

Automated Pressure Tube Defect Analysis

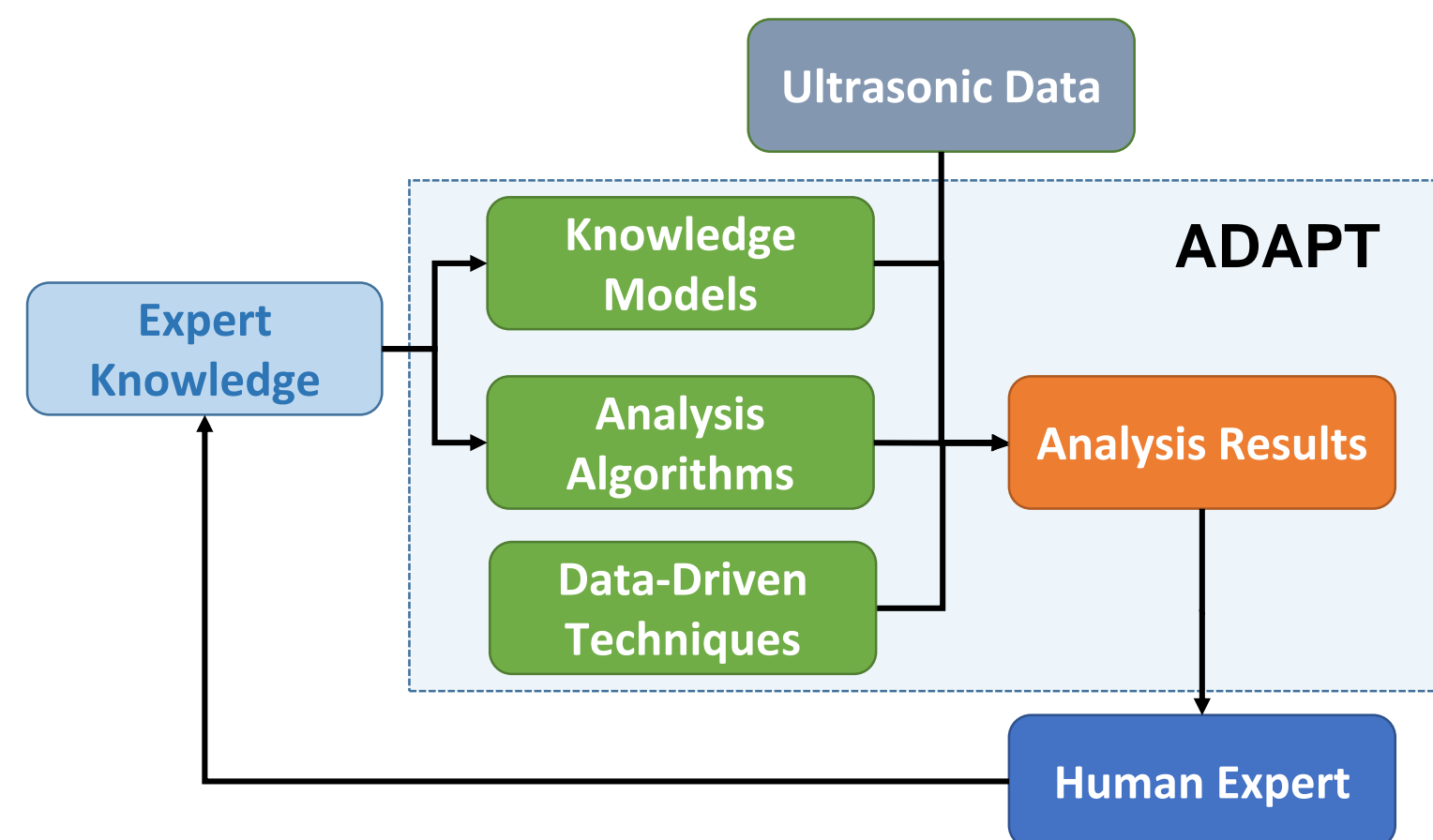
Panagiotis Zacharis, Graeme West, Christopher Wallace, Gordon Dobie, Anthony Gachagan

