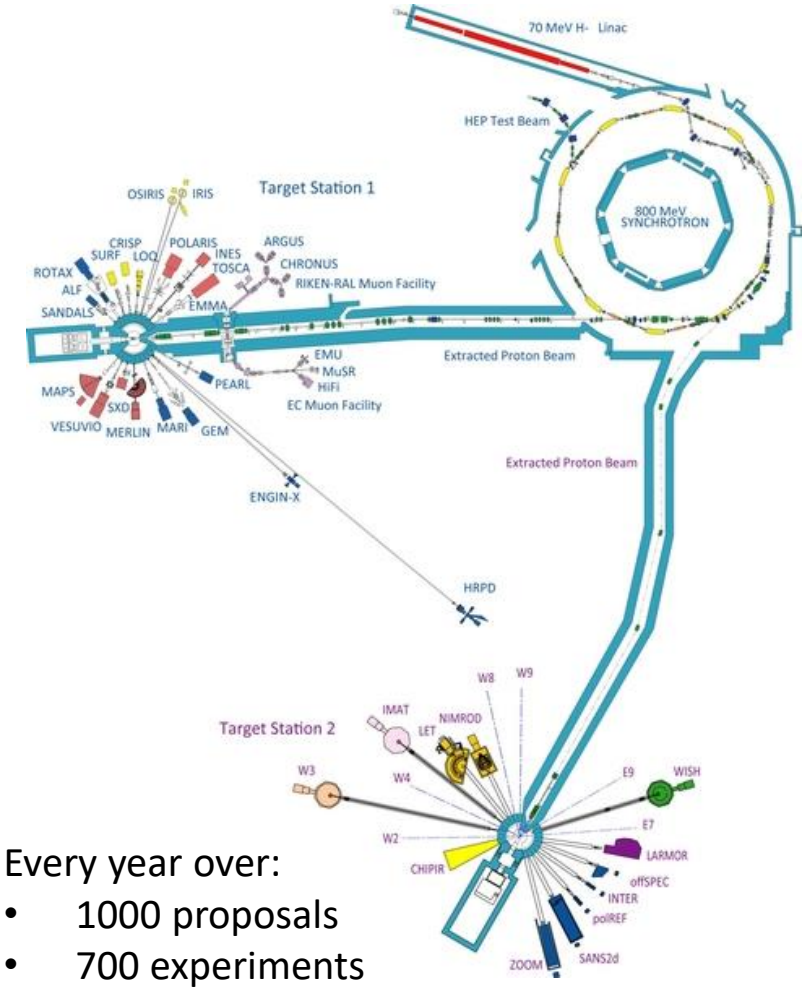
How science facilities work

Freddie Akeroyd
ISIS Experiment Controls Group
Science and Technology Facilities Council
UK Research and Innovation

ISIS Facility

- Pulsed neutron and muon source
- Based at Rutherford Appleton Laboratory, Oxfordshire, UK
- ~30 experiment beamlines
- World leading materials research facility
- https://www.isis.stfc.ac.uk/



Every year over:

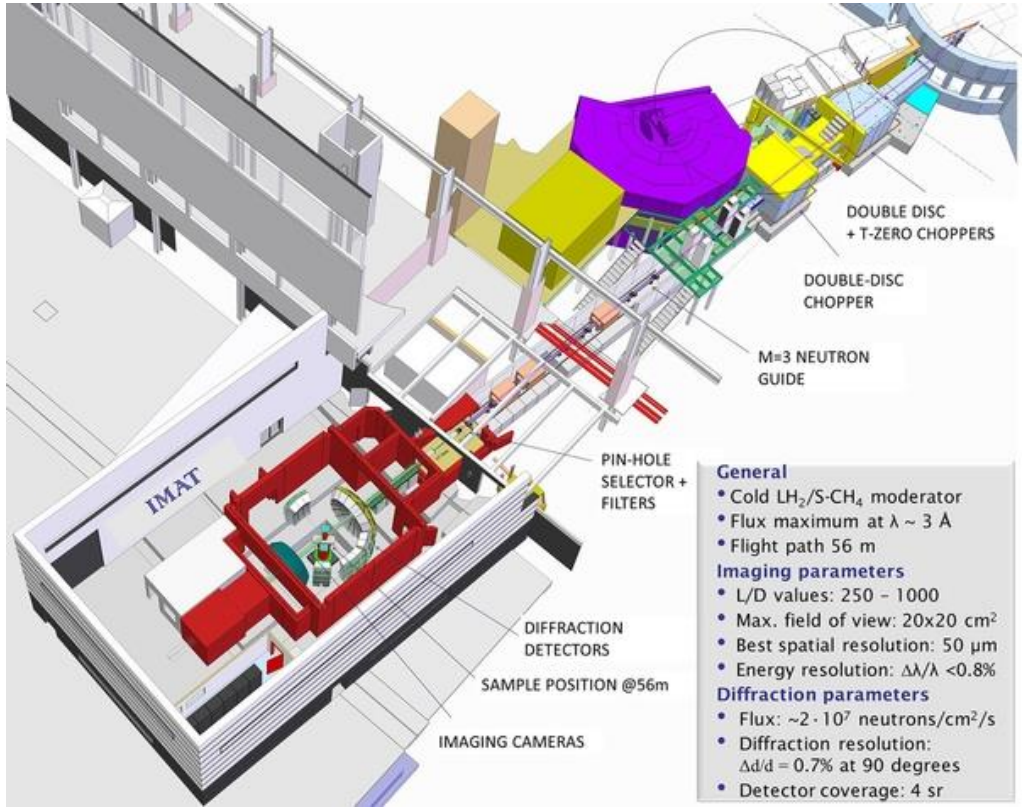
- 1000 proposals
- 700 experiments
- 400 publications

