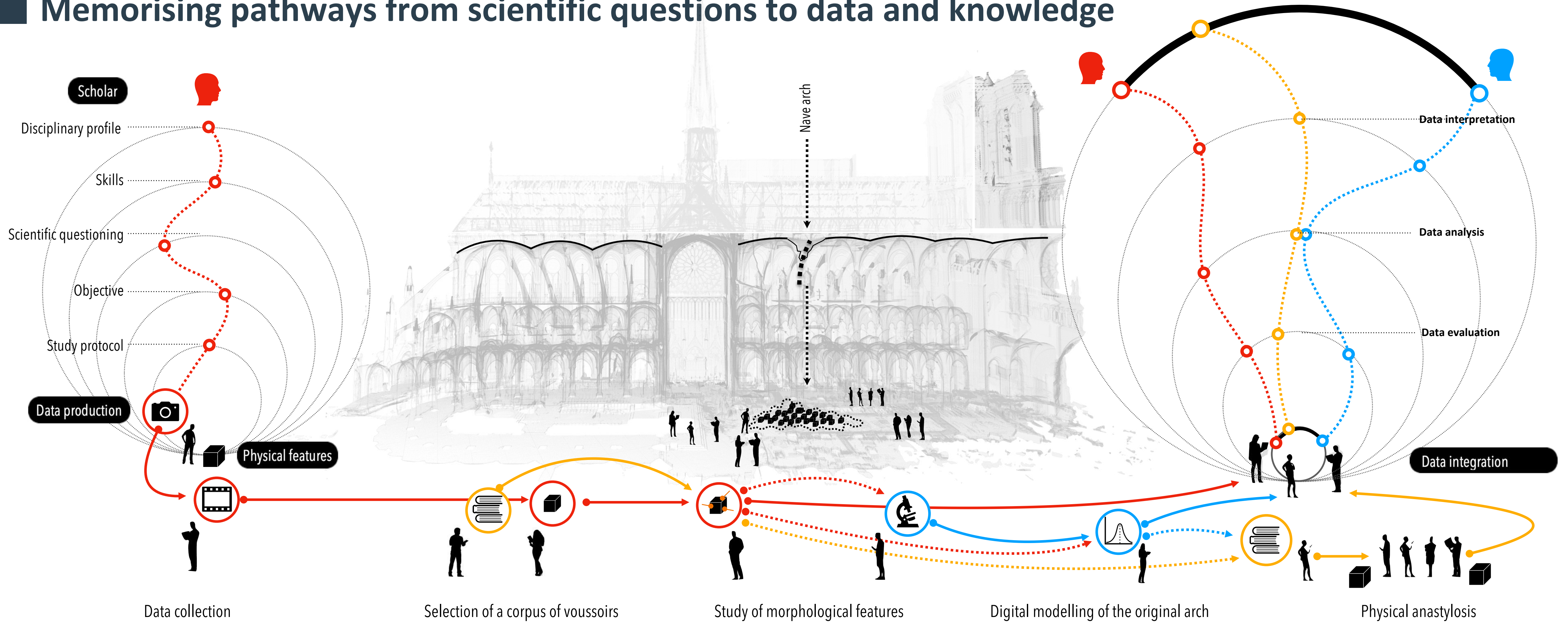Texts, Images, Sounds, Videos and 3D representations can technically be merged into collaborative frameworks today. *How to link the collaborative data production to a sustainable balance between human analysis and computational support?*

linking physical features of a heritage object with collective knowledge

Towards a cathedral of data & knowledge in heritage science. Livio De Luca, CNRS, 2022

Memorising pathways from scientific questions to data and knowledge

Scholar

Disciplinary profile

Skills

Scientific questioning

Objective

Study protocol

Data production

Physical features

Nave arch

Data interpretation

Data analysis

Data evaluation

Data integration

Data collection

Selection of a corpus of voussoirs

Study of morphological features

Item1

Item2

Digital modelling of the original arch

Physical anastylosis

Analysing links between material objects and objects of knowledge

Item1
Item 2
Item 4

Wooden beam

Mechanical behaviour

Historic documentation

15.04.2019

Form

Space

Time

Knowledge domain

T-1   T0   T+1   T+2

Spatio-temporal regions of the Forest (timber roof) before and after the fire

Remains of a wooden beam   **Remains of a forged nail**

Scholars

Disciplinary profiles

Skills

Scientific questionings

Objectives

Study protocols

Overlapping region of interest

Nave

after 1289, before 1313
around 1290

PND.MP2N8 (1179/1272)
PND.ref E3 (1185/1289)
PND.net E3 (1185/1289)
PND.FLP7 (1178/1292)

Dendrogroup 4

Material provenance

Remains classification

First works for the restoration of Notre-Dame de Paris 2019 - 2021

Emergency works

Comparative analysis of temporal states : before / after fire

Reality-based 3D condition report

Scientific Data & knowledge for the 'reconstruction à l'identique'

The "forest" - timber roof

Collapsed vaults

Technological framework Interlinking software bricks into a open and reusable digital ecosystem

Esmeralda

Data ingestion

Archeogrid

Data indexing and categorisation

OpenThéso

Management of controlled vocabularies

Aïoli

2D/3D/4D semantic annotation

3D-HOP

Interactive analysis of 3D objects (remains)

