The ISIS Neutron Chopper Suite: From Development to Operations

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The ISIS Target Station 2 Chopper Suite: From Development to Operations

- Background and history to 2005
- Target Station 2 chopper developments
  - Mechanical
  - Power and Control
  - Timing system integration
- Installation and operational experiences
- The future

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Rutherford Appleton Laboratory

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Harwell Science and Innovations Campus

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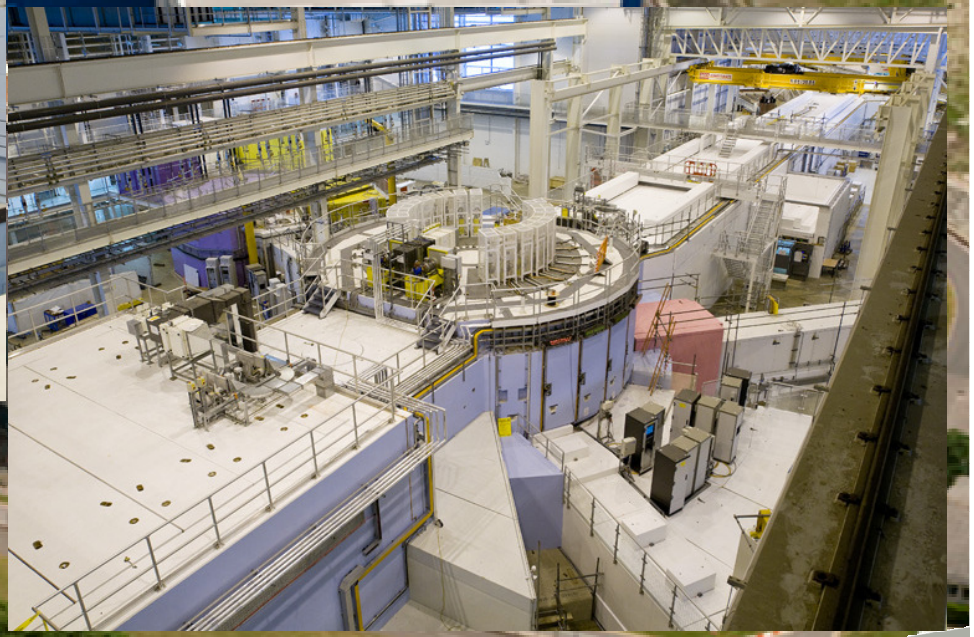
Two Target Stations



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Choppers at ISIS

- 25 operational neutron beamlines
- 42 operational choppers
  - 10 T_0 choppers
  - 29 disc choppers (including 4 high speed)
  - 3 Fermi choppers
- In-house design, installation & operational support

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Chopper History at ISIS

- 1984 – first neutrons produced
- Facility officially opened in 1985
- Instruments included HET (T_0 + Fermi)
- By 1990, chopper designs were mature (HRPD, IRIS, LAD etc.)

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80s/90s Technologies

- T_0 and disc choppers
  - 50Hz, belt drives
  - Polaron-Cortina thyristor drives, ABB motors
  - Analogue control systems
  - Rotating seals, oiled bearings
  - ‘Analogue’ timing control
- Fermi choppers
  - Forschungszentrum-Jülich
  - 600Hz
  - Analogue power supplies
  - ISIS slit packages (~50mm)

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1990s

- Inverter control for Fermi choppers
  - MAPS instrument
- IGBT drives for T_0 and disc choppers
- Development of solid state inverter drives
  - Bosch-Indramat
- Major upgrade to timing hardware
  - PLD technology

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2000 - 2005

- 100Hz T_0 chopper
  - Higher level of balance
- Higher positional accuracy
- Direct drive
  - Water-cooled asynchronous motors
  - No belt, no coupling
- Condition monitoring implemented
- Improved handling and maintenance techniques
- Counter-rotating disc chopper
- Large Fermi slit packages (~80mm)

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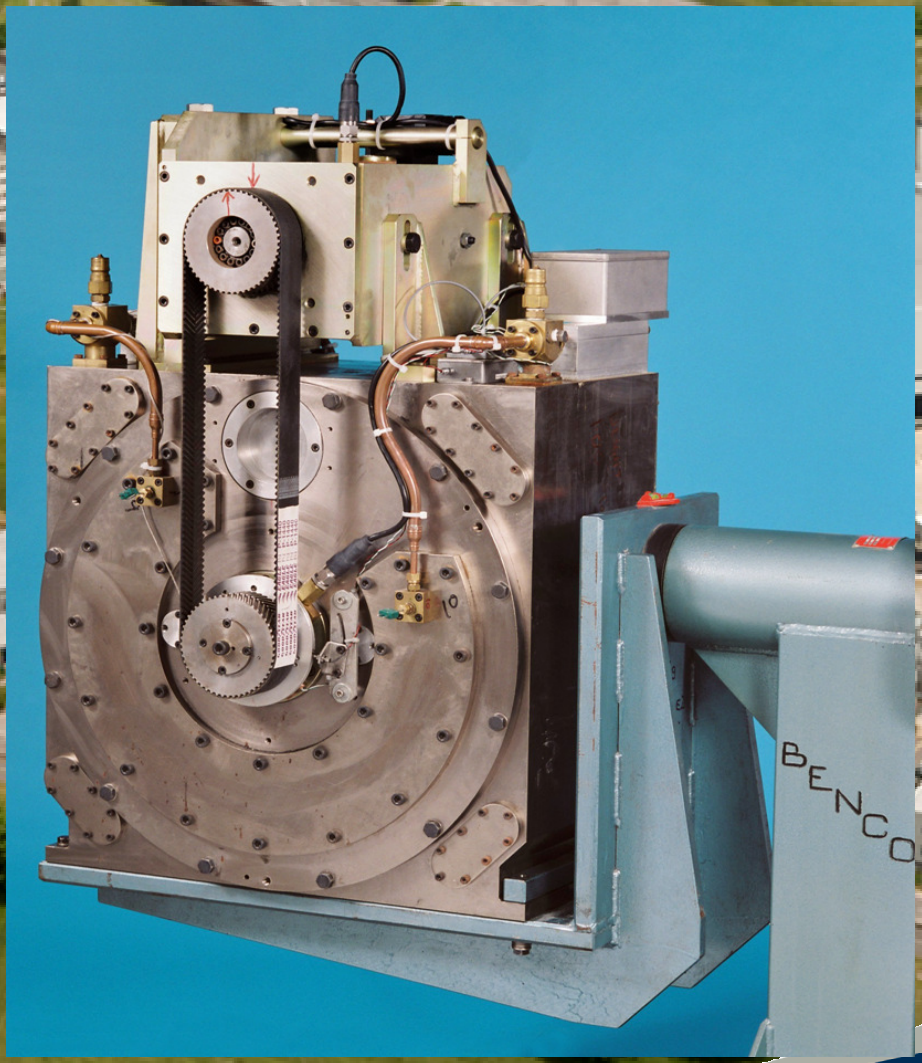
100Hz T_0



