



**CHANGE**  
CULTURAL HERITAGE ANALYSIS  
FOR NEW GENERATIONS  
[change-itn.eu](http://change-itn.eu)



# Imaging for Cultural Heritage - experiences from the MSCA ITN project CHANGE

Jon Y. Hardeberg, CHANGE co-ordinator  
Colourlab – Department of Computer Science  
NTNU – Norwegian University of Science and Technology  
Gjøvik, Norway



Colourlab  
 NTNU  
Kunnskap for en bedre verden



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## CHANGE - Background

- Cultural Heritage (CH) objects are continuously undergoing changes/degradations over time.
- It is important to **monitor, estimate and understand** these changes, to enable slowing down of the deterioration process and/or better conservation treatments.
- A variety of new **imaging modalities** (e.g. hyperspectral and 3D) and **analysis algorithms** are becoming available, and may complement traditional analytical tools
- Significant gaps in knowledge and skills in the sector



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This project has received funding from the European Union's H2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 813789

## CHANGE – Project Overview

- EU funded project
  - Innovative Training Network (ITN)
  - Marie Skłodowska-Curie Actions
  - 4 years: May 2019 – April 2023
  - 4 MEUR funding
- Co-ordinated by NTNU
  - Colourlab, Department of Computer Science, Gjøvik, Norway
  - Co-ordinator: Jon Yngve Hardeberg
  - Deputy co-ordinator: Sony George
  - Project manager: Anneli T. Østlien
  - Financial Officer: Anne Hilde R. Nymo
- **Interdisciplinary approach**
  - Conservation science
  - Imaging science
  - Visual computing
- 18 partner institutions throughout Europe
  - Alamin Mansouri (University of Burgundy, France)
    - WP3 - Multiscale and multimodal strategies and systems for change capture and tracking of CH assets
  - Robert Sitnik (Warsaw University of Technology, Poland)
    - WP4 - Computational methods for change studying (characterization, visualisation and monitoring) of CH assets
  - Clotilde Boust (C2RMF/CNRS, France)
    - WP5 - Application: Change during the alteration and conservation of CH artefacts
  - Christian Degrygn (Haute Ecole ARC, Switzerland, and Château de Germolles, France)
    - WP6 - Dissemination, Exploitation, and Communication
- 15(14) PhD students/Early Stage Researchers
  - And their supervisors

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## CHANGE – Main Scientific Objective

- To develop and apply **imaging based methodologies** to assess and monitor any **change** to which cultural heritage artifacts are faced during their exposure to the atmosphere and their conservation treatments (revised)



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## CHANGE – overall goal

- **Train** a new generation of multi-skilled researchers specialised in the study and monitoring of changes of cultural heritage objects.

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## CHANGE – Researcher Training

- **Training by research** (15 ESR projects)
  - Leading towards PhD degrees
- **Secondments/internships/mobility**
- **Introductory courses**
- **In-depth workshops**
- **Transferrable skills**
- **Kick-off training event**
  - Paris, France, October 2019
  - Including IS&T's Color and Imaging Conference
- **Mid-term meeting**
  - NTNU, Norway, September 2020
- **CHANGE Schools** (5-10 days)
  - NTNU, Norway, February 2020
  - C2RMF/UBFC, France, **JUN-2020** **Nov-2021** March 2022 +online
  - WUT, Poland, **November 2021** +online
  - HESSO, Switzerland, June 2022
- **Closing event**
  - With IS&T's Archiving Conference in Oslo, Norway, June 2023




Photos: Hands-on training at the Academy of Fine Arts, Warsaw


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## CHANGE – Beneficiaries




**NTNU**  
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**Hes·so**  
Haute Ecole Spécialisée de Suisse occidentale  
Fachhochschule Westschweiz  
University of Applied Sciences and Arts Western Switzerland