Department of Electrical and Electronic Engineering, University of Strathclyde, Glasgow

Email : panagiotis.zacharis@strath.ac.uk

Overview

- ❖ The Automated Data Analysis of Pressure Tubes (ADAPT) software has been developed to provide decision support to analysts interpreting ultrasonic inspection data
- ❖ The knowledge based system incorporates human expertise and has undergone testing at Strathclyde and at Bruce Power
- ❖ Data-driven techniques enable the automation of more subjective tasks

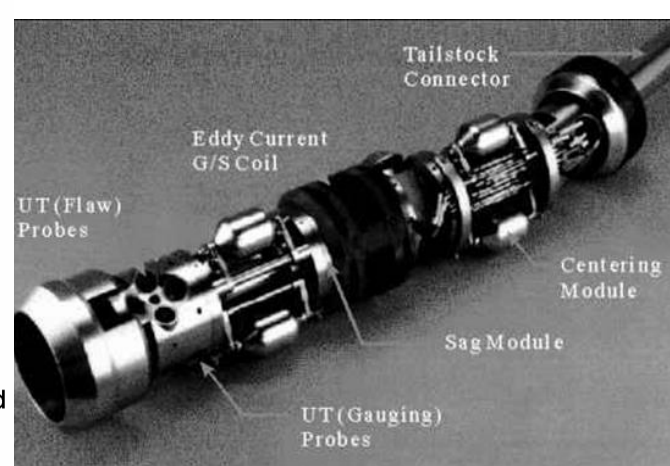
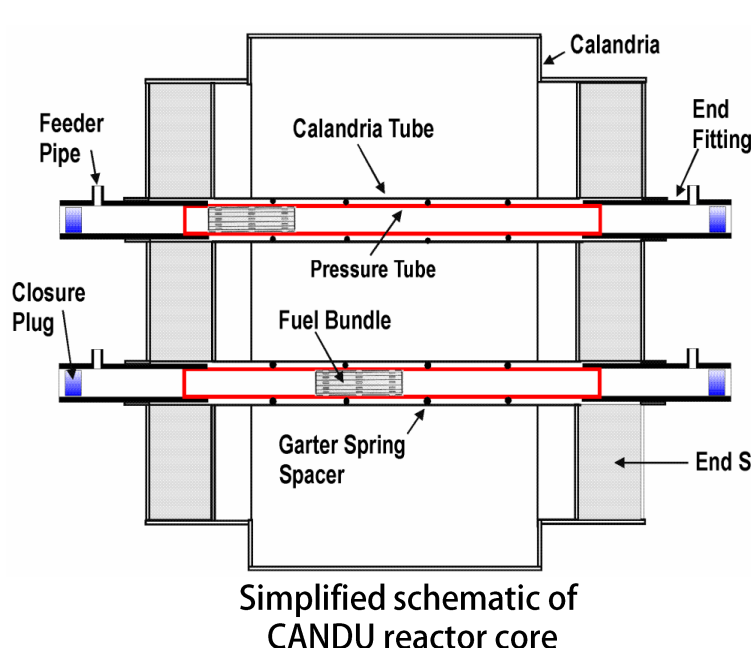


