OAK RIDGE National Laboratory

High Fidelity Sensing & Machine Learning Inside the Control Loop

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Advanced Reactor Systems

ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Hi-Fi Sensing and ML in the Loop (Example: Tesla Autopilot)

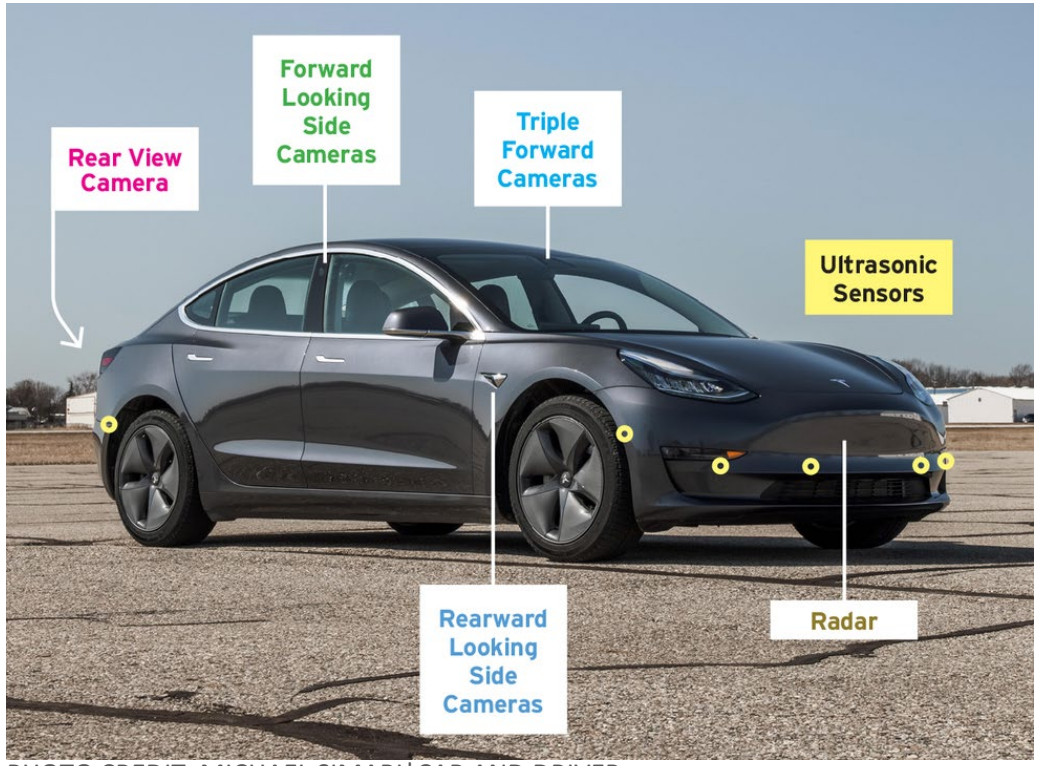
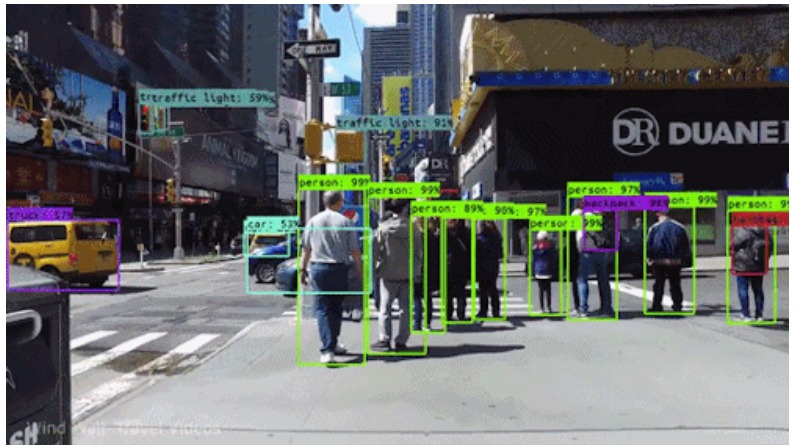
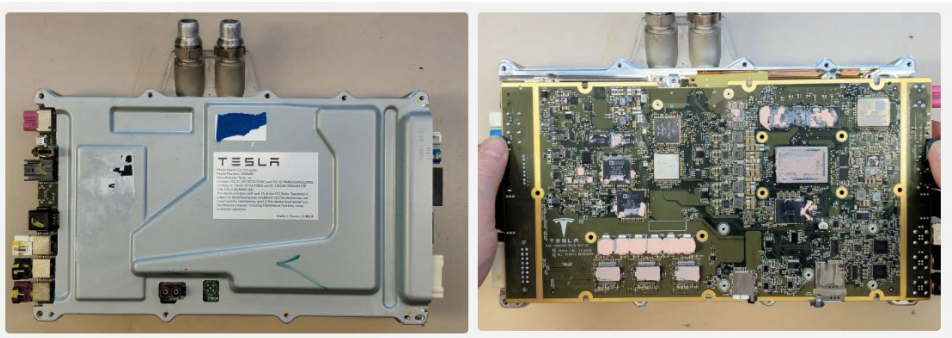