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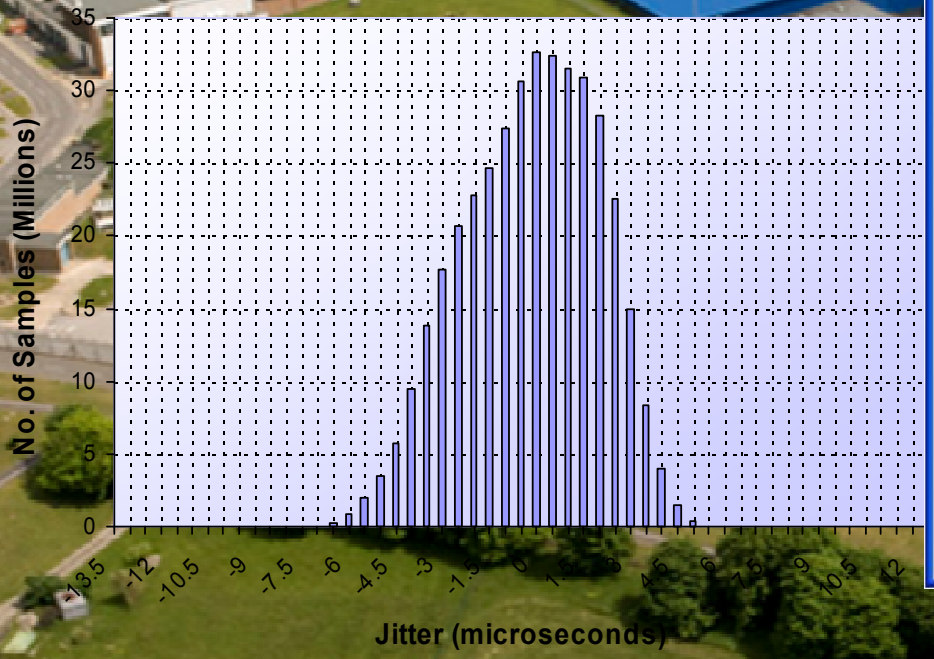
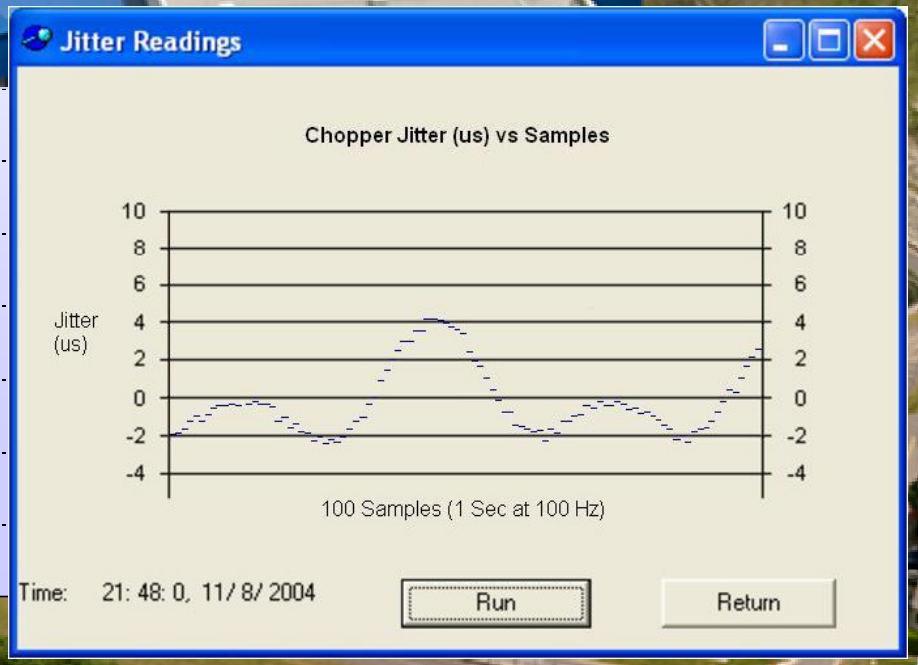
100Hz T_0

100Hz Chopper:
45 day jitter monitoring



100Hz Chopper:
Jitter over 1 second period



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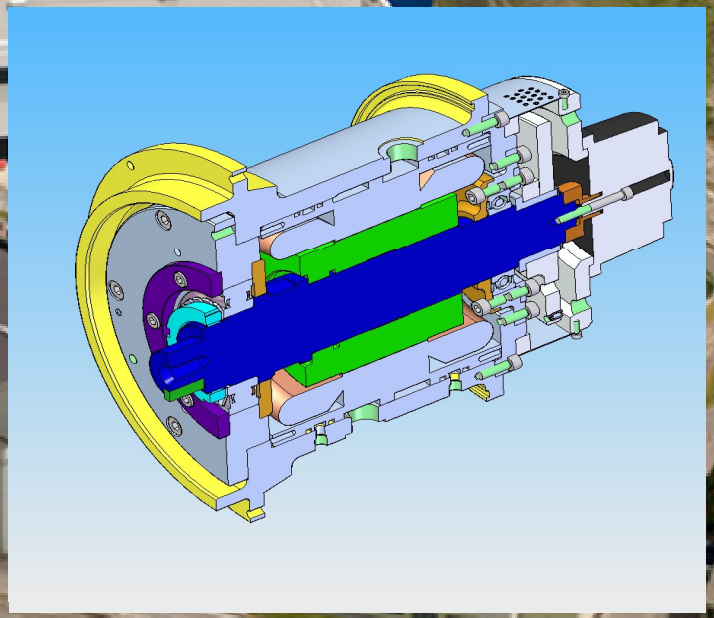
Direct Drive