**Cyprus University of Technology**



**CENTRE DE RECHERCHE ET DE RESTAURATION DES MUSÉES DE FRANCE**





**UBFC**  
UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ



**UNIVERSITEIT VAN AMSTERDAM**

**SCHWEIZERISCHES NATIONALMUSEUM. MUSÉE NATIONAL SUISSE. MUSEO NAZIONALE SVIZZERO. MUSEU M NAZIUNAL SVIZZER.**





**POLITECHNIKA WARSZAWSKA  
WARSAW UNIVERSITY OF TECHNOLOGY**

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## CHANGE – Partner Organizations



**CHÂTEAU DE GERMOLLES**





**CRC**  
CENTRE DE RECHERCHE SUR LA CONSERVATION



**HEXAGON**



**neo**  
NORSK ELEKTRO OPTIKK AS

**NASJONALMUSEET FOR KUNST, ARKITEKTUR OG DESIGN**



**7reasons**  
Medien GmbH



**ACADEMY OF FINE ARTS  
WARSAW**



**RIJKSMUSEUM  
amsterdam**



**unine**  
UNIVERSITÉ DE NEUCHÂTEL



**inp** Institut national du patrimoine

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## CHANGE External Expert Advisory Board

- Harry Verwayen: Executive Director, Europeana Foundation, Netherlands
- Eleanor Fink: Former Getty director in all issues regarding e-CH Preservation and Senior Advisor to World Bank for CH preservation and protection, USA;
- Fenella G. France: Chief, Preservation Research and Testing Division Library of Congress, USA;
- Roy Berns: Rt. Professor at RIT, Gray Sky Imaging, USA
- Mark Mudge: President and co-founder of Cultural Heritage Imaging, USA;
- Jim Shyu: Chinese Culture University, Taipei, Taiwan;
- Greg Bearman: Rt. Imaging scientist at NASA JPL, ANE Image, USA;
- Luca Pezzati: CNR, E-RIHS Coordinator, Italy

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## Our Early Stage Researchers (ESR)



- ESR1**  
Imaging techniques for change documentation and monitoring of **challenging CH materials**
- ESR2**  
Quality Evaluation in CH Digitization
- ESR3**  
Registration techniques for differential and multi modal data



- ESR4**  
Analysis and **visualization** of multi modal image data in CH surfaces monitoring
- ESR5**  
Portable **multi modal device(s)** for surface measurement/monitoring



- ESR6**  
Development of multi modal image **data fusion** methods for change monitoring
- ESR7**  
Microscopic **3D imaging** and conservation



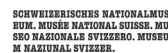
- ESR8**  
Capture and characterization of change in the **appearance** of CH objects surface
- ESR9**  
**Appearance change** assessment: Link between local geometry and global appearance descriptors



- ESR10**  
Imaging-based documentation and analysis for change monitoring of novel dry-cleaning restoration/conservation methods for **unvarnished paintings**



- ESR11**  
Analysis and assessment of degradation of **polychrome artworks**
- ESR15**  
Use of **imaging techniques** to characterize and monitor the surface of historical oxidized, patinated and varnished **metals**



- ESR12**  
Analysis and monitoring of degradation of **ancient glasses**




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- ESR13**  
Monitoring of the surface appearance of **daguerreotypes** during their first tarnishing, electrolytic cleaning and possible re-tarnishing after treatment




- ESR14**  
Enrichment of 3D volumetric data with **metadata** and semantics

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## ESR1 - Imaging techniques for change documentation and monitoring of challenging CH materials



**NTNU**  
Kunnskap for en bedre verden

**Agnese Babini**

**Host Institution:** NTNU  
**PhD Enrollment:** NTNU

**Main Supervisor**

- Sony George (NTNU)

**Co-Supervisor(s)**

- Jon Yngve Hardeberg (NTNU)
- Tiziana Lombardo (SNM)

**Objectives**


- Development of imaging techniques for documentation of transparent/translucent artifacts (focus on stained glass).
- Development of tools for monitoring micro-macro changes in appearance of transparent/translucent CH artifacts using multi modal imaging (focus on stained glass).
- Development of methods for data visualization and virtual rendering/restoration.