PHOTO CREDIT: MICHAEL SIMARI|CAR AND DRIVER

- 750MB per second of mixed data (per car)
- Edge compression (compressed sensing) and data processing with GPU
- Aggregated and sent to cloud for ML
- Deployed to car as fleet automation
- Always learning



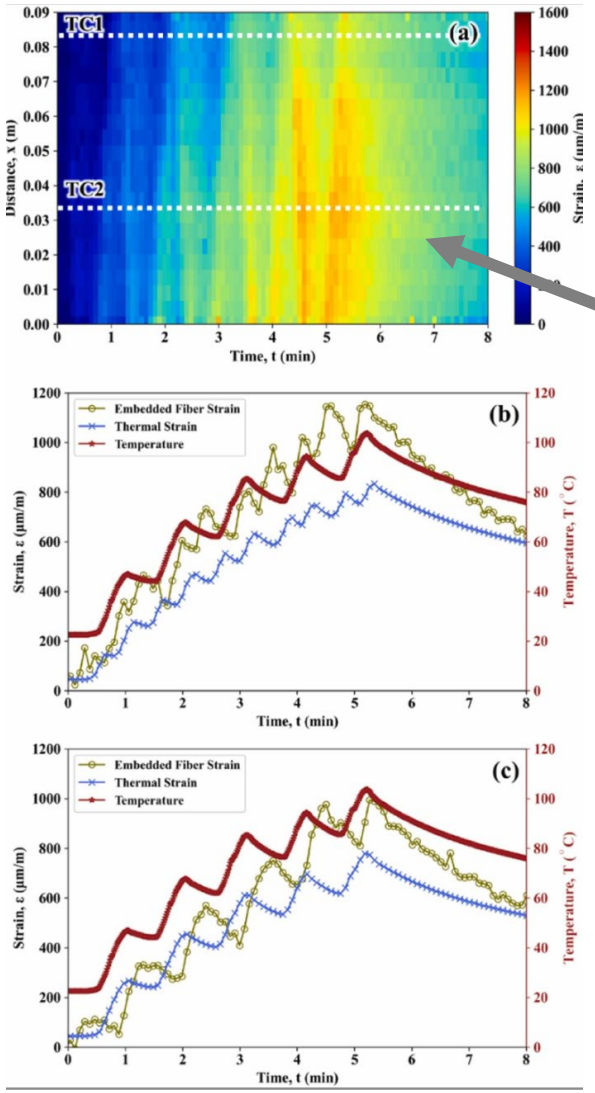


Tesla Car Computer, Source: Ingineerix

AMD Ryzen Embedded			
VideoCardz	V1000	V2000	V3000
Core Architecture	14nm Zen/12nm Zen+	7nm Zen2	6nm Zen3
Maximum Configuration	4C/8T	8C/16T	8C/16T
Maximum GPU Cores	11 CUs (GCN5/Vega)	8 CUs (GCN5/Vega)	12 CUs (RDNA2)
PCI Express Support	16x PCIe 3.0	20x PCIe 3.0	20x PCIe 4.0
Memory Support	Dual DDR4-3200/2400 ECC	Dual DDR4-3200 ECC	Dual DDR5-4800 ECC

https://videocardz.com/newz/tesla-car-computer-features-zen-ryzen-embedded-apu-and-discrete-navi-23-gpu

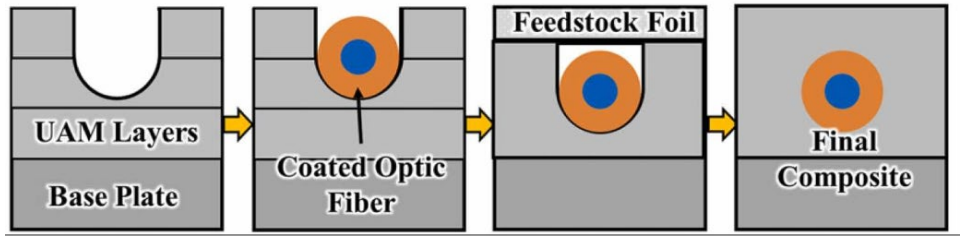
Hi-Fi Sensing for Advanced Nuclear Application



Large spatio-temporal data sets

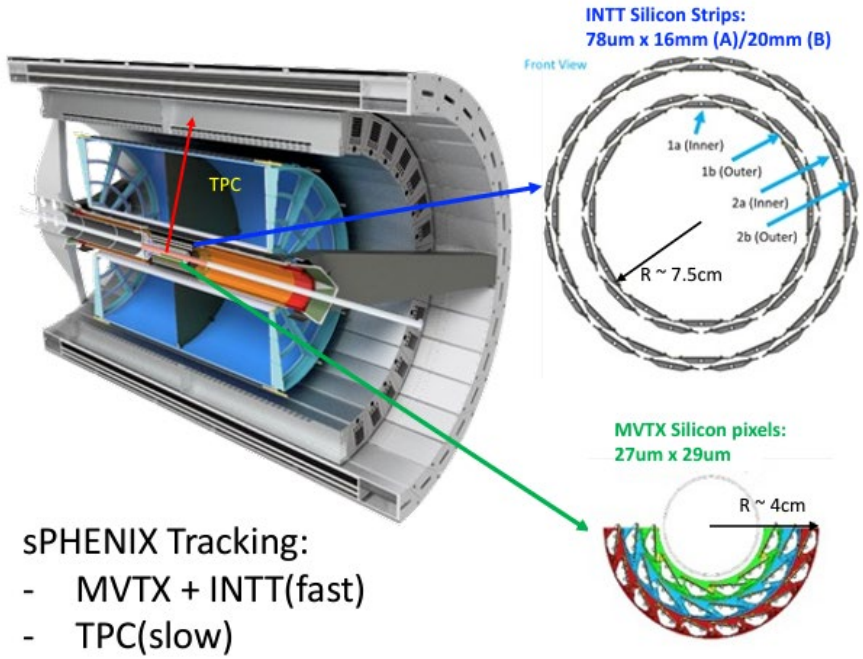
- Research already underway
- Nuclear and radiation detectors with similar function to image and video
- Advanced distributed sensing with fiber optic and acoustics
- Embedded sensors

