

Expansion and Refinement of EPRI Virtual Mockup Capabilities Update: 2025 NRC-EPRI TIE

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Outline

- EPRI Virtual and Synthetic Flaw software suite:
 - MVM0 "Modify Virtual Mockup Type Zero"
 MVM1 "Modify Virtual Mockup Type Zero"
 CVR "CIVA Reader"
 - **UVRW** "UltraVision Reader Writer"
- In this presentation:
 - Summary of recent improvements
 - Update on ongoing collaboration and industrial partnerships
 - New deliverable (November 2024)
 - Perspectives: 2025 and beyond



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Summary of Recent Improvements

MVM in conjunction with CIVA

Summary of Recent Improvements

- Concept and workflow presented in §3 of the 2023 TR*; however, further improvements made during 2024:
 - Multiple channels can be processed e.g., TFM with multiple modes
 - Scan/index axes can be manually exchanged
 - Overlays can be drawn in 2D and 3D for certain configurations: Plate, cylinder, certain types of weld and 2D CAD imports
 - Blending parameters now contained within the configuration file (improves auditability)
- Case study: Synthetic flaw insertion for AHC data file
 - In 2024, further data files with synthetic insertions were generated



BUILD MOCKUP: INSERT SIMULATED DATA TO DIFFERENT CHANNELS



* Nondestructive Evaluation: Virtual and Synthetic Mockups—Electronic Implantation of Virtual and Synthetic Flaw Responses into Previously Recorded Data. EPRI, Palo Alto, CA: 2023. 3002026416 (publicly available)

Mockup Cleaner

Summary of Recent Improvements

- Concept:
 - Prominent reflections that are limited along the rotation axis are suppressed closer to the level of the noise floor
 - Background noise left unaltered
 - Features that are consistent along the length of the rotation axis should be left unaltered
- The concept was illustrated in §2.3 of the 2023 TR*; however, further improvements made during 2024:
 - Operation and associated threshold now integrated into the configuration file (improves auditability)
 - User specifies which channel and beam is to be cleaned
 - Region can be drawn to clean a specified part of the beam



* Nondestructive Evaluation: Virtual and Synthetic Mockups—Electronic Implantation of Virtual and Synthetic Flaw Responses into Previously Recorded Data. EPRI, Palo Alto, CA: 2023. 3002026416 (publicly available)

"Missing" Scan Lines

Summary of Recent Improvements

- "Missing" scan lines can be removed using the UVRW tool function "Fill Missing"
- Specified can lines can be rendered "missing" using the UVRW tool function "Insert Missing" which reads a configuration file





Files Containing TFM Channels

Summary of Recent Improvements

- MVM0 can modify data files containing TFM acquisitions
 - Requires "linear" option enabled to store TFM "beams" in the same channel
 - If not checked, MVM1 can be used to visualise the TFM but not yet to modify; simple workarounds can be implemented if necessary
- Configuration process is agnostic of acquisition type





Update on Industrial Partnerships

Overview

Update on Industrial Partnerships

- Five external collaborators past and present are involved in the EPRI virtual flaw and synthetic flaw project
 - EPRI project team provides worked examples, guidance, software improvements upon request

- Long-term aims:
 - Develop virtual flaw and synthetic flaw technology for the benefit of the NDE industry
 - Provide EPRI members and collaborators the ability to generate their own virtual mockups
 - Qualification of virtual flaw and synthetic flaw technology for all training, educational and demonstration purposes







Collaborative Activity with ÚJV Řež, a. s.

Update on Industrial Partnerships

- Activities completed in **2024**:
 - Versions of software callable from command line compiled and provided with documentation and worked example of batch script
 - Allows batch running
 - Application: Image augmentation for deep learning; development tool for random creation of virtual flaws
 - At this collaborator's request, the following capabilities were added to the software suite:
 - Improved workflow to import simulated CIVA data
 - Controlled ability to insert and remove "missing" scan lines from data files by configuration file
 - File modification not directly involving the data e.g., adjusting a scan range

- Perspectives for 2025:
 - Some visualisation issues to be fixed
 - Ensure compatibility with Windows
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 - Aim for full regulatory acceptance for this technology in personnel qualification

EPC

December 2024: ÚJV delivered virtual mockups to ČEZ for personnel qualification

Collaborative Activity with Nucleoélectrica Argentina s. a.