Viewer NDP

Multimodal analysis of 4D scenes

Interlinking framework
n-Dimensional data correlation engine
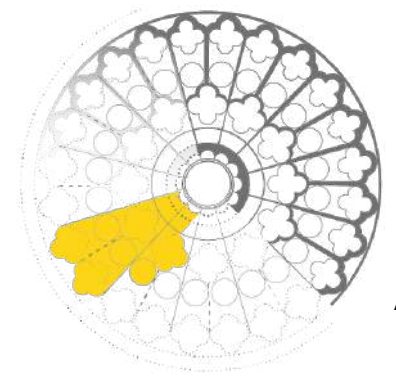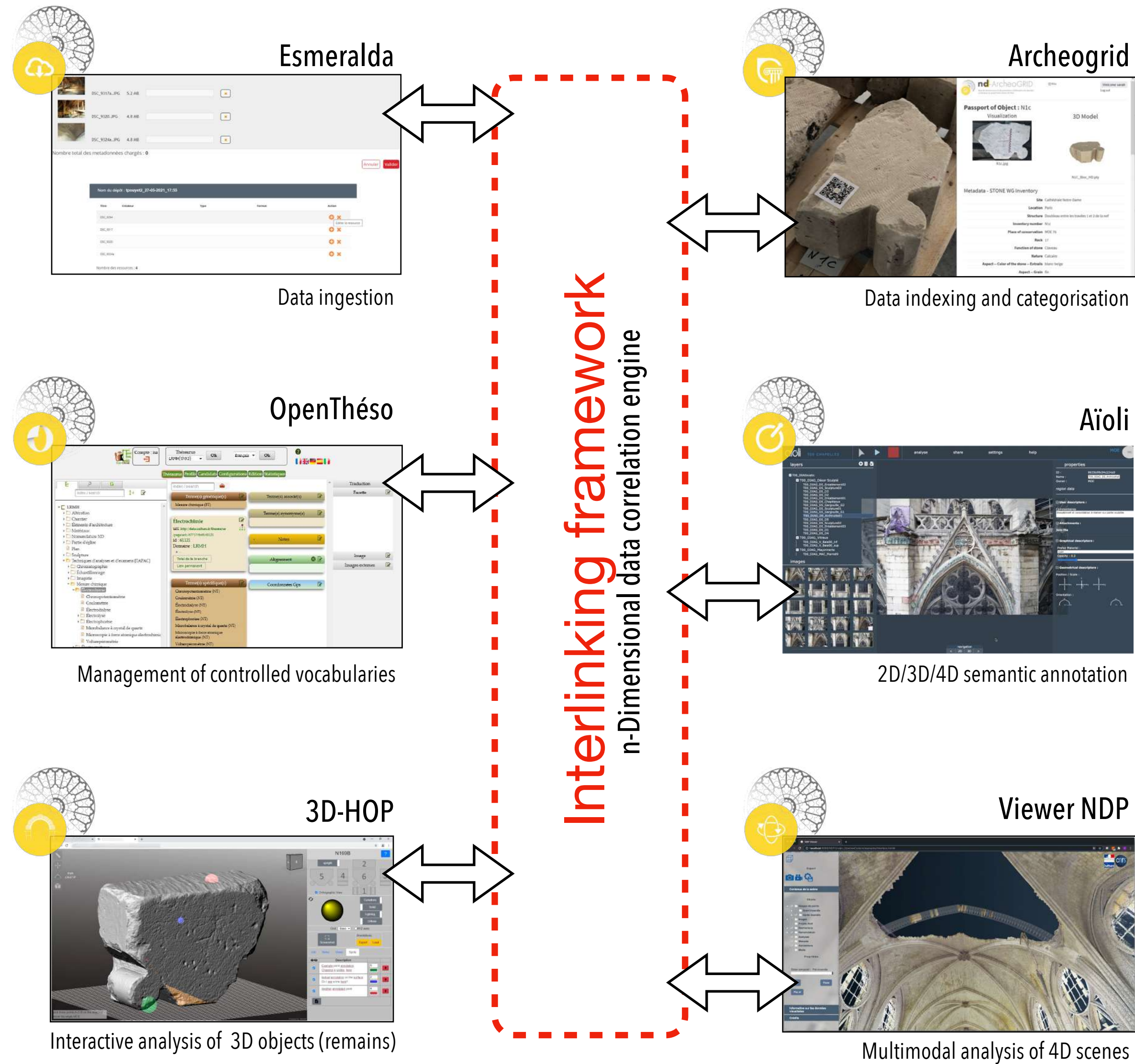
n-dame

A federative initiative

> software from labs
> open and reusable
> fostering interoperability
> towards new standards

Fully based on Web technologies

Digital resources for experimenting with data curation, analysis and correlation
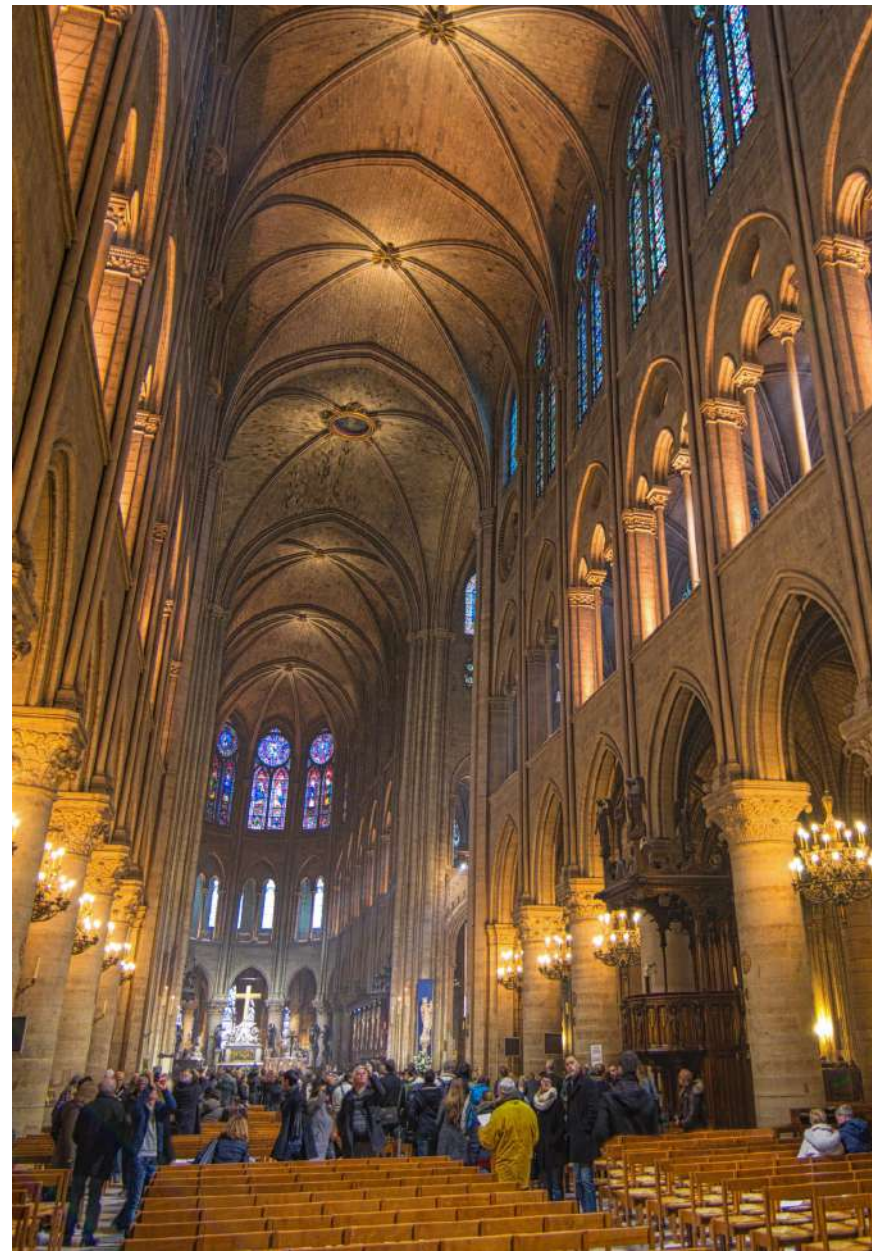