The Automated Data Analysis of Pressure Tubes (ADAPT) software tool

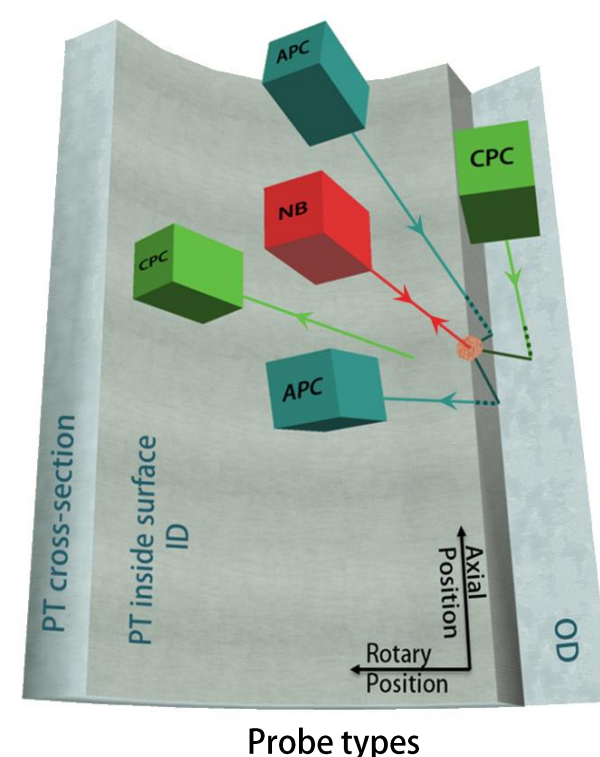
- ❖ The software identifies features and calculates parameters of the data, mirroring the existing analysis process to provide decision support
- ❖ Recent testing has demonstrated performance comparable to that of a human analyst in a fraction of the time currently required
- ❖ Side-by-side sessions with analysts highlighted key areas for improvement related to “edge cases” and large-scale analysis

CANDU Pressure Tubes - Inspection

- ❖ Pressure tubes are critical components of CANDU reactors as they contain the fuel bundles and the pressurised coolant (D_2O)
- ❖ Delayed Hydride Cracking at areas of high tensile stresses is a potential failure mechanism for pressure tubes
- ❖ During shutdown outages, a subset (normally 10-20) of pressure tubes is selected for inspection



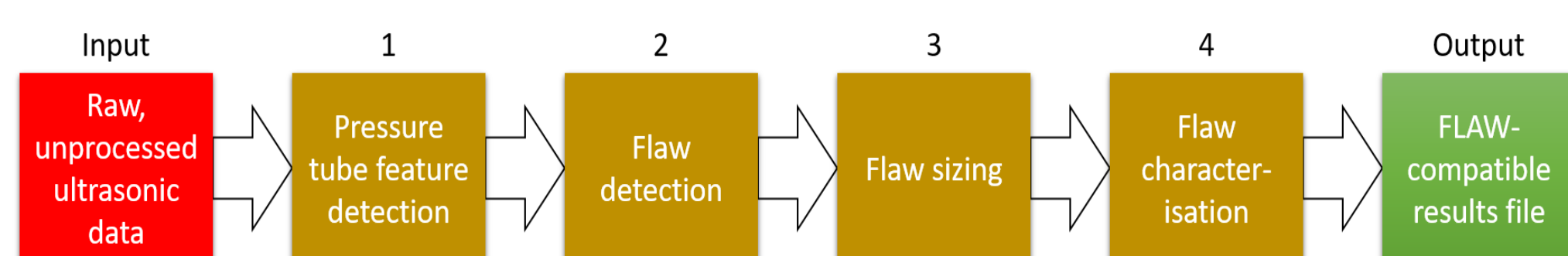
Inspection tool (CIGAR)