Update on Industrial Partnerships

- Activities completed in **2024**:
 - Manufacture of training sets for thermal sleeve inspection in conical DMW configuration
 - Manufacture of training sets for AQB (IRAM-MN-ISO 9712 training course)
 - Trained a NDE UT data analyst in a first-of-a-kind
 DMW inspection using virtual flaw technology
 - Implemented procedure: PDI EPRI-ENC-DMW-PA-1 at Atucha NPP
- WIP: Initiated a study on synthetic flaw generation (CIVA) in quantitative comparison against virtual flaws with EPRI collaboration

- Perspectives for **2025**:
 - Ability to export modified data to the OmniScan (X3+) format
 - Obtain approval for use in operator certification
 - UT Phased Array; IRAM-MN-ISO 9712 "Non-destructive testing; Qualification and certification of personnel"

EPCI

 Collaboration with EPRI to assemble a library or catalogue of standard and basic flaws

Training data sets built for AQB governing qualification and certification of personnel

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Collaborative Activity with PNNL

Update on Industrial Partnerships

- WIP for 2024-2025 and beyond:
 - Technical assessment of digitally-modified and simulated flaw technology
 - Collaboration with EPRI project team:
 - Investigate appropriate use and limitation boundaries for the use of virtual flaw for personnel qualification
 - Consider requirements for incorporation into ASME code
 - Understanding of regulatory framework with NRC needed for such incorporation

2024 Deliverable

- Technical brief "EPRI Virtual Mockup and Synthetic Mockup Suite of Software Tools" November 2024 publicly available
 - In-depth overview of four tools in the suite
 - Worked examples of selected newer capabilities
 - Automated removal of indications in an acquisition but retaining geometric features e.g., weld root
 - Demonstrated manipulation of missing scan lines for sectorial data
 - Insertion and blending of CIVA simulated data into acquired data file*

EPRI	
TECHNICAL BRIEF	
EPRI Virtual Mockup and Synthetic Mockup Suite of Software Tools	

Research Question

How and where can the EPRI suite of tools for the electronic implantation of virtual and synthetic data support the mondestructive evaluation (MDD) industry to address contemporary challenges involving training and personnel qualification? This report provides a summary overview of said suite of tools, their capabilities, and commentary on th perspectives and feedback of external project collaborators.

Key Takeaway

Industrial NDE has made use of electronic manipulation of acquired data sets [1, 2] to generate variation data sets (generally called virtual data sets or synthetic data sets, depending on the data source) to realize significant savings of both time and money, as compared to having to build a corresponding physical mockup and to scan it. The ability to rapidly and efficiently generate a library of virtual data sets for minimal costs; therefore, desizable.

For the past several years, EPRI has compiled and refined various standaione software tools (3, 4). The EPRI staff has distributed them to interested parties outside of EPRI, providing them with the ability to generate their own virtual data sets in-house, with guidance and support from the EPRI project team. Readers of this report with potential interest in collaboration are fixed to constant the project team for further information.

Key Points

- There are currently four tools in the suite—two of which concern generation of virtual mockups; the third is for synthetic mockup generation, and the fourth is for miscellaneous processes of data manipulation not covered by the first three.
- These tools support manipulation for acquired data files in the .UVData or .BeamData formats; in addition, reading of
 simulated CIVA [5] data is supported for synthetic data.
- Future collaboration will extend capability to other file types as required and when necessary.
- External collaborators show great interest in using these tools for generating large data sets for a variety of reasons, not limited to data augmentation for machine learning (B), training and education of ultrazonic testing (UT) practitioners, and generation of data sets for personnel qualification.

Ebbi

*Appears in other recent publications, also publicly available:

- Nondestructive Evaluation: Development of a Versatile and Efficient Virtual Mockup Modification System. EPRI, Palo Alto, CA: **2022**. 3002023719
- Nondestructive Evaluation: Virtual and Synthetic Mockups—Electronic Implantation of Virtual and Synthetic Flaw Responses into Previously Recorded Data. EPRI, Palo Alto, CA: 2023. 3002026416

Perspectives: 2025 and beyond

- Encoded training and qualification sets (2025+):
 - Set of unflawed open samples procured (SMW and DMW of various thicknesses)
 - Used in conjunction with current inventory of PD samples; the number of virtual mockups that can be generated is multiples of the number of physical mockups
 - Can be used as training data for encoded analysis or added to UT simulator to increase population of available hands-on training data
 - Looking into potential future use for UT in lieu of RT qualification and training datasets
- Advanced methods involving synthetic flaw and data generation (2026+):
 - Virtual flaws to be complemented or supplemented using synthetic where virtual flaws are deficient or inadequate
 - Assemble library of known responses from given search units
 - Refine modelling techniques for flaw simulation



Technical report planned for Q4 of 2025; likely to be made publicly available





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