- Modular design
- Secondary bearing surfaces
- Higher positional accuracy
- Longer runtime between maintenance
- Shorter maintenance time
- Fewer wearing components



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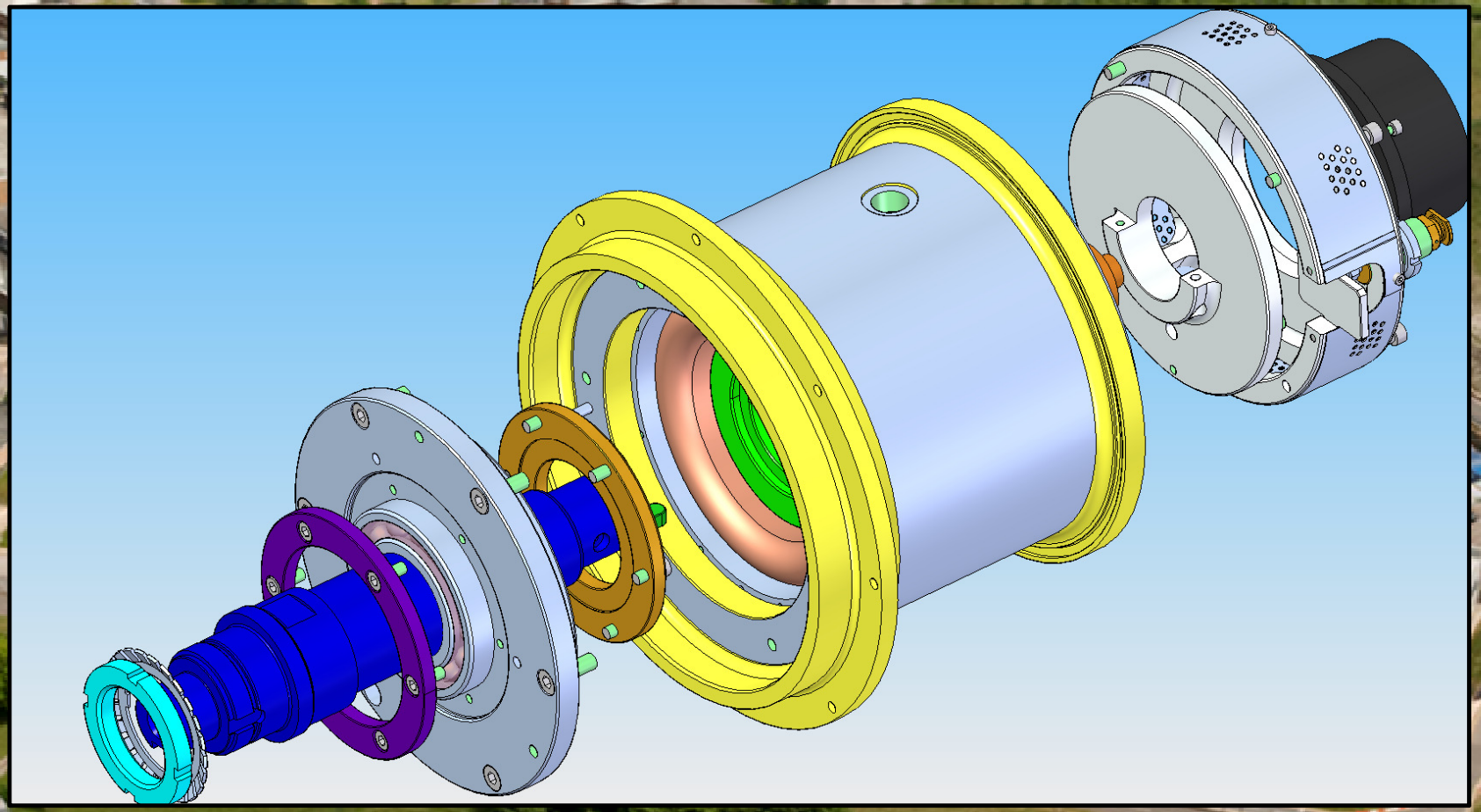
Motor Assembly



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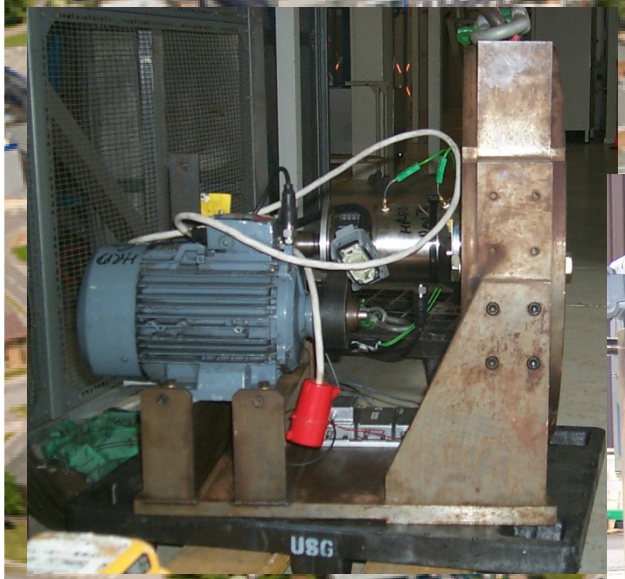
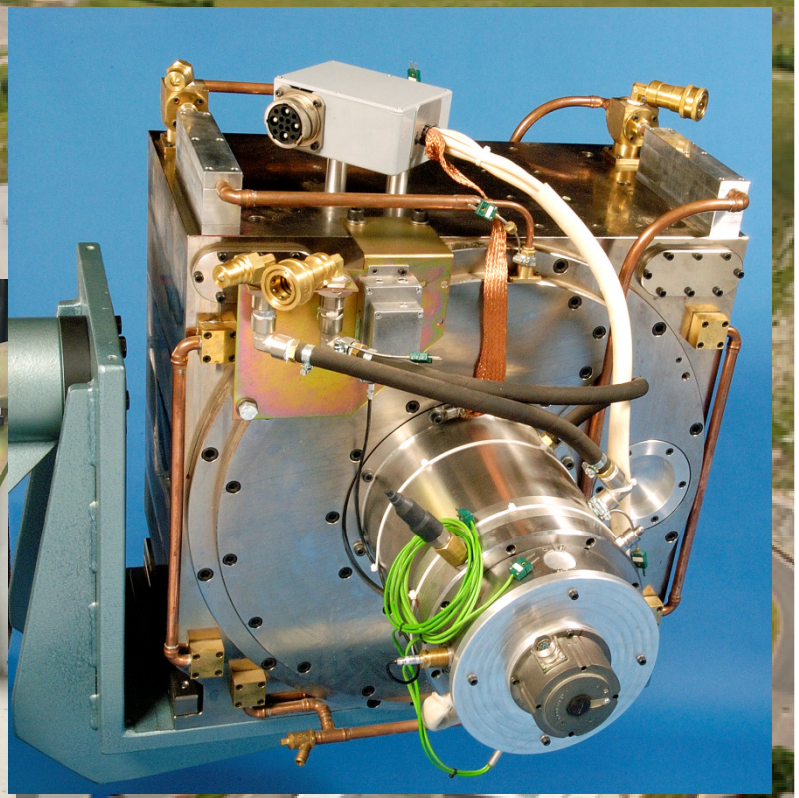
Direct Drive Choppers