**Expected Results**


- Prototype of imaging system for digitisation of optically complex CH artefacts
- Change monitoring tools for challenging objects using multimodal imaging
- Hardware and software tools for mass digitisation and processing of multimodal images.

**Planned Secondments**


- CNRS - Digitization of films and photography materials
- SNM - Modelling and monitoring of degradation of glass artefacts
- UBFC - Methods for monitoring micro-macro changes in appearance using multimodal imaging



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## ESR2 - Quality Evaluation in CH Digitization



**NTNU**  
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**Dipendra Jee Mandal**

**Host Institution:** NTNU  
**PhD Enrollment:** NTNU

**Main Supervisor**

- Marius Pedersen (NTNU)

**Co-Supervisor(s)**

- Clotilde Boust (C2RMF)
- Sony George (NTNU)

**Objectives**


- Identification of quality attributes to be evaluated in CH digitization.
- Development and implementation of tools/methods for evaluation of quality attributes and interactive visualization methods for presenting the results.
- Validation of the tools/methods through comparison to ground truth data from for example physical and chemical tests and expert assessment.

**Expected Results**


- Quality attributes for the evaluation of CH.
- Tools for quality evaluation.
- Validation of tools.
- Guidelines for quality evaluation.

**Planned Secondments**

- CNRS & NM - Interview with experts and analysis of existing tools for identifying attributes.
- WUT & MKW - Quality evaluation of user interface, visualization tools.

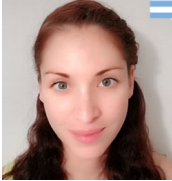




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## ESR<sub>3</sub> - Registration techniques for 3D differential and multi modal data

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**Evdokia Saiti**

**Host Institution:** NTNU  
**PhD Enrollment:** NTNU

**Main Supervisor**

- Theoharis Theoharis (NTNU)

**Co-Supervisor(s)**

- Alamin Mansouri (UBFC)
- Robert Sitnik (WUT)

**Objectives**


- Developments of registration algorithms suitable for successive surface scans of 3D objects across time without external reference points.
- Developments of multi modal registration algorithms that can automate the tedious process of registering multi modal data (e.g., surface and mineral scans) without external reference points.

**Expected Results**


- Novel registration algorithms for successive surface scans across time and for multi modal object scans, both without the need for external reference points.

**Planned Secondments**

- UIO - Identifying the challenges in real objects at Viking ship museum.
- MKW - Exposure to potential users of their results, through the CH researchers.






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## ESR<sub>4</sub> - Analysis and visualization of multi modal image data in CH surfaces monitoring

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**Sunita Saha**

**Host Institution:** WUT  
**PhD Enrollment:** WUT

**Main Supervisor**

- Robert Sitnik (WUT)

**Co-Supervisor(s)**

- Theoharis Theoharis (NTNU)
- Alamin Mansouri (UBFC)
- Noëlle Lynn Wenger Streeton (UiO)

**Objectives**


- Identification of digital model representations for CH objects from different modalities (surface- and volumetric-based).
- Development of analysis and visualization methods for selected CH objects, with automated and interactive data processing.
- Validation of methods using CH dummies.
- Application of proposed multi modal analysis and visualization methods in conservation processes (before and after changes detection and assessment).

**Expected Results**

- Data structure and representation of surface and volumetric data.
- Analysis and visualization methods for multi modal image data.


**Planned Secondments**

- UIO - Challenges in imaging, analysis and visualization of CH objects.
- NTNU - Imaging, analysis and visualization of CH dummies.
- UBFC- development and acquisition measurement of the RTI data.

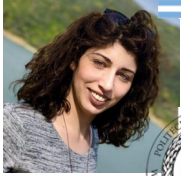




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## ESR5 - Portable multimodal system for CH surface measurement and monitoring

**Athanasia Papanikolaou**


**Host Institution:** WUT  
**PhD Enrollment:** WUT

**Main Supervisor**

- Małgorzata Kujawińska (WUT)

**Co-Supervisor(s)**

- Sony George (NTNU)
- Elizabeth Ellen Peacock (NTNU)
- Jacek Martusewicz (AFAW)



**Objectives**

1. Identification of optimal device configuration for different modalities (geometry, displacements, multispectral) taking into account measurement quality and time, cost of device, and applicability in different scenarios. Followed by development of
2. Device prototype with measurement functionality
3. Validation using CH mock-ups.
4. As a proof of the system applicability, the measurements of CH objects during conservation processes and exposition to environmental changes will be performed.