Science & Technology Facilities Council
ISIS

User based facilities

- Using ISIS as an example, but other large facilities work similarly
- Academic and industrial researchers send or bring samples of interest
- At ISIS we use neutrons and muons to probe the atomic structure
  - A bit like a giant microscope
  - A Synchrontron Light Source would use X-rays to similarly probe atomic structure
- The sample can be measured under a range of varying conditions
  - E.g. temperature, pressure, stress, magnetic or electric field, humidity, …
- ISIS runs 24 hours a day for ~6 weeks at a time
  - Remote monitoring and control is critical
  - Often measurement sequences run automatically and unattended

ISIS Instruments



- Many devices to control and monitor
  - Over 40 axes of motion on many instruments
- Control system critical for successful experiments

Science & Technology Facilities Council
ISIS

Device control

- Two areas where device control is needed:
  1. To deliver and record the neutron/x-ray beam at the sample
  2. To control the experiment conditions of the sample
- The two areas have some differences:
  - In (1) equipment may be more distributed and require tighter timing
  - In (2) equipment is of a wider variety and more changeable
- I will be covering (2) but many of the points apply to (1) also

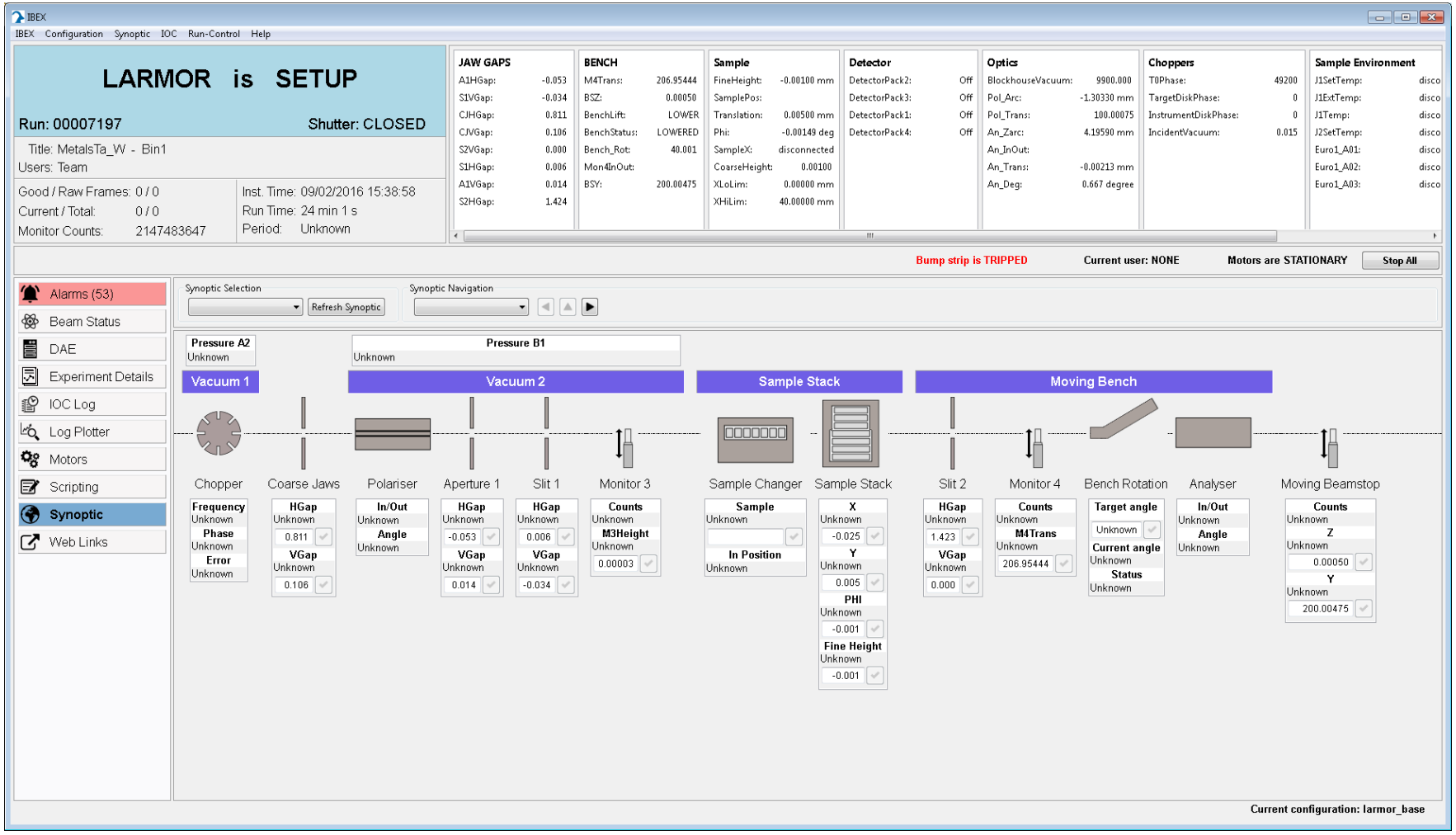
What we need to do

- Provide computer control of many types of devices:
  - Motors, temperature controllers, locally produced electronics, …
- Integrate all these different devices:
  - Allow user to specify sequences of desired value for each experiment
  - Monitor and record values from devices for use in later data analysis and to detect problems
- Support running successful experiments:
  - Abstract device control complexity, clear user interface
  - Checking user sequences are valid before running
  - Make sure the system is reliable and rapidly recoverable

The EPICS collaboration

- Tools for developing distributed low level device control
- Mechanism for coordinating control across multiple devices
- Tools for generating graphical user interfaces
- Tools for archiving and querying recorded values
- Access to many existing drivers shared by other facilities
- A well tested Open Source platform

Instrument Synoptic View in IBEX



Challenges

- Big facilities have long lifetimes (ISIS has been running since 1984)