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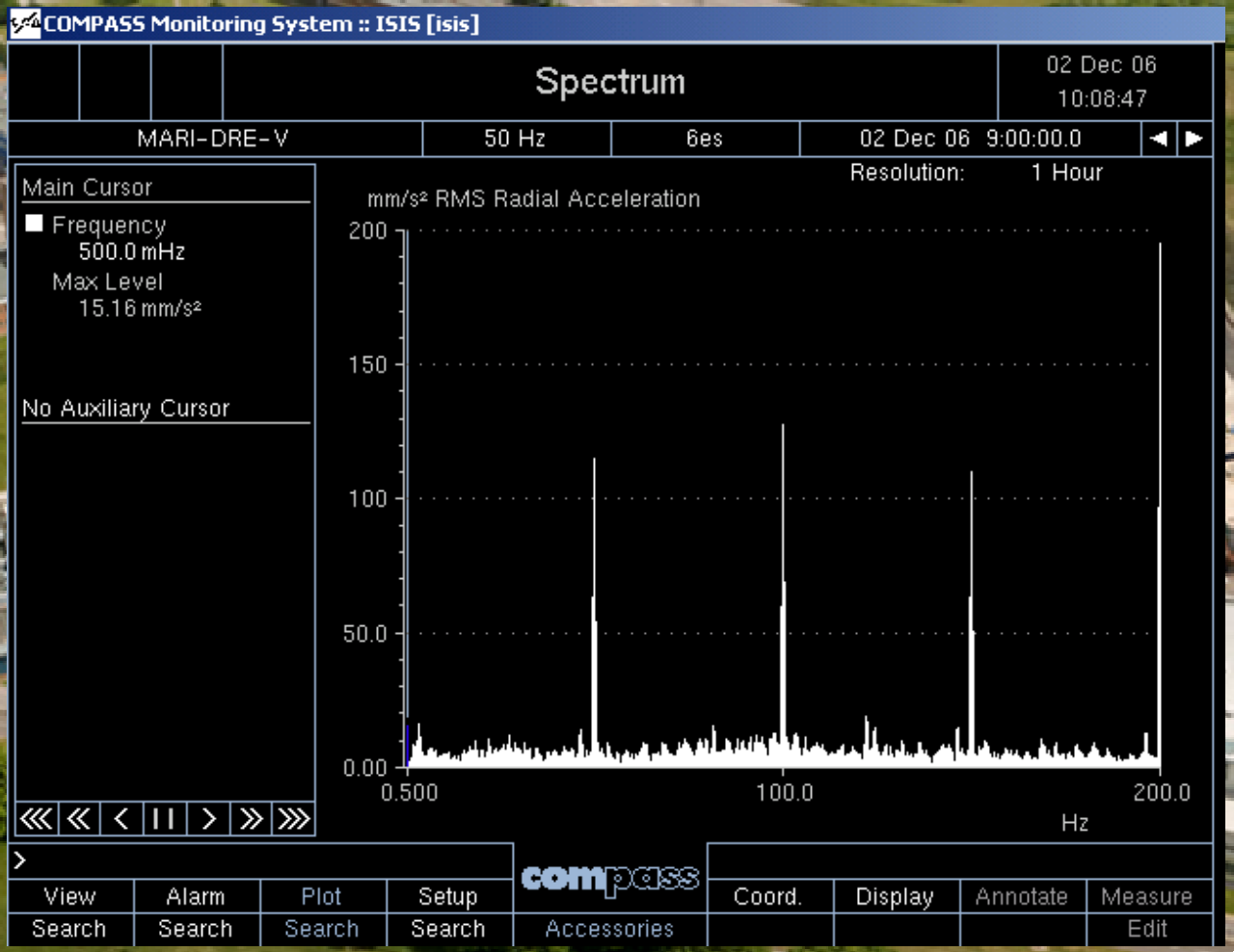
Condition Monitoring - FFT