| Before Fire | April 15, 2019 | Remains removal | Identification and inventory | Temporary storage | Scientific study |
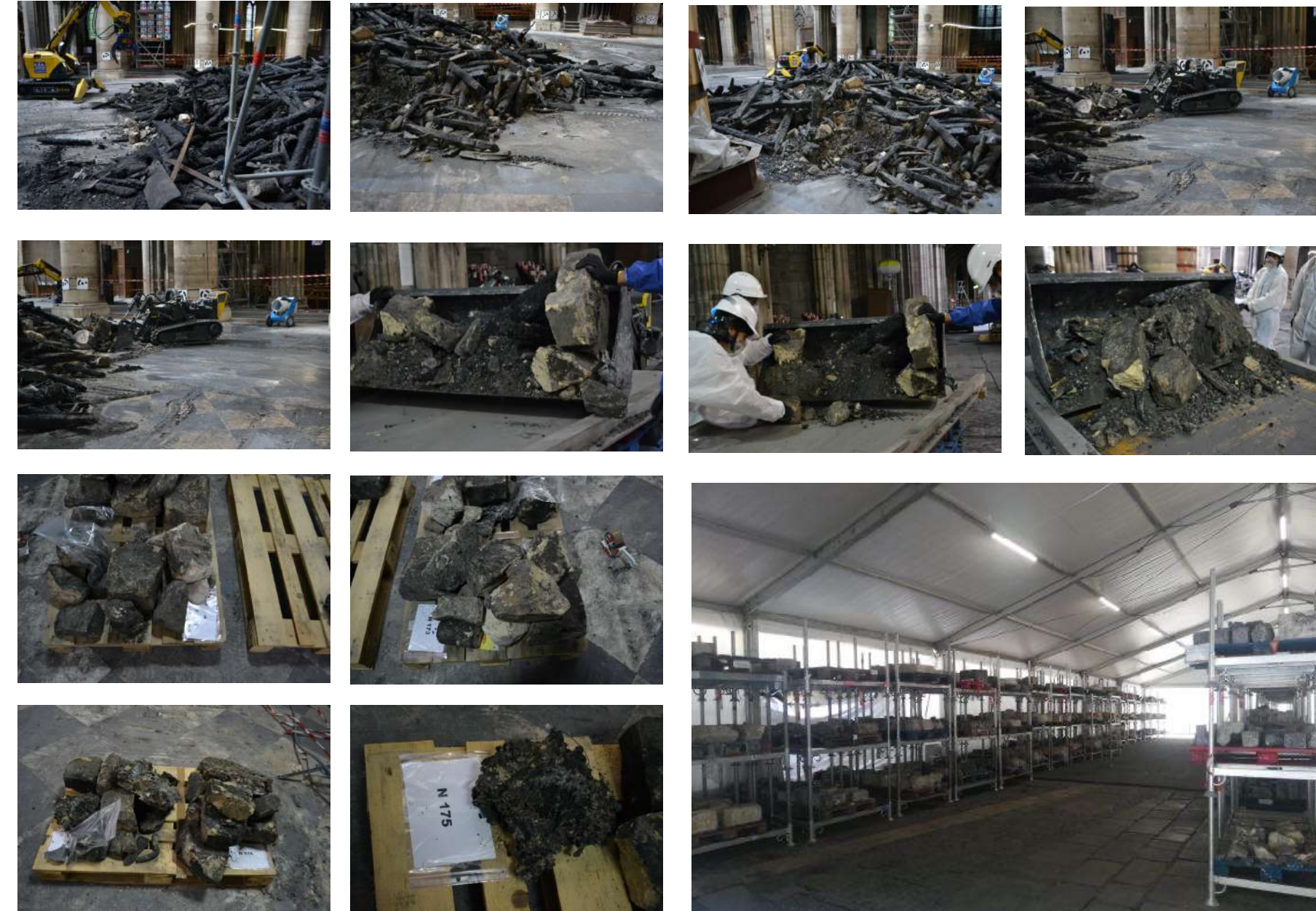
Data collected from cultural institutions, research laboratories, private companies
- 180 000 photographs (before and after fire, during the restoration)
- 5000 3D point clouds (before and after fire, during the restoration)
- hundreds of technical drawings (before fire)
- dozens of structured 3D models relating to the cathedral's condition before and after the fire,
- 5000 documentary sources (archives, bibliography, iconography) relating to the cathedral's history.

Data produced by the Notre-Dame Scientific action
Materials WG (Stone, Metal, Wood, Glass): bibliography, material analysis, technical surveys, drawings, photographs, …
Behaviours WG (Structure and Acoustics): material analyses, acoustic acquisitions, mechanical and acoustic simulations,…
Heritage Emotions WG: Press and web resources, interviews, video documentaries, citizen surveys, …
Digital Data WG: Multi-scale 3D digitisations (from architecture to remains), 3D reconstructions of hypothetical states, …

CNRS and the Ministry of Culture charter for the deposit and use of data
All data will be available in open access in accordance with the provisions of the Etalab 2.0 licence from 2024

Production of on-site/in-lab ready-to-enrich data

Spatial and temporal distribution of data streams

Multi-layered reality-based 3D semantic annotation

Tracking the path from raw data to interpretation

Methodology Initial research in Data production

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Methodology Production of on-site/in-lab ready-to-enrich data

- Ad-hoc digitisation devices for comparative morphological analysis

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- **Easy-to-deploy documentation processes**

Documentation

Who

Where

When

What

How

Processing pipeline

Methodology Production of on-site/in-lab ready-to-enrich data

- Easy-to-deploy documentation processes
- Ad-hoc digitisation devices for comparative morphological analysis
- **Fluent ingestion in the digital ecosystem**

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Methodology Spatial and temporal distribution of data streams

- Easy-to-deploy documentation processes
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- **4D digitisation devices**

Methodology Spatial and temporal distribution of data streams

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- 4D digitisation devices
- **Locating items in space-time**