The ability to measure distributed values generates large spatio-temporal data sets… thus creating new controls opportunities



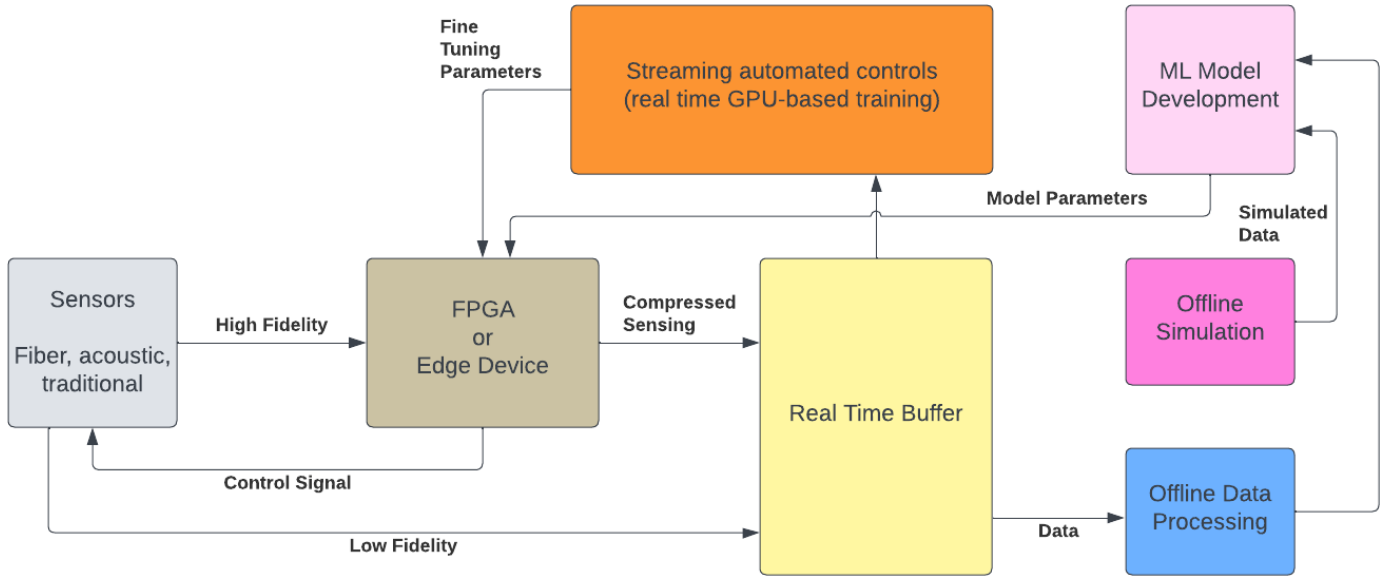
HOLDEN, SWEENEY, PETRIE (2022)
HTTPS://DOI-ORG.ORNL.IDM.OCLC.ORG/10.1016/J.ADDMA.2022.102681

Machine Learning at the Edge for Advanced Nuclear Application



LIU, MING XIONG (2022) INTELLIGENT EXPERIMENT THROUGH REAL-TIME AI: FAST DATA PROCESSING AND AUTONOMOUS DETECTOR CONTROL FOR SPHENIX AND FUTURE EIC DETECTORS

- Research also underway in science community
- ML/sensing integration being deployed in Nuclear Science systems (like SNS and sPHENIX etc)
- Requires a mixture of edge ML for compressed sensing and offline ML for fleet level broadcasting