**Expected Results**

Prototype of portable multimodal acquisition system with calibration and measurement procedures. Examples for implementation of the system to support the CH objects conservation and monitoring their structural health.




**Planned Secondments**

1. ACN - Identification of optimal device configuration for in-situ CH digitization.
2. UBFC - Evaluation of the device, analysis of data acquired in different time periods.
3. C2RMF - Digitization and analysis of real CH objects supporting conservation process.

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## ESR6 - Development of multimodal image data fusion methods for change monitoring

**Jizhen Cai**


**Host Institution:** C2RMF  
**PhD Enrollment:** UBFC

**Main Supervisor**

- Clotilde Boust (C2RMF)

**Co-Supervisor(s)**

- Alamin Mansouri (UBFC)
- Jon Yngve Hardeberg (NTNU)
- Hermine Chatoux (UBFC)



**Objectives**

1. Identify data representations and cross-analysis with heterogeneous multi modal inputs available at the museums- 2D (e.g., spectral, fluoX, and chemical imaging).
2. Visualization of data from heterogeneous sources.
3. Construct data fusion model with computing analysis and other information as object historical data for restoration.
4. Use of the change monitoring methods to analyze paintings and statues at the Louvre museum.


**Expected Results**

1. 2D representation of heterogeneous data.
2. Tools for semi-automatic analysis of large, complex data.




**Planned Secondments**

1. NTNU - Analysis and visualization algorithms.
2. UBFC - Data fusion.
3. UIO - Test model for supporting conservation process.

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## ESR7 - Small scale 3D imaging and processing in cultural heritage

**Yoko Arteaga**

*Host Institution:* C2RMF  
*PhD Enrollment:* NTNU

**Main Supervisor**  
Clotilde Boust (C2RMF)

**Co-Supervisor(s)**

- Nicolas Mélard (C2RMF)
- Jon Yngve Hardeberg (NTNU)
- Angele Dequier (INP)

**Objectives**


1. Development of small scale 3D imaging acquisition for analysis of surfaces.
2. Measurement and modelling of surface details with the support of imaging tools.
3. Early stage detection of micro alterations.
4. Monitoring and assessing restoration and conservation actions by characterisation and analysis of surface details

**Expected Results**


Statistical characterisation tools for tool marks and surface modification processes on CH objects using small scale 3D data

**Planned Secondments**




1. NTNU - 3D printing and appearance measurement.
2. WUT - Color 3D printing from macro to micro scale.



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## ESR8 - Capture and characterization of change in the appearance of CH objects surface

**Ramamoorthy Luxman**

*Host Institution:* UBFC  
*PhD Enrollment:* UBFC

**Main Supervisor**

- Alamin Mansouri (UBFC)

**Co-Supervisor(s)**

- Jon Yngve Hardeberg (NTNU)
- Christian Degryny (HES SO)

**Objectives**


1. Development of complete framework based on **spectral-RTI system**: Acquisition, multi-view data alignment and stitching, joint reconstruction of spectral and angular components of reflectance.
2. Investigation of parameters characterizing change in CH object appearance.
3. Investigation of the link between photo metric parameters and visual judgement through psychosensorial experiments.