A. Image selection

B. Element in image [2D annotation]

C. 2Dto3D propagation to other images

T-1   T0   T +1

T+3   T+2

D. 2Dto4D propagation for selecting the temporal range

Claveau X001
06/07/2019 13:09
09/07/2019 16:46:00

E. Filtering photos basing on the temporal range > 09/07/2019 _16:46

F. Object recognition based on visual similarity

Claveau N028

Methodology Spatial and temporal distribution of data streams

- Easy-to-deploy documentation processes
- Ad-hoc digitisation devices for comparative morphological analysis
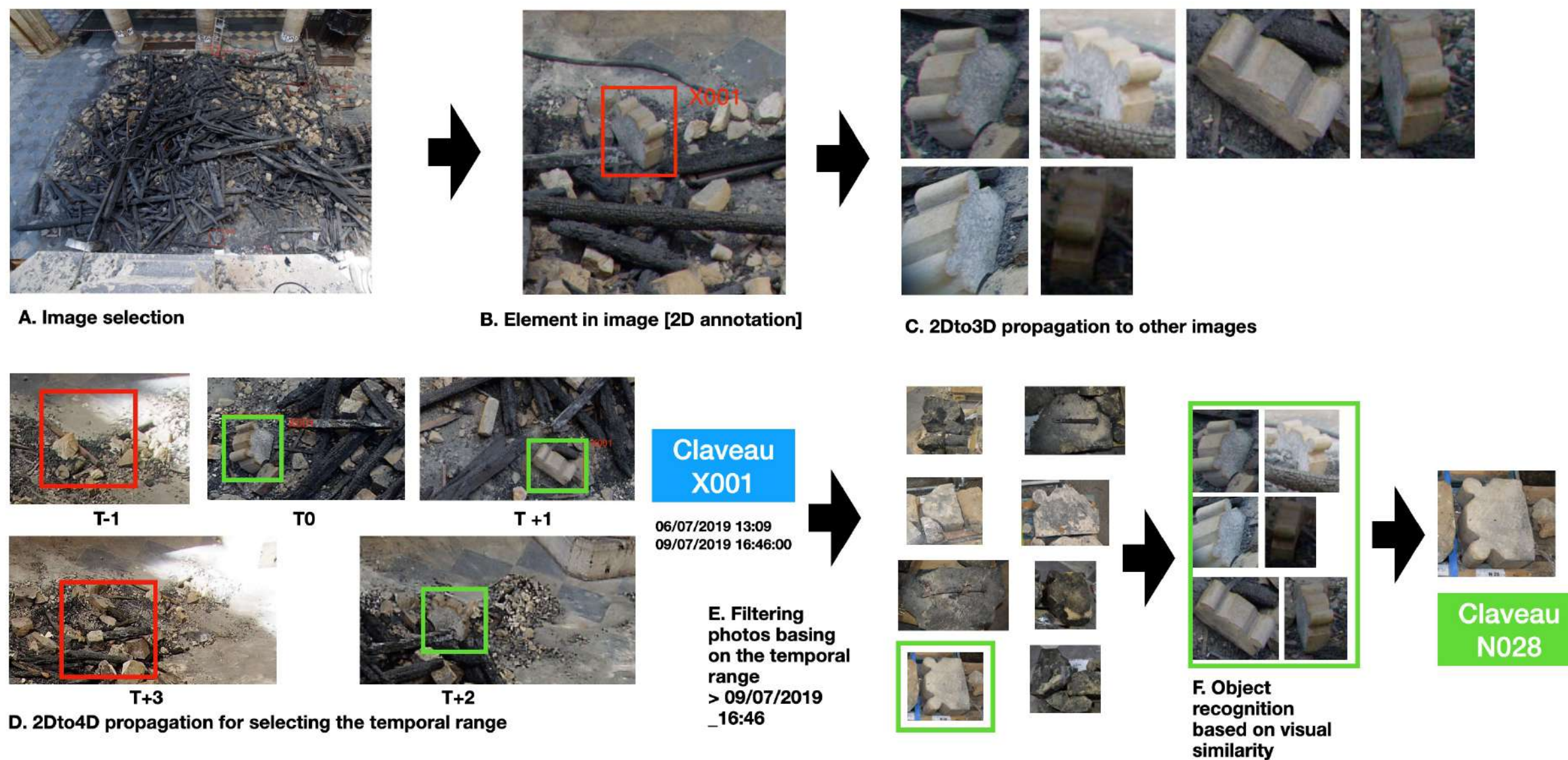- Fluent ingestion in the digital ecosystem

- 4D digitisation devices
- Locating items in space-time
- **manipulation of heterogenous data**

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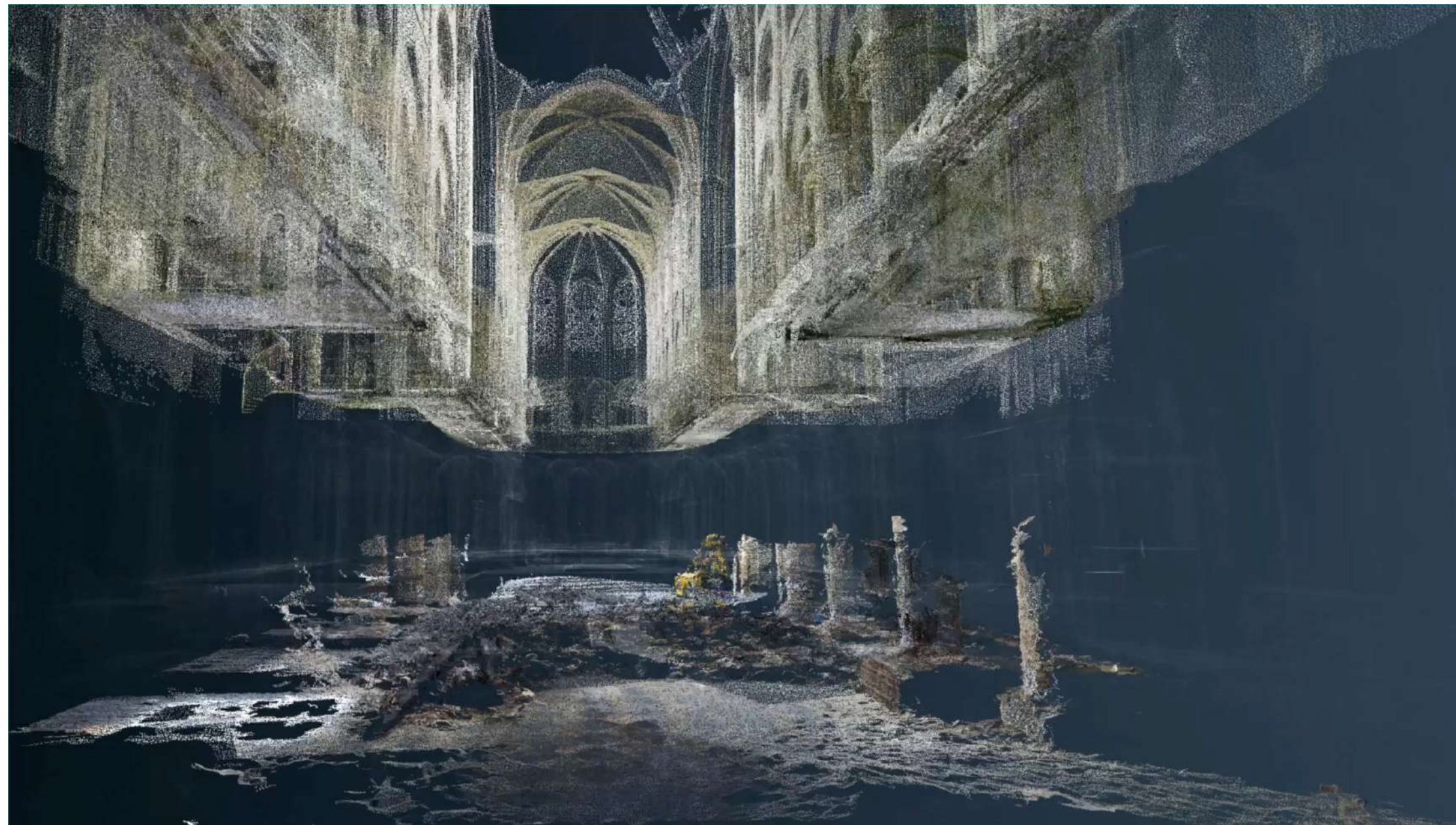- Fluent ingestion in the digital ecosystem