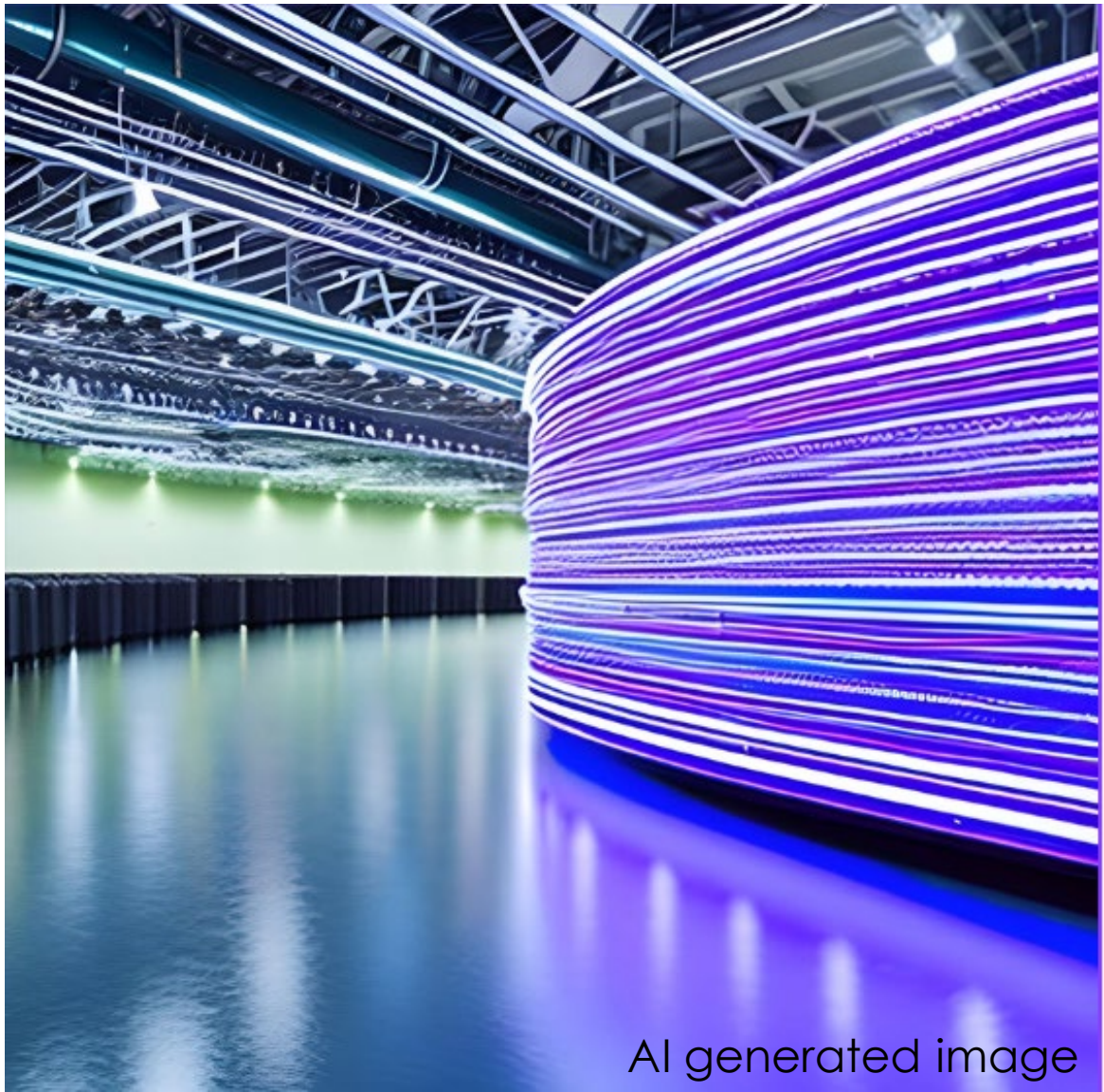


A vision of the future: a digital nervous system

- Like humans: seeing, touching, tasting, hearing, smelling…***the state of your plant processes***
- High fidelity data, but not all data is of value
- Need to discard superfluous information and compress sensing (compressed sensing w/ML)
- Need to research and solve the lack of rare events issues, this can only be done with a combination of data collection and traditional physics-based modeling (Digital Twin)
- Integrating it into the control system

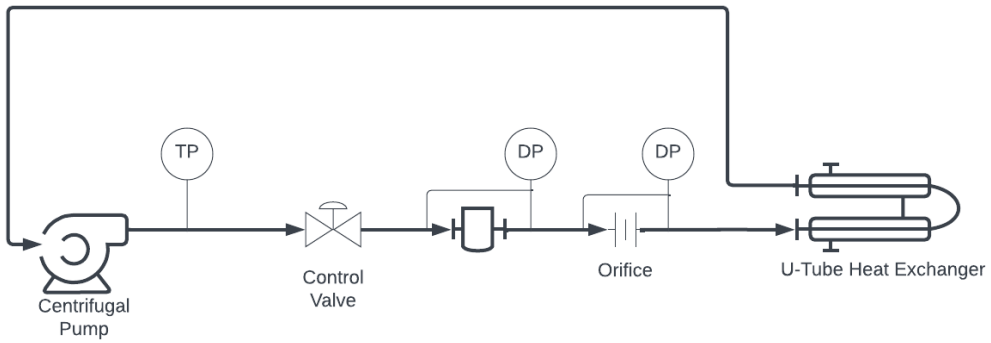
Professional *listening* for "groaning" of bad coolant pump and *smelling* for anti-freeze leaks