Probe types

Knowledge-Based Models

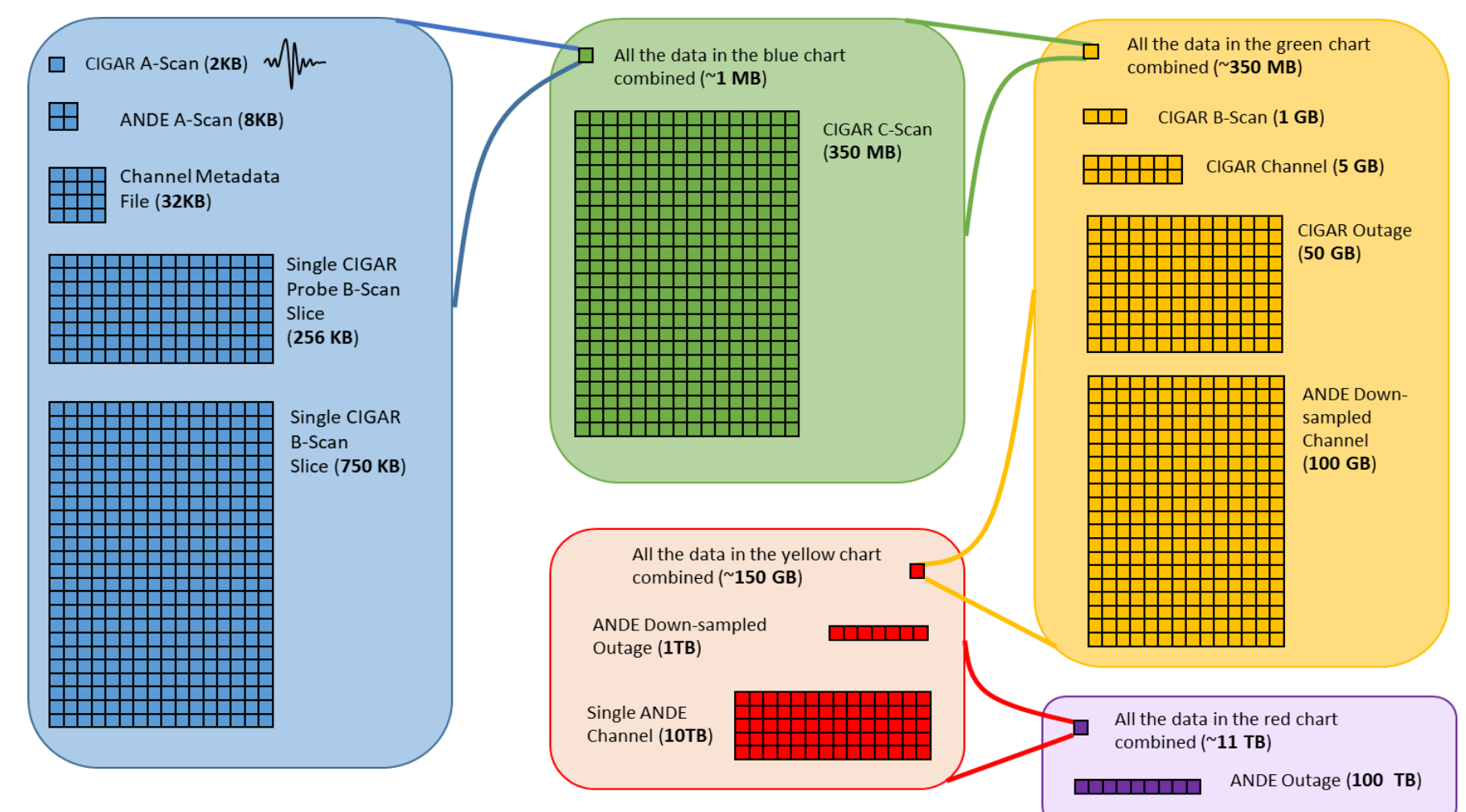
- ❖ The system provides a knowledge-based end-to-end approach to processing the data
- ❖ Formalisation of both the domain knowledge and the problem solving strategy, enabling their representation and incorporation into a system that emulates the decision making process of an expert
- ❖ Decisions at each stage of the process are auditable and understandable by all involved in the process



ADAPT: A high-level flowchart of the major modules comprising the automated analysis process

Data Challenges

- ❖ The use of more advanced ultrasonic inspection equipment has improved efficiency and resolution of inspections
- ❖ This is introducing significantly higher requirements for data processing and analysis
- ❖ The current **ANDE** tool records approximately 2000 times more data for the same channel than the previous **CIGAR** tool captured