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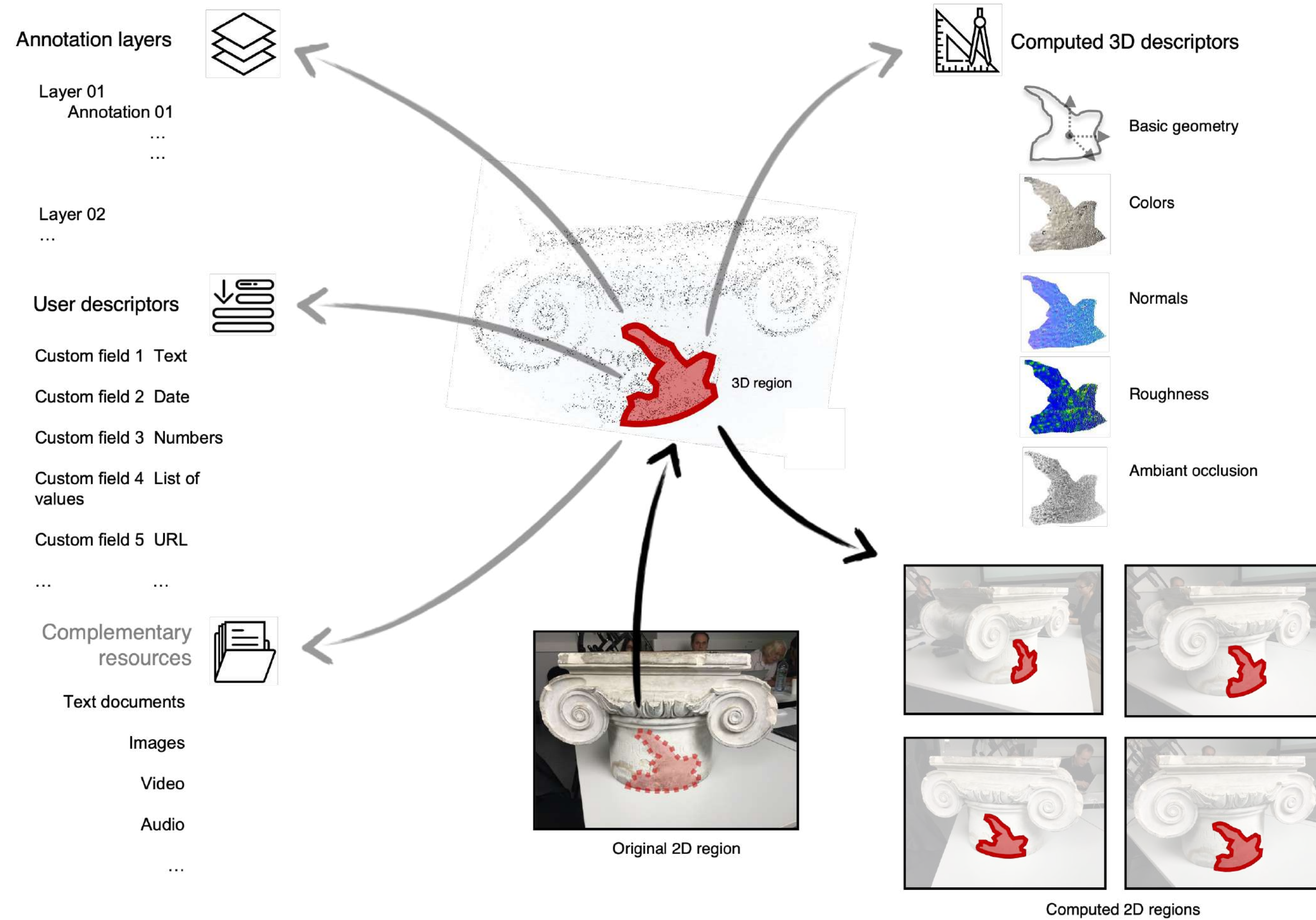- Locating items in space-time
- manipulation of heterogenous data

Methodology Multi-layered 3D semantic annotation

Annotation layers

Layer 01
    Annotation 01
        ...
        ...

Layer 02
...

User descriptors

Custom field 1 Text

Custom field 2 Date

Custom field 3 Numbers

Custom field 4 List of values

Custom field 5 URL

...   ...

Complementary resources

Text documents

Images

Video

Audio

...

Original 2D region

3D region

Computed 3D descriptors

Basic geometry

Colors

Normals

Roughness

Ambiant occlusion

Computed 2D regions

- Easy-to-deploy documentation processes
- Ad-hoc digitisation devices for comparative morphological analysis
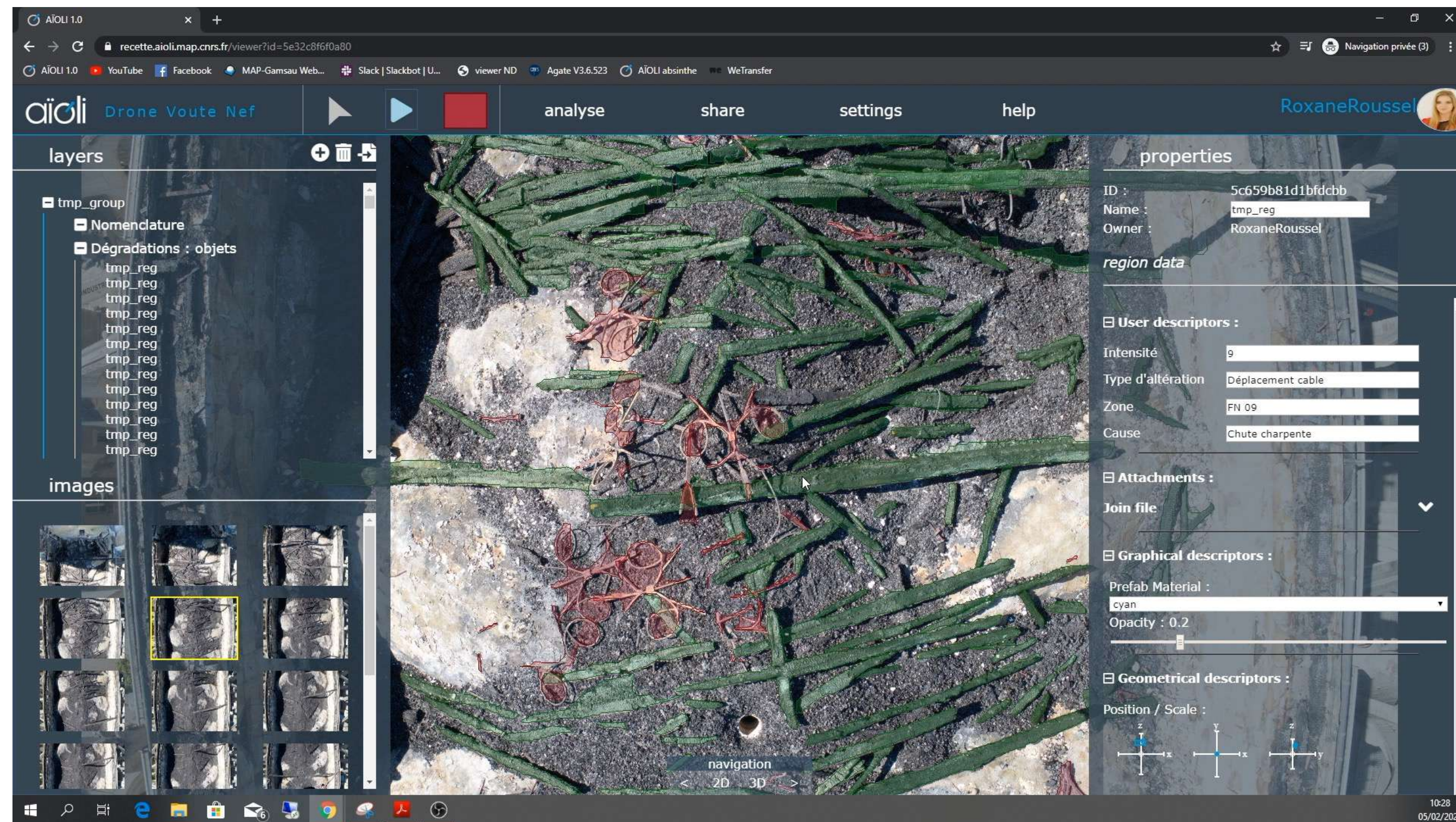- Fluent ingestion in the digital ecosystem