https://autorestorer.com/articles/diagnose_replace_a_faulty_water_pump_pt1-1831



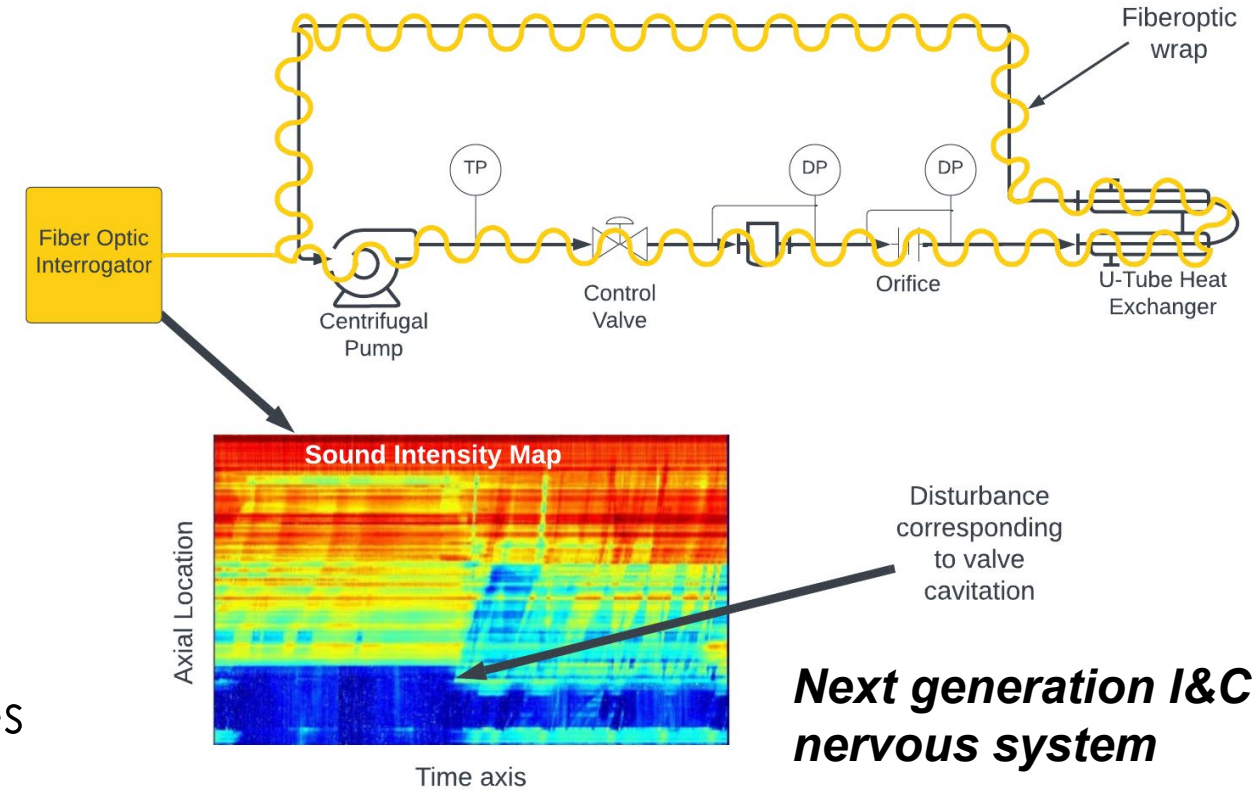
AI generated image

A vision of the future: a digital nervous system



Traditional I&C on flow loop

- Distributed acoustic sensing (DAS) with fiber optics allows the I&C system to *listen* to the flow loop and generate an entire new spectrum of actionable data and information



Next generation I&C nervous system

- Distributed temperature
  - Distributed strain
    - Distributed compositional analysis,
      - Distributed moisture analysis ….