- Computing hardware and interfaces evolve
- Need reliability and rapid recovery from system failures
  - Limited time allocated for each user's experiment
- Devices move between different beamlines
- New equipment always needing to be integrated
- Scientists wishing to run ever more complex experiments

How we operate device control?

- We use virtual machines for primary control
  - Maintain standard system setup, rapid recovery onto new hardware
- We use network based device control wherever possible
  - Often via Ethernet to RS232/422/485 terminal servers (Moxa NPort)
- We avoid devices that require introducing another computer
  - USB (mixed results with Ethernet to USB converters)
  - PCI-X, PCI-E

How do we interact with equipment vendors?

- Scientists/technicians will research possible new equipment
  - We will provide input on remote control / integration options
- Depending on the purchase value, multiple quotes or a tender could be required
- We have also used contract effort for EPICS software development
  - Integrating new devices
  - Adding higher level interfaces and complex control

What we look for in a new device

- A long lifetime interface, preferable Virtual Machine compatible
  - E.g. Direct Ethernet, RS232/422/485 (via Ethernet to serial)
- Remote access/control that can be integrated reliably into EPICS
  - Is the mechanism/protocol for remote device access well documented
  - Is it possible to set (ideally with some confirmation) and query values
  - Does an EPICS driver already exist and fulfil our requirements
  - Can we access all required and likely future functionality via remote interface
  - A simple ASCII command protocol e.g. SCPI (via EPICS StreamDevice), SECoP
  - Or using a standard already well supported in EPICS e.g. Modbus, OPC UA
  - Can the device be emulated? This helps us with our automated testing
  - Can vendor GUI program and EPICS remote access operate simultaneously

Summary

- Facilities need to integrate and automate the unattended remote control and monitoring of many different devices
- For operational functionality, longevity and reliability we consider criteria such as those on the previous slide when choosing devices
- EPICS allows us to build and manage a distributed control system
- The next talk will discuss some of the EPICS tools (StreamDevice, OPC UA) that help with device integration