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- **Experimenting with reality-based 2D/3D annotation**

Methodology Multi-layered 3D semantic annotation

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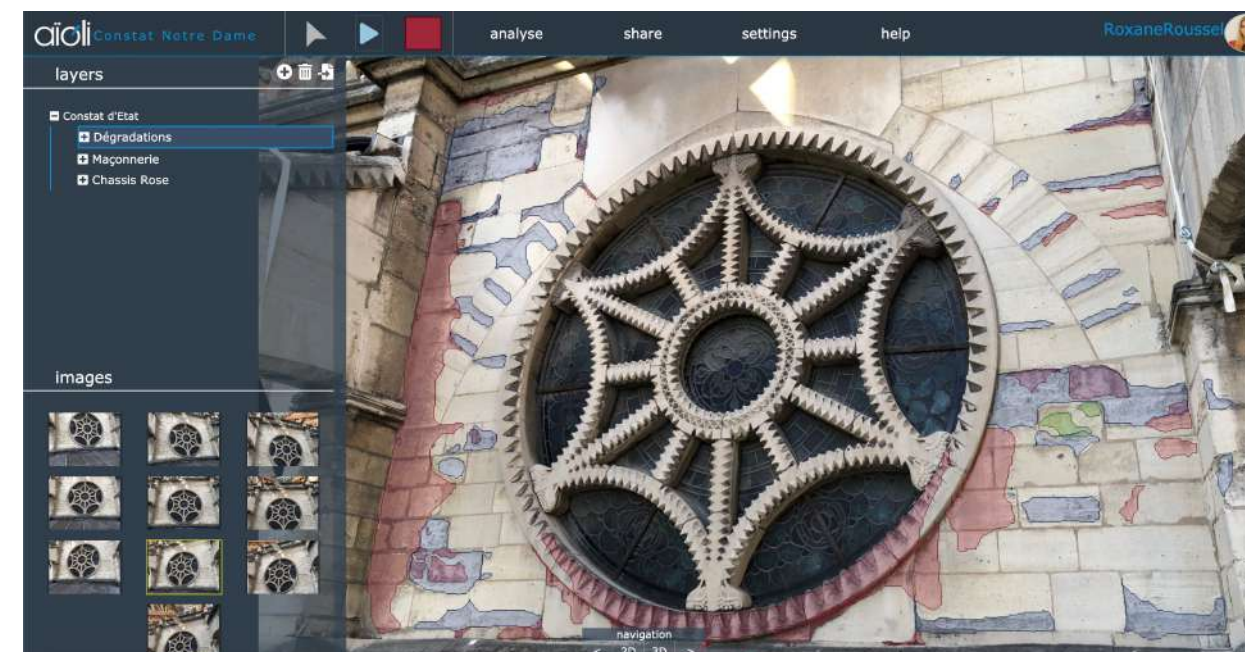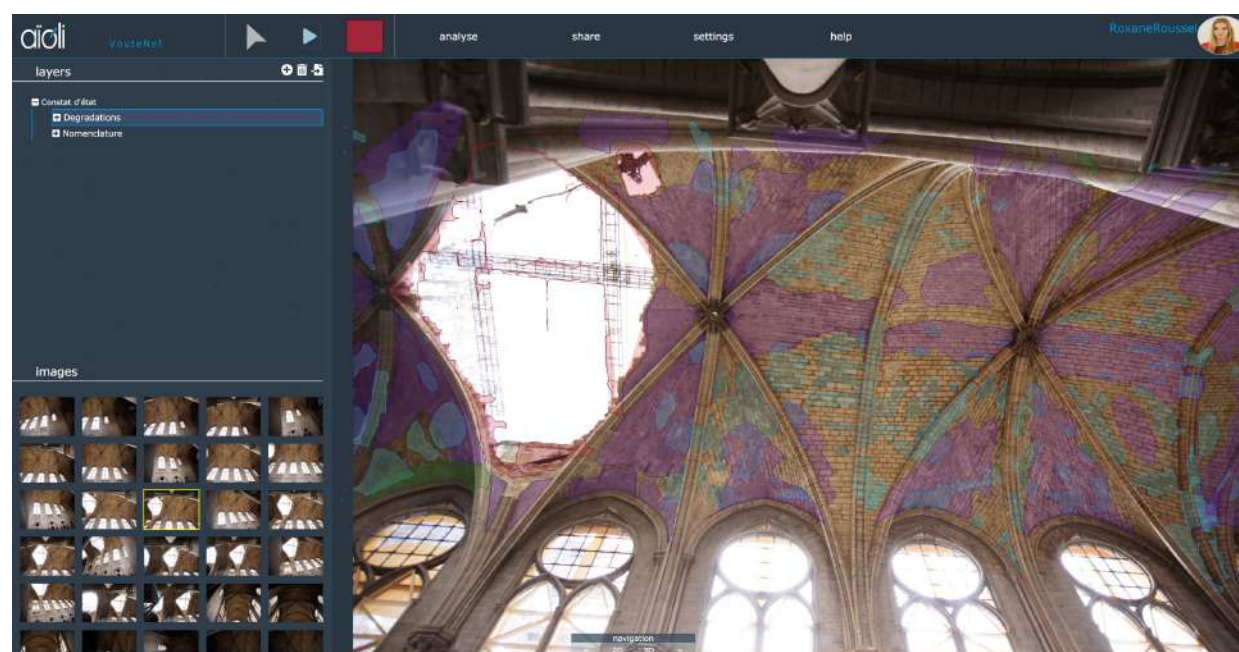- **Experimenting with reality-based 2D/3D annotation**