there are many new opportunities

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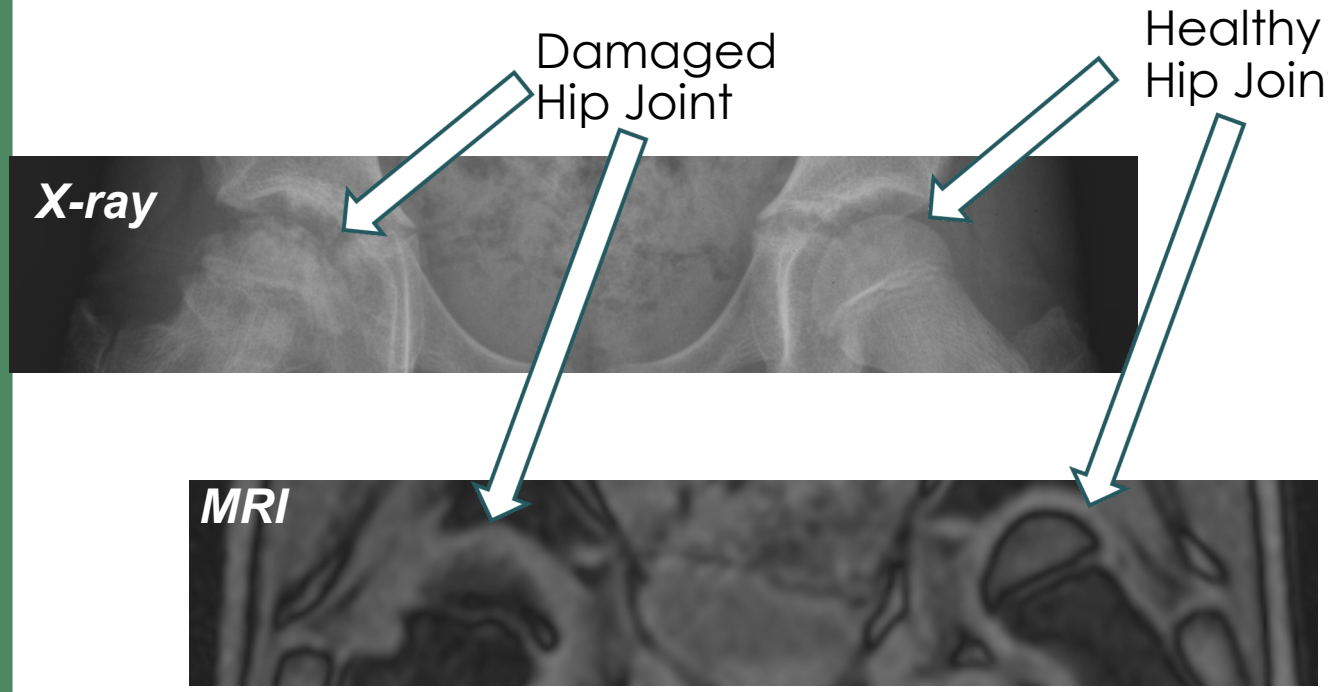
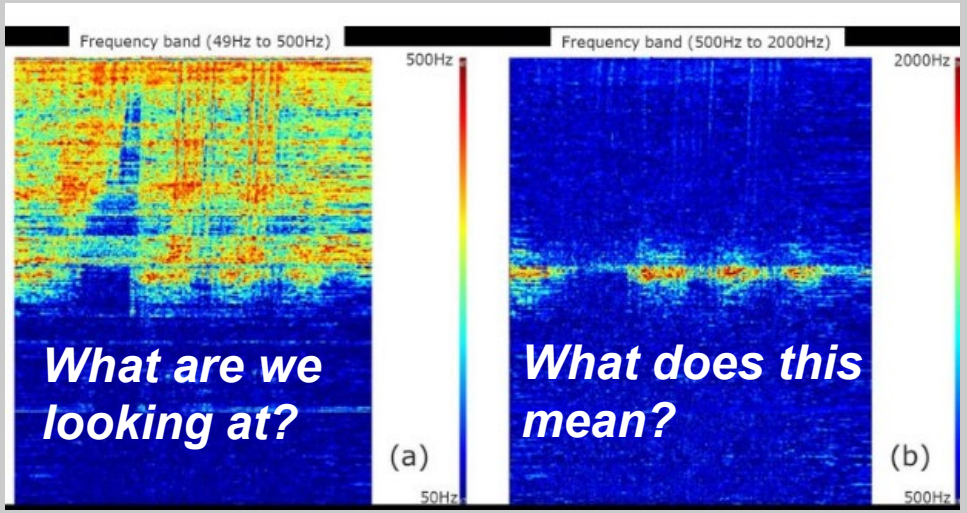
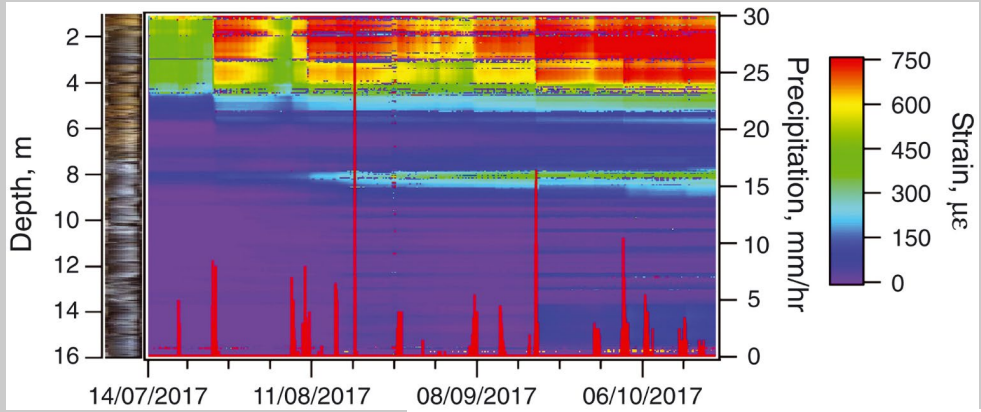
Where we are: an analogy

- Distributed sensing is in the same spot that radiology was decades ago.
- There is a need to develop ***diagnostic*** interpretations of the data

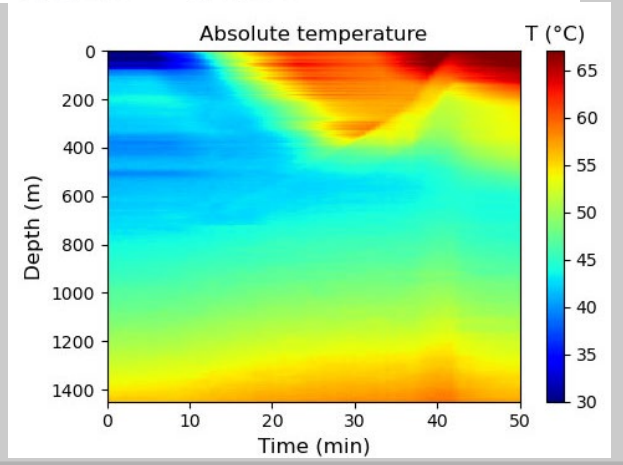


- Radiology is now being automated
- AI/ML used to characterize cancer or identify other diseases from imaging data