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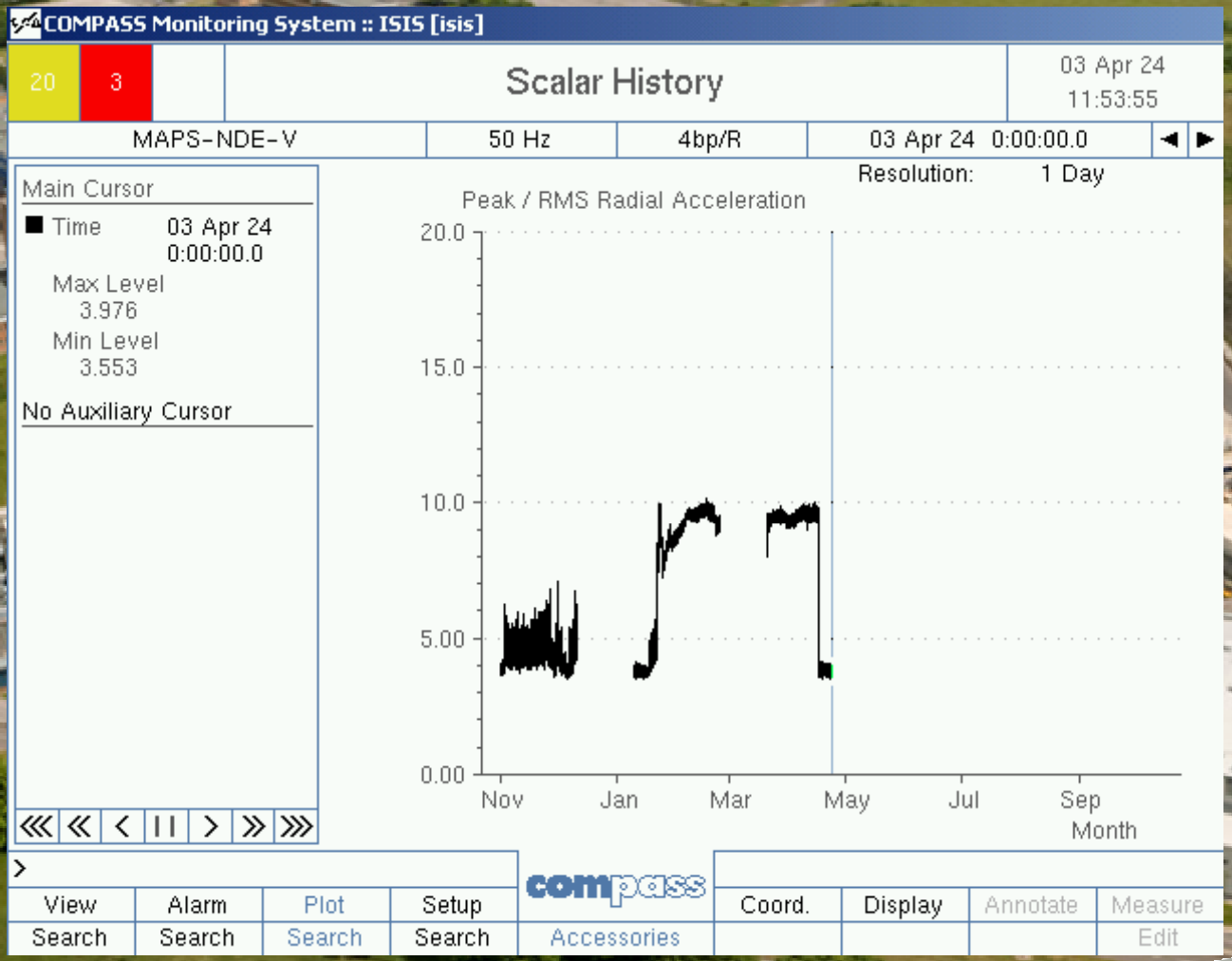
Condition Monitoring – Pk/RMS



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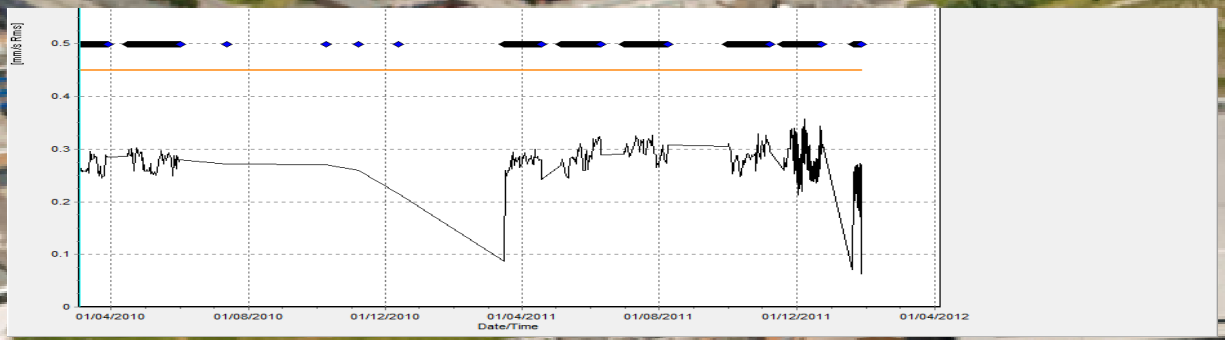
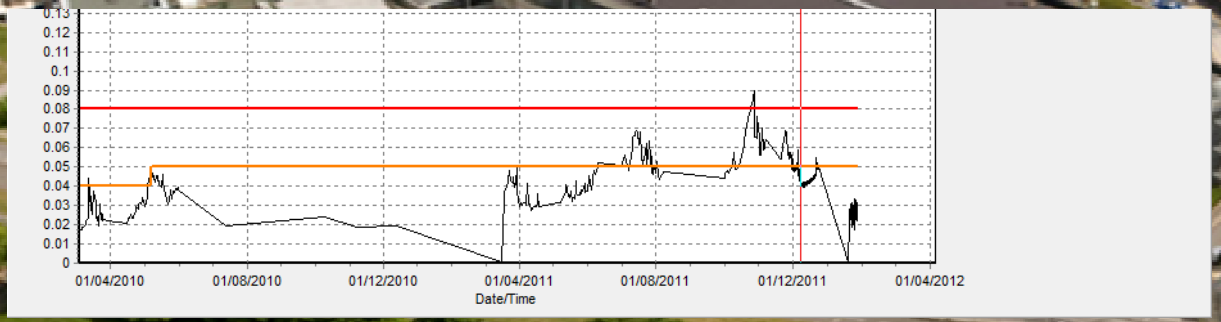
Vibration Analyses