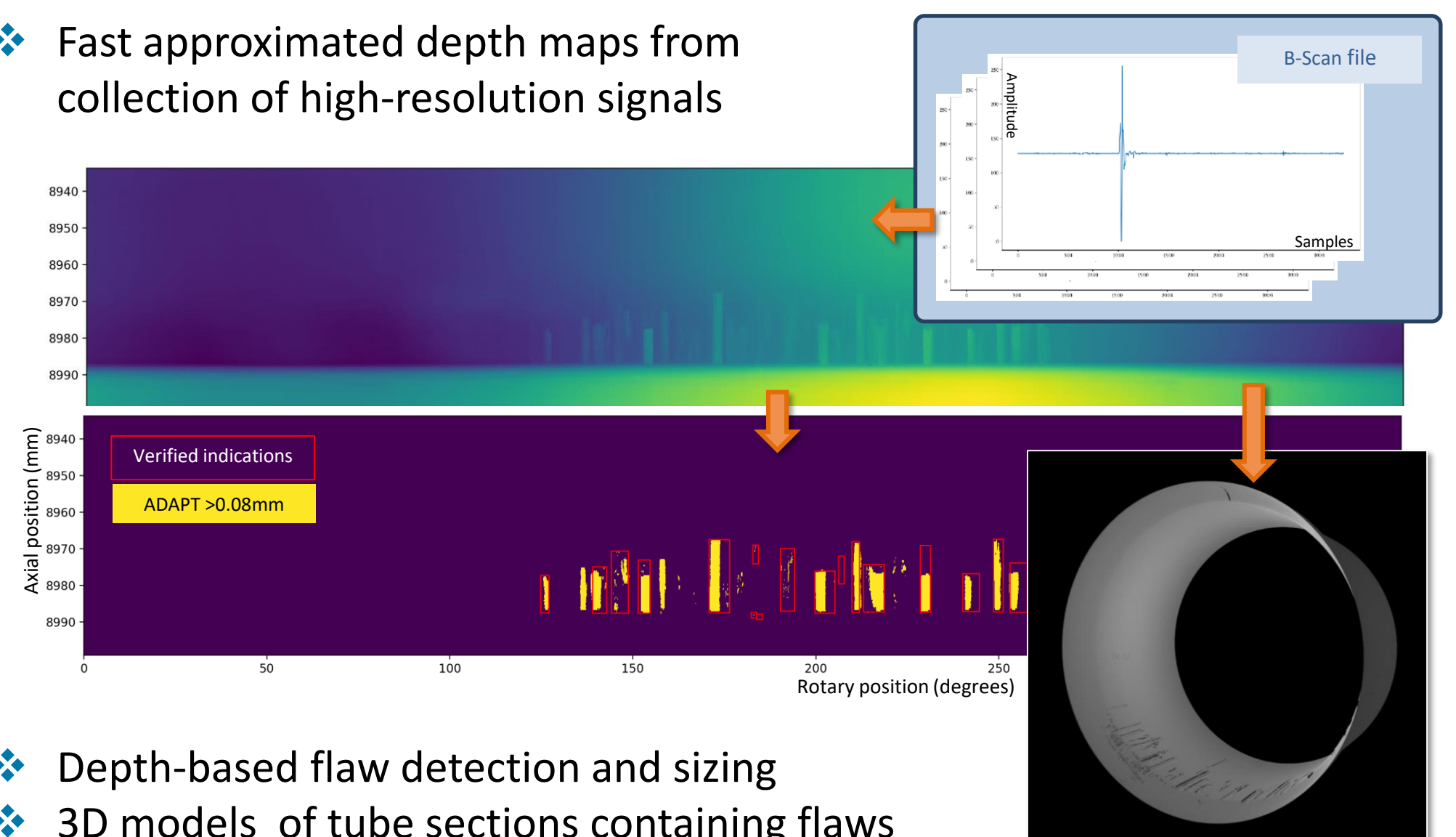


Illustrative sizes of pressure tube ultrasonic inspection datasets

- ❖ Current analysis procedures utilise down-sampled ANDE data, for which compatibility has recently been added to ADAPT
- ❖ Preliminary work is ongoing at Strathclyde to enable analysis of full ANDE datasets, identifying scalable and efficient analysis technologies

Data-Driven Techniques and Visualisation

- ❖ Fast approximated depth maps from collection of high-resolution signals



- ❖ Depth-based flaw detection and sizing
- ❖ 3D models of tube sections containing flaws

Results

- ❖ Applied to inspection set containing ANDE data from 12 pressure tubes
- ❖ **Detection rates:**
- ❖ **Location and sizing:**

- All flaws recorded:
408 out of 443: **92%**
- Flaws with depth > 0.10mm:
237 out of 247: **96%**

Note:
Minimum depth of dispositionable flaws:
0.15mm

