# FMC User Group

## Online meeting (MS Teams)

## 12 October 2023, 4.00-5.00PM

# Agenda

### Present

*Online:* Tom Bertenshaw (TB), Shiva Bhat, George Connolly, Larissa Fradkin (LF), Yann Gelebart, Katherine Kirk, Nans Laroche, Benoit Lepage, Dave Lines (DL), Terrill Massey , Renato Nogueira, Andrew Ouellete, Parhaam Parikhaah, Abhishek Saini, Andreas Schumm (AS), Jim Skelton, Sumana Sumana, Jonathan Taylor, Ray Ten Grotenhuis, Wilson Vesga, Paul Wilcox (PW).

### Minutes of last meeting

Summary and status of actions

- PW to update website to reflect discussions on group's objectives. **DONE**.
- PW to review ECUF format, compare with MFCM, and discuss with EPRI if there is a common way forward. **ONGOING** (through EDF activity).
- All to continue to suggest speakers / topics. **ONGOING**.
- PW to contact BAE Systems about possible talk on qualification of inspection using FMC/TFM. **DONE** (it turned out that inspection was ultimately achieved with regular PA techniques)
- PW to organise next meeting. **DONE**.

### Chair's update

PW continues to attend *NDE File Formats Group* (a sub-group of the *Sharable NDE Models* group, both led by Prof Steve Holland, Iowa State University; Dr Dave Forsyth, TRI Austin), which has ambitious aim is to define a self-documenting, hyper-consistent structure for any type of NDE data using HDF5 as the container. The idea is that user communities (such as the FMC User Group) for different modalities / applications define their own sub-classes within this framework. There has now been a gradual convergence on the philosophy and general data model. Next stage is to develop detailed requirements for different modalities. Ultrasonic array data is acknowledged as being likely to be the most challenging.

PW had attended the *ASNT Research Symposium* (Columbus, Ohio, June 2023) and presented in the *Open Source Model Development* session on *Progress and Challenges in Defining an Open Format for Full Matrix Capture Ultrasonic Array Data*. The talk contained reflections on technical, non-technical, and philosophical issues around developing an open format.

**ACTION: PW to make presentation available on FMC User webpage.**

PW reported that a Python library for the MFMC format was in the advanced stages of development (current version available for testing at https://github.com/paulwilcox1971/MFMCPy) and contains:

- Functions to write probe data, focal law data, sequence data, and append frames to a sequence.
- Functions to read probe data, focal law data, sequency data, and frames from a sequence.
- A function the check an MFMC file for compliance with the MFMC specification, the checking processes includes:

    - Checking all mandatory data is present;
    - Checking that mandatory data, and optional data if present, conforms to the specification requirements in terms of type and size;
    - Checking that cross-referenced objects (focal laws and probes) exist and that cross-referenced entries within objects (e.g. probe elements) are within data bounds;
    - Checking that data sizes are self-consistent.
- Some preliminary "helper" functions are provided that offer a translation between engineering parameters (e.g. pitch, element size, and number of elements for a 1D linear array probe) and MFMC data, and *vice versa*.

**ACTION: PW to complete Python library and produce release with documentation and examples.**

Next meeting of the FMC User Group will be in early part of new year, possibly another hybrid event as part of the RCNDE Technology Transfer day.

**ACTION: PW to arrange next meeting.**

## Presentation from Andreas Schumm (EDF)

AS summarised interactions regarding file formats that he had had over the summer:

- 18/07: First of three exchanges with Evident (after ECNDT Lisbon)
- 09/08: Presentation of a detailed comparison of ECUF and MFMC at *EPRI Working Group*
- 16/08: Same presentation to *Shareable models group* (Iowa State University initiative)
- 29/08: Presentation on the format landscape at *EPRI Research Integration Committee*, sparked idea to merge both groups
- 11/10: *Shareable models group*
- 12/10: *FMC User Group* (this meeting)
- 18/10: Invitation to present on the format landscape at *European Network for Inspection Qualification (ENIQ)* meeting

EDF are compiling a detailed list of desired functionality and noting which are present already in the MFMC and ECUF formats, with intention of providing a prioritised list of things to implement in future – ideally in a single format. He made the point that any product should have "conceptual integrity" in that all features adhered to a common philosophy. The MFMC has such a philosophy (whether it is the correct one for all users is subject to debate), which AS summarised as:

- stay focused – do not try to solve all problems at once; focus on one technique (UT) with well-defined use cases (imaging of raw acquisition data).
- be brief – require only the minimum amount of compulsory engineering data; everything not strictly needed for the targeted use cases is optional or custom.
- be non-ambiguous – avoid redundancy; whenever possible, rely on implicit data (e.g. derive probe pitch from element positions, derive number of elements from number of element positions in file).