Overall Vibration



Totalled acceleration enveloped energy

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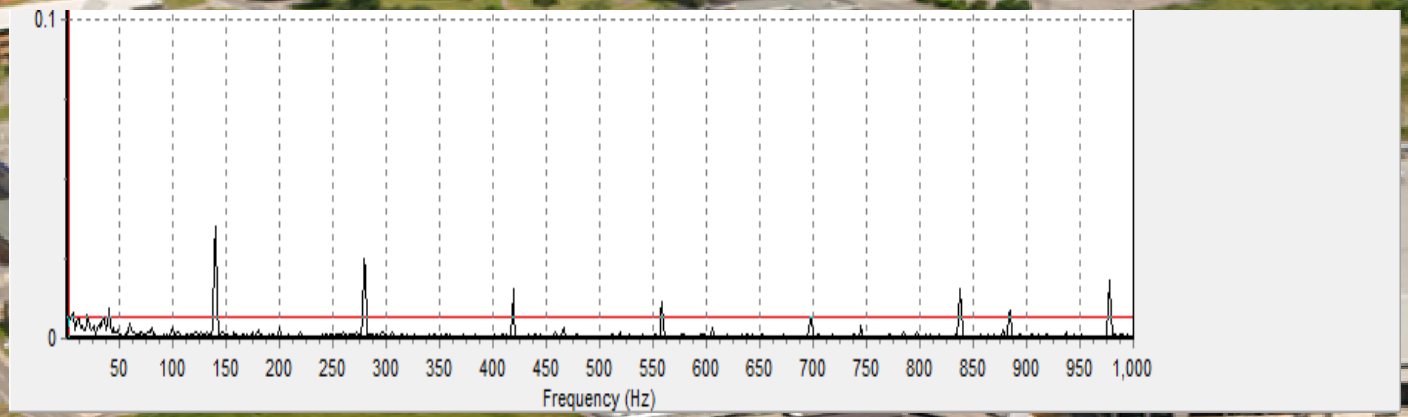
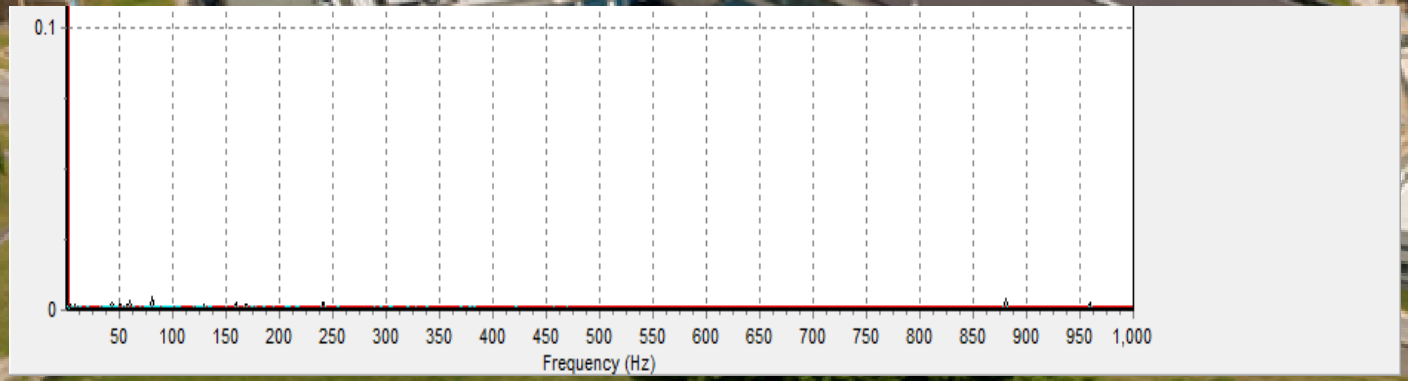
Condition Monitoring - FFT



Before bearing change



After bearing change

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2005: TS2 Developments
3 drivers for change:
• Specification
• Design Risk Assessment
• Obsolescence
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Specification

- Timing buses
- 10Hz rep. rate
- Chopper speed and beam size
- High speed
- Undefined disc aperture size
- Counter- *and* co-rotation

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Design Risk Assessment

Title: TS2 In-house Choppers Design Risk Assessment		Assessed By: S. Wakefield, P. Galsworthy, T. Carter, P. Chorley, J. Salisbury, M. Brind		Date of Assessment: 26/06/06 Reviewed: 23/03/07		
Step 1 What are the hazards?	Step 2 Who might be harmed and how?	What are you already doing?	Step 3: What further action is necessary?	Step 4: How will you put the Assessment into action?		
Hazard/Task or Situation				Action by whom	By when	Done
Rotor overspeed ultimately leading to mechanical failure in an open pit or chopper test bay.	Chopper staff could be hit by high speed debris or crushed if a T_0 rotor seized instantaneously and rotated the entire chopper (possible, but unlikely). Choppers need to be run in Chopper Lab and in pits without top shielding in place.	Design of chopper housing should minimise hazard (thick casing, profiled interior). Overspeed protection was carried out in the Mark 2 control crates. This was, however, dependent on software and long cable runs. We consider this to be inadequate given the new technologies available.	The new chopper drives are designed with a Bosch drive safety module. Overspeed protection is performed by this module, not by the Mark 3 control crates.	T. Carter	31/12/06	Yes
Rotor over-acceleration, particularly during initial set-up and testing in the Chopper Lab, leading to mechanical failure.	As above.	Investigated (with Bosch) the use of the Bosch drive safety module for over-acceleration protection. At this time, however, the feature is not available.	A torque limit will be set up in software: this is not part of the Bosch safety module. Only Electrical Engineers, trained in the set-up of Bosch drives may change drive parameters.	Chopper Team	Immediate.	Yes
Remote start control: accidental operation or faulty operation	Chopper Team staff could be working on a chopper when it starts, either by deliberate act or through software/firmware fault leading to the potential for electrocution.	Remote start is currently available on existing choppers.	Remove remote start capability from TS2 choppers and all obsolescence work. Institute lock-off procedure for work on choppers.	T. Carter / P. Chorley. M. Brind	Chopper commissioning	
Consequence of using E-stop: drive down or torque-disconnect?	Drive down takes ca: 5min, but power supply remains energised: electrocution risk:	Torque-disconnect implemented.	Risk of electrocution is considered greater than entanglement by the Chopper Team, given that	T. Carter	Immediate.	Yes