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- Experimenting with collaborative 2D/3D annotation
- **Extending the reality-based 3D annotation to hypothetical representations**

Methodology Multi-layered 3D semantic annotation

Attribute data: archeological analysis, typologies, material samples

- Easy-to-deploy documentation processes
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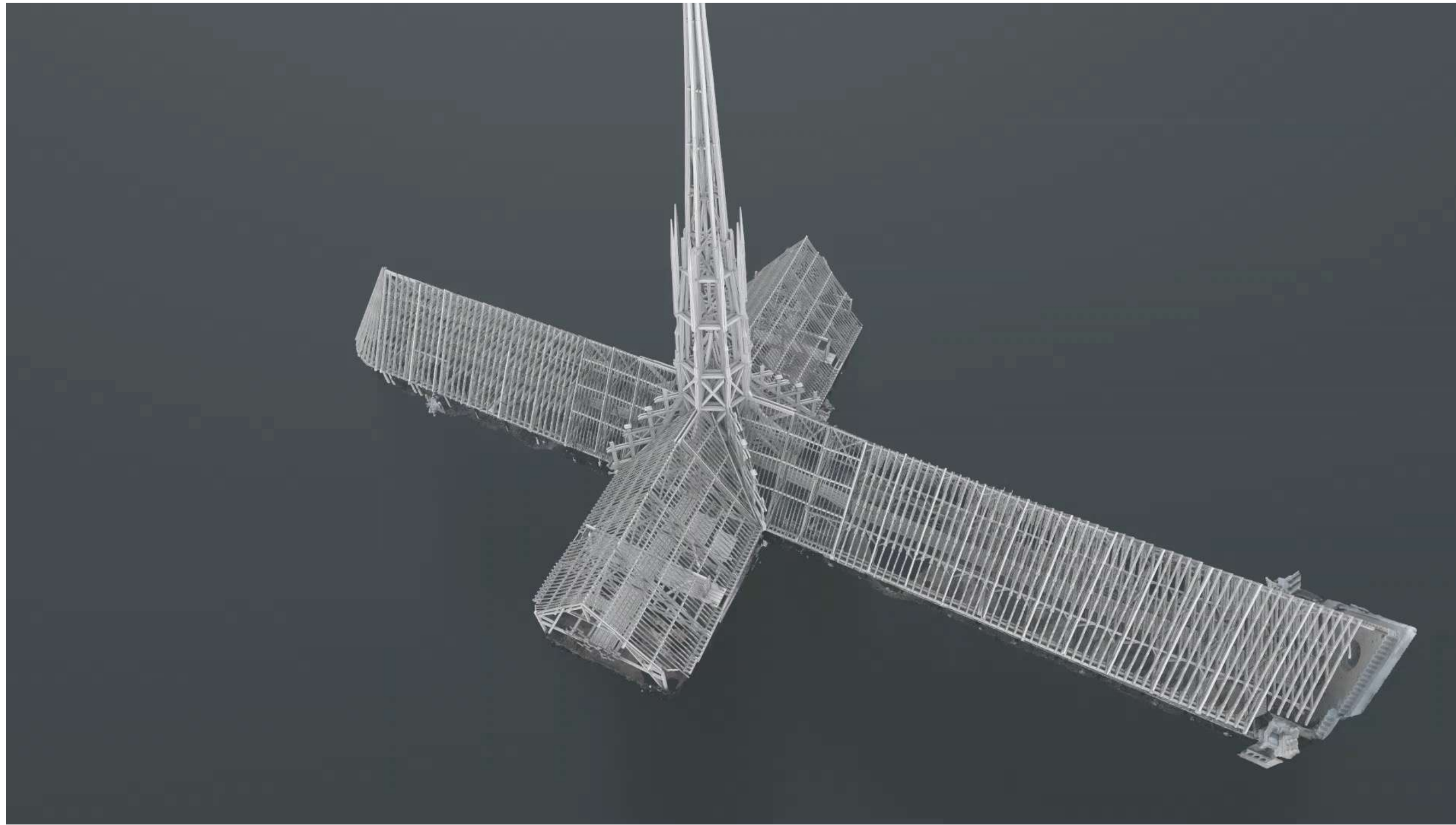- Fluent ingestion in the digital ecosystem

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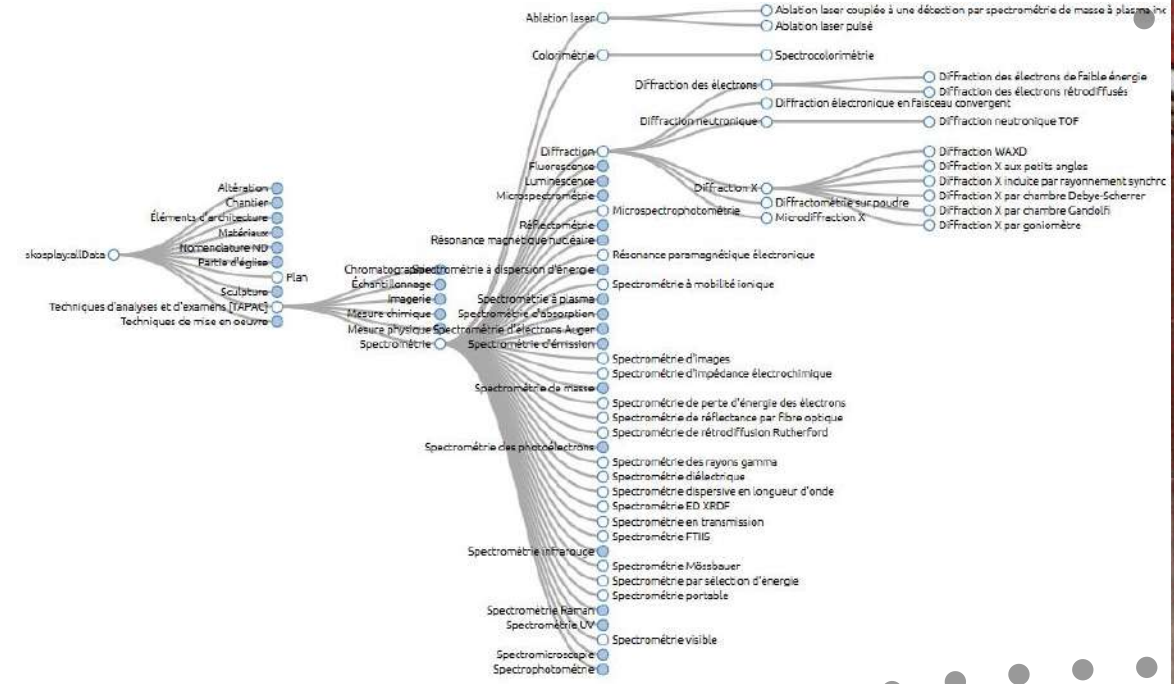- Fluent ingestion in the digital ecosystem

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Custom field 1   Text

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...   ...