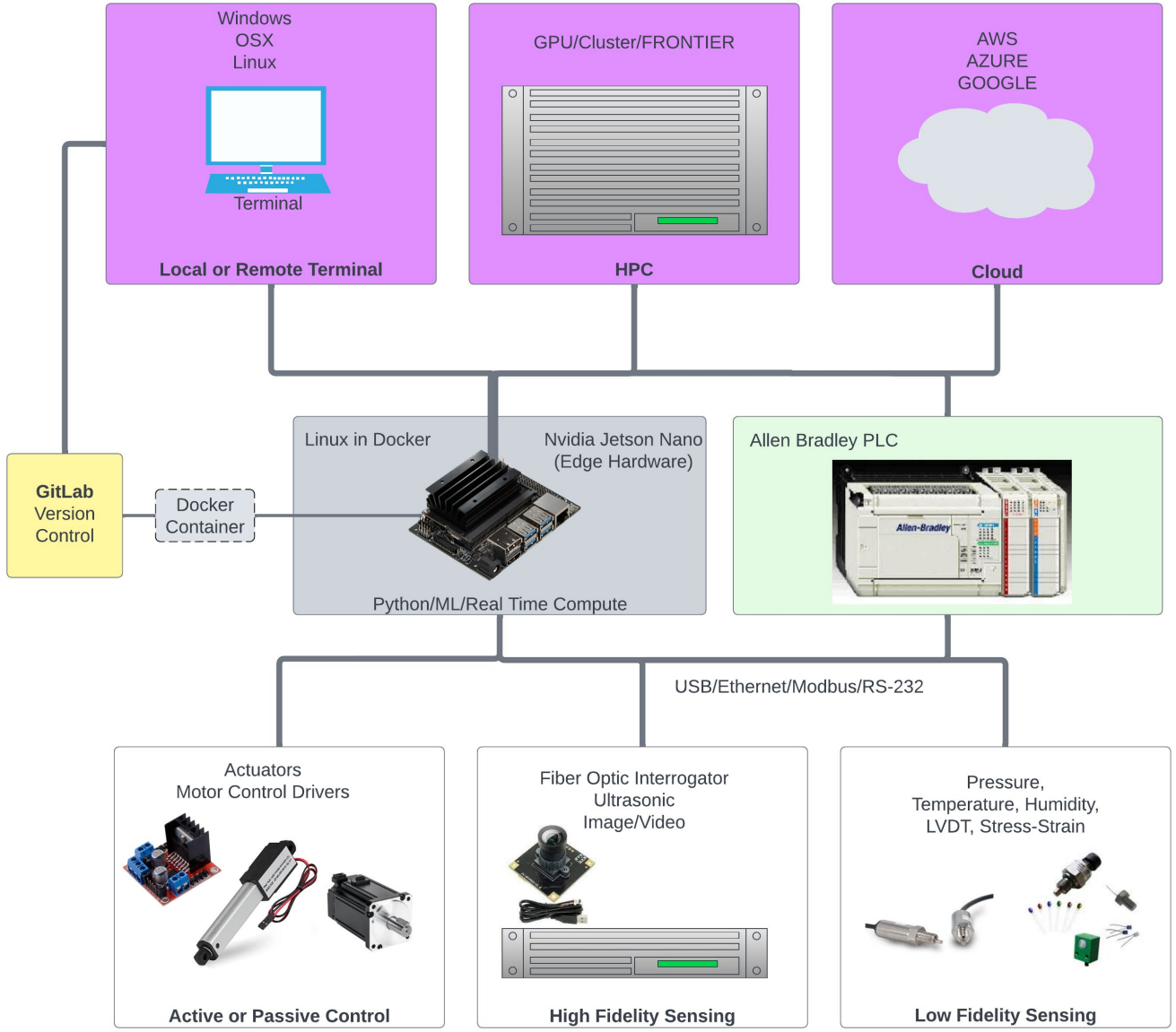


Distributed sensing diagnostics



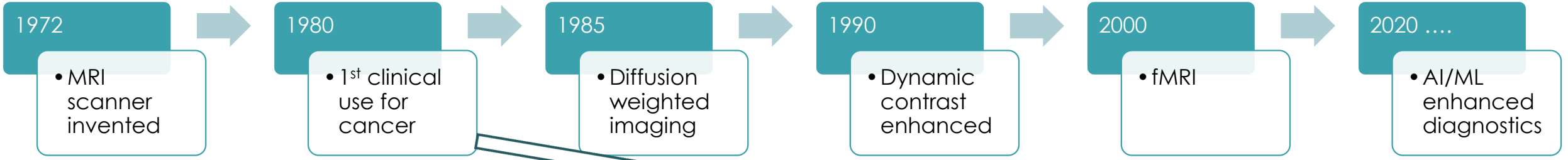
The need: integrated hardware in the loop test beds

- Adding high fidelity sensing inside the control loop brings new challenges in data handling
- I&C systems need a digital architecture that can handle broad types and quantities of data
- The need for edge hardware for compression sensing and implementation of ML
- Connectivity to high performance computing to aggregate and train data driven models