With such a philosophy, other decisions follow naturally – a whitepaper might therefore be helpful.

DL commented that there were potential issues with numerical precision when trying to recover the exact value of implicit data.

AS also reported on work undertaken in the French working group on defining a UT "dictionary" of minimum requirements based on MFMC and ECUF, for UT array data storage independent of file format.

**ACTION: AS to disseminate dictionary to this group when complete.**

**ACTION: PW to produce whitepaper on philosophy of MFMC format for discussion.**

## Presentation from Tom Bertenshaw (GKN)

TB described challenge where aim is a post-build (and ideally pre-machining) inspection of Additively Manufactured (AM) titanium components. Initial work using an immersion FMC/TFM-based inspection showed promising results with small pore-like targets (spherical bottomed holes, ∅0.8 mm and ∅1.2 mm) could be detected at depths of up to 80 mm when inspected from the smooth baseplate side of the component. Future challenges include using adaptive TFM to deal with uncertainty in exact post-build shape of component, and inspection through the rough, post-build surfaces on the other side of the component.

## Any other business

PW repeated the request for contributions to future meetings, e.g. on practical application of FMC-based inspections, inspection qualification, relevant research.

**ACTION: contact PW if you have something to present a future meeting.**

LF at Sound Mathematics requested potential end-user partners to join an InnovateUK bid into the BridgeAI programme. Details are overleaf and anyone interested should contact LF directly (l.fradkin@soundmathematics.com).

**ACTION: Any interested parties to contact LF.**

*Brief description of technology*

There are two applications designed to use data collected by PAUTs (Phased Array Ultrasonic probes) and apply Explainable AI (Decision Trees) to generate NDT (Non-Destructive Testing) reports:

- AutoNDE characterises possible fatigue, stress-corrosion and rough cracks.
- FFS_ASSESS uses industrial standards to assess fitness for service of inspected structures.

*Detailed description of technology*

NDT (Non-Destructive Testing) is a technique used by many industries to evaluate damage to components and structure if any. Data necessary for such damage are more and more often collected using PAUTs (Phased Arrays of Ultrasonic Transducers). Some NDT inspections, which utilize PAUTs are already automated but interpretation of data they collect is not. Automation of data interpretation is desirable, because industry anticipates a severe shortage of suitably qualified and experienced personnel and because there is a pressure for both speeding the NDT inspections and increasing their reliability. We have developed two applications capable of using PAUT data to create two-dimensional images of inspected structures and interpret them to generate NDT inspection reports: AutoNDE has been trained to characterize fatigue, stress-corrosion and rough cracks, while FFS_ASSESS can create corrosion maps, analyze them and apply ASME or BS/EU standards to assess fitness for service of various pressure vessels. Both codes are meant to be used by PAUT certified inspectors to increase production speed and accuracy of their inspection reports, thus increasing safety and operational expenditure across a wide variety of dual-use industry and government domains. They can be adjusted to interpret similar images obtained by any other means.

*Value proposition*

Increased speed: Our software can automate the interpretation of PAUT data (or images of damage created by any other means), which can significantly reduce the time required for generating NDT inspection reports.
Improved accuracy: Our software is trained to characterize fatigue, stress-corrosion, and rough cracks and assess corrosion maps. The required processes are often to elaborate for human inspectors to carry out in full.
Reduced costs: Our software can help to reduce the cost of NDT inspections by reducing the need for manual data interpretation and report generation.
Increased safety: Our software can help to improve safety by characterizing defects or corrosion that could pose a risk to personnel or the public. It can help to ensure that damage, which could lead to catastrophic failures, is not missed.

*Any external funding to date:*

InnovateUK Grants:

- 2011 “Automated ultrasonic NDE”, £150,000
- 2014–2015 “Semi-Automated Crack Characterisation”, £80,739
- 2017-2019 “AI for Energy Security”, £69,843
- 2019-2021 “CHIMERA”, £155,435
- 2021-2022 “CHIMERA 2 ”, £ 25,000.
- 2020-2022 “Automon”, InnovateUK and CNRC NRC, £ 50,322
- 2022 - 2024 Smart Grant, “Explainable AI for Industrial Ultrasonics”, £137,538