Computed 3D descriptors

Basic geometry

Colors

Normals

Roughness

Ambiant occlusion

Supervised and unsupervised machine learning

Complementary resources

Text documents

Images

Video

Audio

...

CA07_DECOR_E:
Décor peint: Fresque sur la vie de Saint-Marcel, évêque de Paris (IVème-Vème s.)
Scène représentée: Saint Marcel bénissant la foule et guérissant un malade
Source de l'annotation: CATHEDRALE NOTRE-DAME DE PARIS - Etude de Diagnostic à la suite de l'incendie du 15 avril 2019 Philippe VILLENEUVE, Rémi FROMONT, Pascal PRUNET, Architectes en Chef des Monuments Historiques - Décembre 2020

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- **Analysing user / computed descriptors**

Methodology Tracking the path from raw data to interpretation
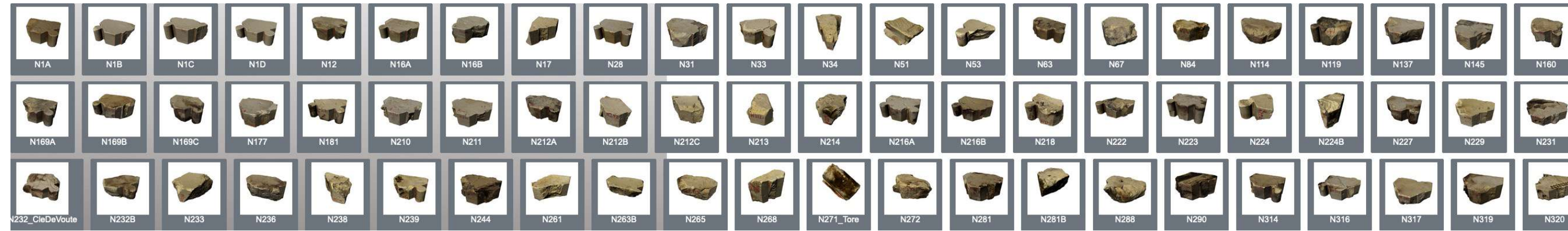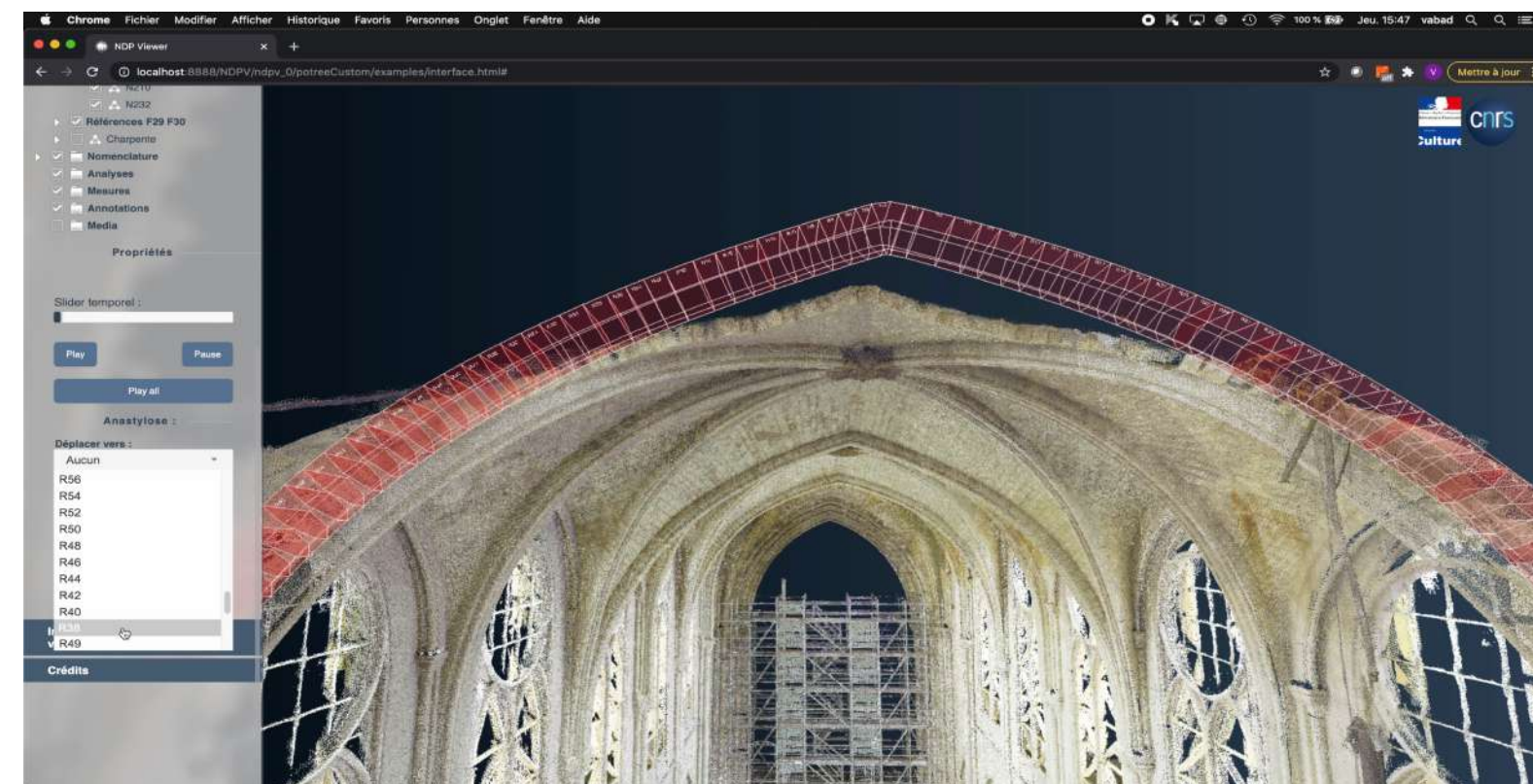

Dimensional attributes   Constructive details   Spatial location of the fall position   Lapidary marks

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- Experimenting with collaborative 2D/3D annotation
- Extending the reality-based 3D annotation to hypothetical representations

- Analysing user / computed descriptors
- **Studying links between observation in real and digital spaces**

www.notre-dame.science

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