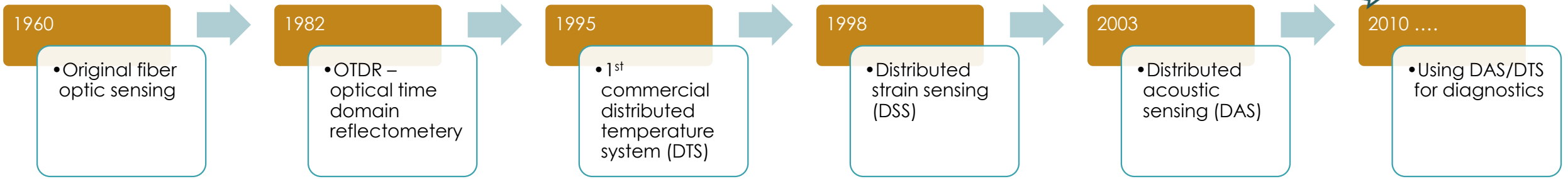


Where do we go from here

- Medical diagnostic imaging

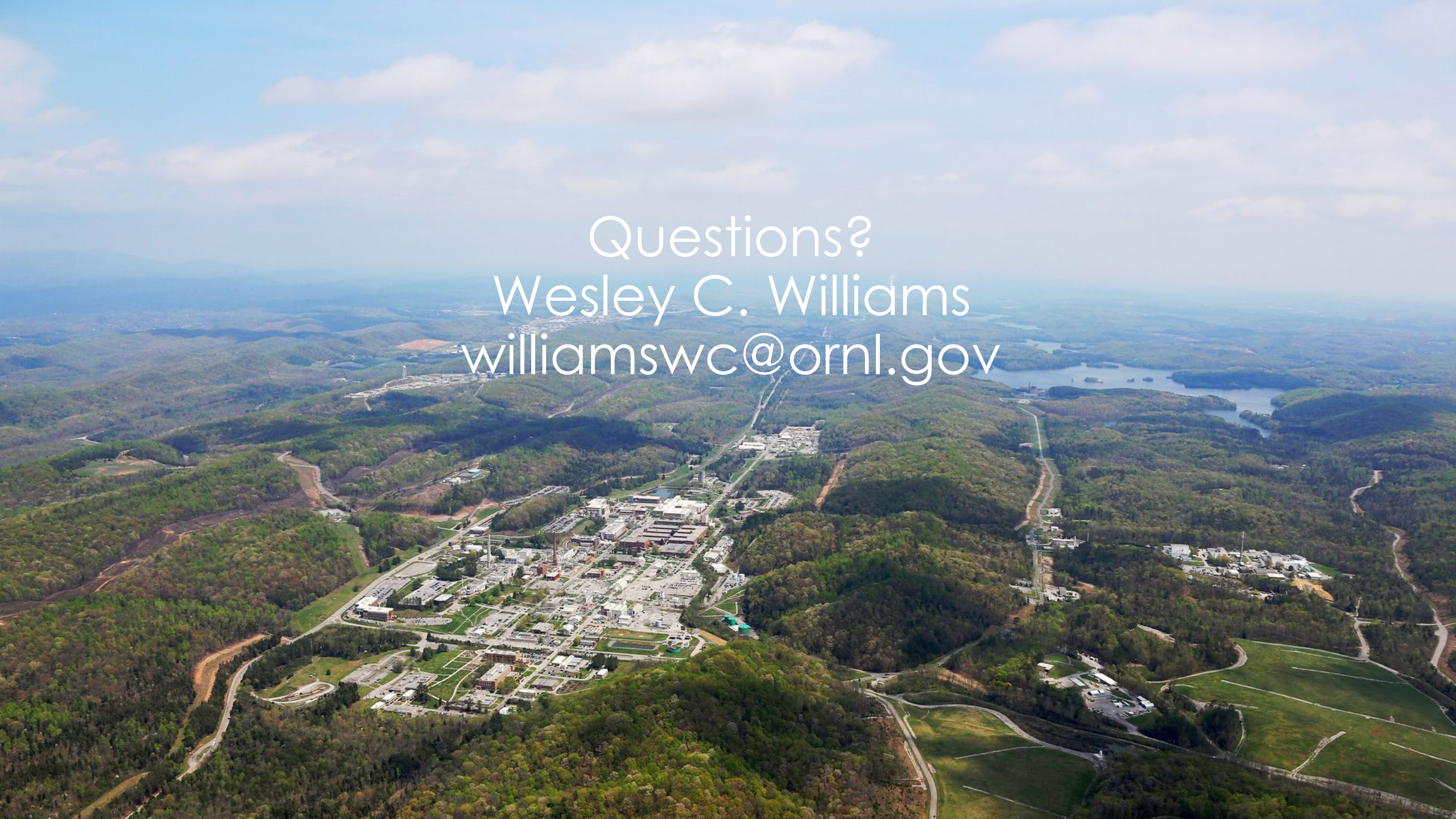


- Distributed fiber optic sensing



- The next decades are already outlined, HOWEVER,

  now we have AI/ML to help accelerate the development of the diagnostics


Questions?
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