**Expected Results**


1. A pioneer non-dome based spectral-RTI system.
2. Spectral- RTI methods for appearance quantification

**Planned Secondments**


1. WUT - Automation of spectral-RTI acquisition.
2. UIO - Digitization and analysis on wood samples.
3. GDPB - Acquisition of wall-painting images
4. NTNU - Psycho-visual experiments



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## ESR9 - Appearance change assessment: Link between local geometry and global appearance descriptors



**David Lewis**

Host Institution: UBFC  
PhD Enrollment: UBFC




**Main Supervisor**

- Alamin Mansouri (UBFC)

**Co-Supervisor(s)**

- Robert Sitnik (WUT)
- Gaetan Le Goic (UBFC)



**Objectives**

- Investigate the relation between changes in appearance and its underlying geometric mechanisms.
- Surface roughness reconstruction by combining stereo-photometry and 'Shape From Focus'.
- Acquisition at the same scale of surface 3D information and the photometric attributes.
- Local and global singularities detection on 3D surfaces with impact on photometric attributes and global appearance.
- Model and reverse-model of the link between surface 3D and appearance through photometric attributes


**Expected Results**

- Methods for appearance change (global, local and over time) detection and quantification using multiscale image based methods.
- Methods for local 3D reconstruction (roughness).
- Methods for change assessment (acquisition, modelling and rendering).


**Planned Secondments**

- WUT - Acquiring BRDF and study different methods.
- GDPB - Acquisition on wall-paintings.
- C2RMF - Co-validation of appearance change quantification perceptually and photometrically

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## ESR10 - MUNCH: Monitoring Munch's monumental Unvarnished oil paintings: exploring Novel change documentation methods and Cleaning techniques via Hyperspectral imaging



**Jan D. Cutajar**


Host Institution: UiO  
PhD Enrollment: UiO

**Main Supervisor**

- Tine Frøysaker (UiO)

**Co-Supervisor(s)**

- Jon Yngve Hardeberg (NTNU)
- Edith Joseph (HES SO)



**Objectives**

- Identify paints vulnerable to dirt accumulation and related cleaning methods, and of interest for hyperspectral imaging
- Develop representative paint mock-ups for documentation via hyperspectral imaging and cleaning tests
- Perform relevant accelerated aging and testing followed by documentation via hyperspectral imaging
- Investigate, evaluate, and document changes with support of two case-study paintings by Edvard Munch in the UiO Aula.


**Expected Results**

- Mock-up samples
- Hyperspectral documentation of Munch's Aula paintings and related mock-ups (and possible toolkit for implementation by conservators),
- Further investigation of possible cleaning methods for the unvarnished Aula paintings

**Planned Secondments**



- NTNU - Multi modal imaging for documentation.
- HES SO - Chemical analysis of CH samples.

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## ESR11 - Analysis and assessment of degradation of metal artworks

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**Silvia Russo**

**Host Institution:** HES SO  
**PhD Enrollment:** UNe

**Main Supervisor:**

- Edith Joseph (HES SO)

**Co-Supervisor(s):**

- Jean-Baptiste Thomas (NTNU)
- Laura Brambilla (HES SO)

**Objectives**

- Development of methodology based on multi-modal analyses for the assessment of the different factors in the formation of metal soaps.
- Evaluation of analytical protocol on mock-up samples presenting characteristic degradation features.
- Validation of the proposed multi-modal analyses methodology on real artworks.


**Expected Results**

- Mock-up samples simulating metal soaps degradation.
- Multi-modal imaging based protocol to evaluate and monitor the conservation state of poly chrome artworks and the early formation of metal soaps.

**Planned Secondments**


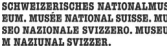
- NTNU - Digitization of poly chrome artworks, investigation of its limits and potentials.
- C2RMF - Development of degradation model of poly chrome artworks.
- CUT - Integration of characterization and visualization data for conservation documentation.

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## ESR12 - Analysis and monitoring of degradation of historic glasses

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**Deepshikha Sharma**

**Host Institution:** SNM  
**PhD Enrollment:** UNe

**Main Supervisor**

- Tiziana Lombardo (SNM)

**Co-Supervisor(s)**

- Edith Joseph (HES SO)
- Sony George (NTNU)

**Objectives**

- Definition of a multi-modal analytical approach to assess different degradation factors and forms.
- Selection of imaging techniques to document and monitor altered glasses.
- Development of methodology for characterizing different alteration forms and products using imaging and spectroscopy.
- Assisting glass restorer/conservator in the selection and evaluation of new cleaning procedures on mock-up samples


**Expected Results**

- Mock-up samples of degraded historical glasses and their artificial aging.
- Specific multi-modal protocol and of imaging techniques to document and monitor historical glasses degradation.