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Obsolescence

- Bosch-Indramat upgrades
- Fibre optics
- FPGA
- Diagnostics / GUIs
- PC networking
- Condition monitoring
  - Improved measurement technology
  - Improved analytical techniques
  - Improved hardware
  - Object-oriented software

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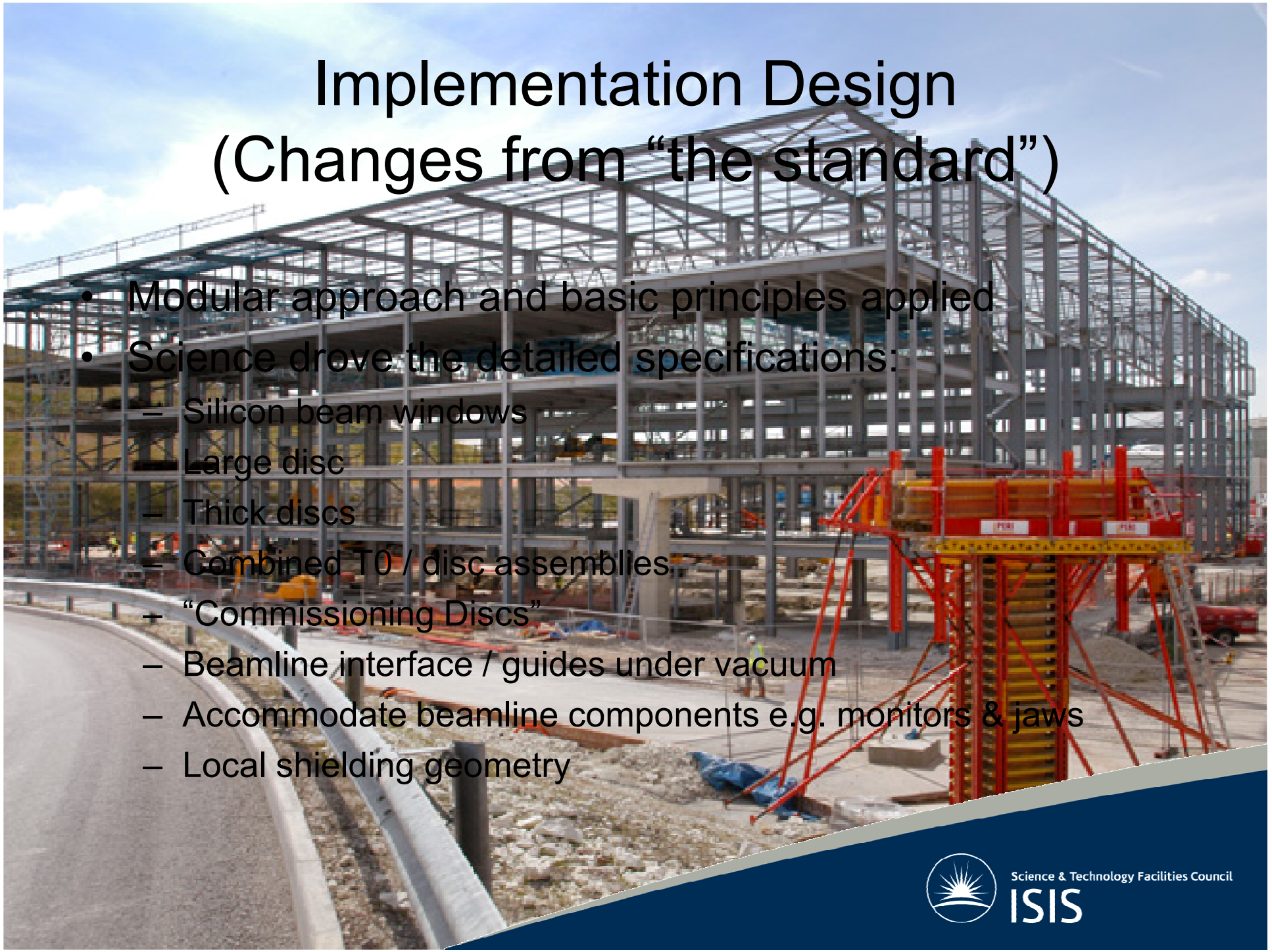
Implementation Design (Changes from “the standard”)



- Modular approach and basic principles applied
- Science drove the detailed specifications:
  - Silicon beam windows
  - Large disc
  - Thick discs
  - Combined T0 / disc assemblies
  - “Commissioning Discs”
  - Beamline interface / guides under vacuum
  - Accommodate beamline components e.g. monitors & jaws
  - Local shielding geometry