**Planned Secondments**

- NTNU - 3D visualization of degraded mock-up samples.
- C2RMF - Testing multi spectral imaging techniques on degraded mock-up samples.
- UBFC - Testing spectral-RTI system to detect appearance changes due to degradation mechanisms.

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## ESR13 - Low-budget portable device for technical imaging of cultural heritage artifacts


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**Alessandra Marrocchesi**

**Host Institution:** UvA  
**PhD Enrollment:** UvA

**Main Supervisor:**

- Robert G Erdmann (UvA)

**Co-Supervisor(s):**

- Christian Degriigny (HES SO)
- Martin Jürgens (RM)

**Objectives**

1. Development of a low-budget portable device for the technical imaging of different cultural heritage artifacts — ranging from paintings to reflective metallic objects — and the software for its control
2. Development of new machine learning algorithms for the monitoring, quantification and visualization of change
3. Imaging of selected artifacts. Three main case studies are considered: mummy portraits, works on paper and daguerreotypes.


**Expected Results**

1. Novel device for the technical imaging of cultural heritage artifacts
2. Novel software tools to detect and quantify object changes that are applicable to a wide range of case studies




**Planned Secondments**

1. HES SO - Spectral-RTI to detect surface changes during controlled electrolytic cleaning of silver tarnish.
2. NTNU - Digitization of daguerreotypes, investigation of its potentials and limits.
3. CUT - Integration of characterization and visualization data for surface change documentation.

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## ESR15 - Characterization of surface change of historical metals by imaging and computer vision

**Amalia Siatou**

**Host Institution:** HES SO  
**PhD Enrollment:** UBFC

**Main Supervisor(s):**

- Christian Degriigny (HES SO)

**Co-Supervisor(s):**

- Alamin Mansouri (UBFC)
- Laura Brambilla (HES SO)
- Gaëtan Le Goïc (UBFC)

**Objectives**

1. Detection, Characterization and monitoring of common corrosion phenomena
2. Use of imaging techniques: Selection of appropriate ones, testing of acquisition and processing protocols on artificially aged mock-up samples.
3. Application of selected imaging techniques on CH artifacts, followed by interpretation and evaluation.

**Expected Results**

1. Mock-up samples mimicking common corrosion phenomena
2. Protocols of acquisition and processing to characterize and monitor oxidized, patinated and varnished metal surfaces.
3. Validation of the protocols on real CH artefacts.

**Planned Secondments**

1. WUT - Multi modal analysis and visualization of real CH objects.
2. NTNU - Imaging modalities to monitor changes in CH artifact data acquired in different time periods.
3. UBFC - Testing spectral-RTI system to detect appearance changes.

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## Wrap-up

- The CHANGE Project makes a difference in the cultural heritage sector!
  - Cutting-edge research in the field of cultural heritage imaging
  - 14 Early Stage Researchers who are about to become **experienced researchers** with a unique interdisciplinary skill set that the cultural heritage sector needs
    - Different but compatible
    - «In the market now»
- Check out <https://change-itn.eu/> for more information
  - Papers, data, etc.
- Watch out for our **book**, to be published by Routledge in 2024
- **Don't forget computer science and imaging science when thinking about conservation science or heritage science**
- We are now open for new collaborations and projects in this field
  - Nationally and internationally
  - [jon.hardeberg@ntnu.no](mailto:jon.hardeberg@ntnu.no)

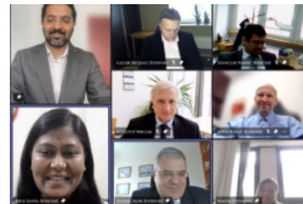
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Evdokia Saiti has successfully defended her thesis!



Yoko Arteaga has successfully defended her thesis!



Sunita Saha has successfully defended her thesis!



Amalia Siatou has successfully defended her thesis!

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