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Large Disc Choppers

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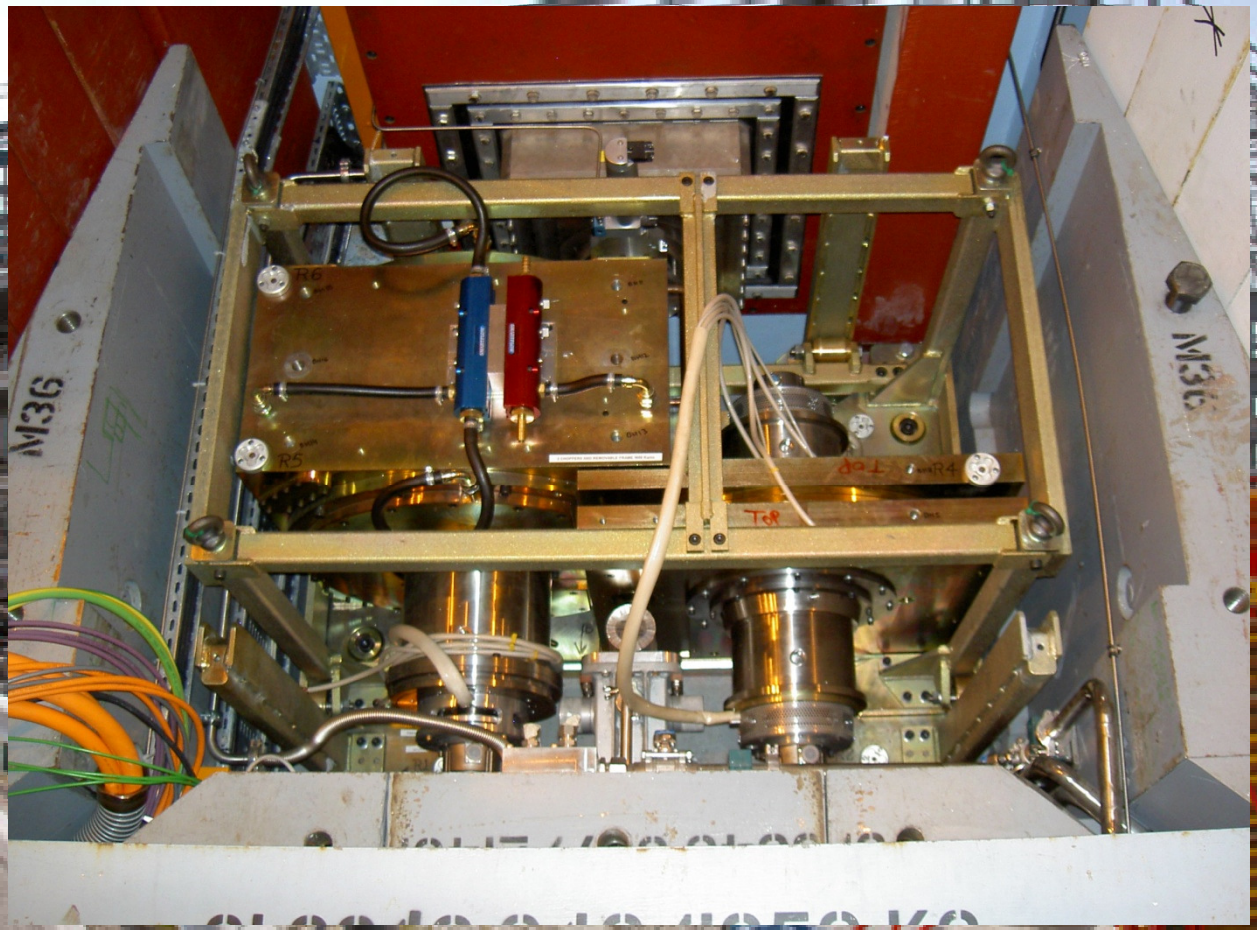
Combined Chopper Assembly



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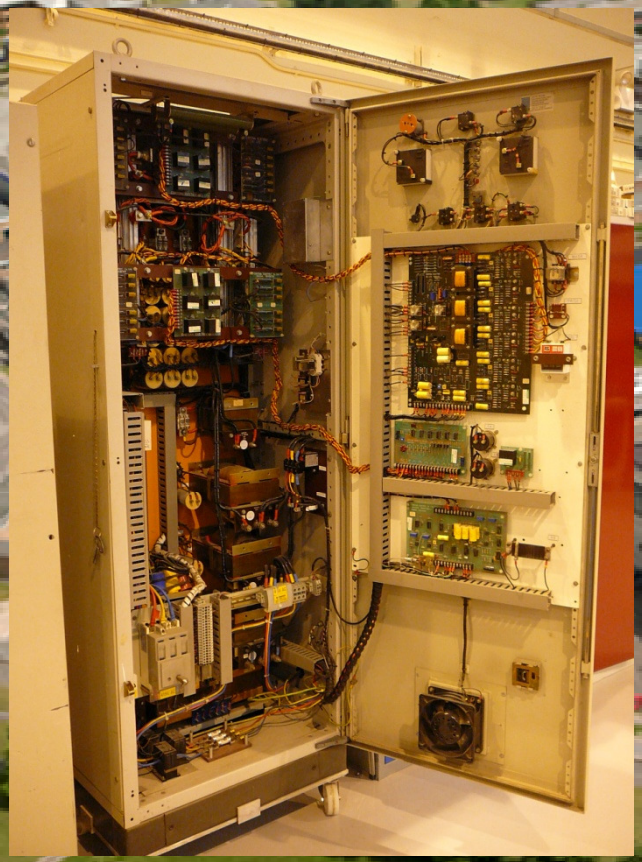
Power and Control Systems



Cortina

Diax04 (Indramat)

IndraDrive

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Power and Control Systems

Diax04

IndraDrive

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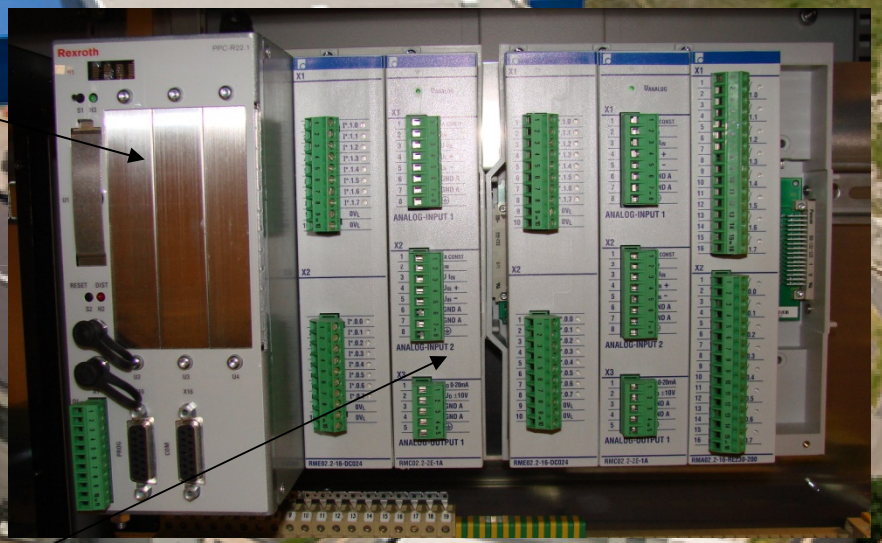
Power and Control Systems



Combined Motion & Logic Controller

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Power and Control Systems

Complex keypad

Touchscreen

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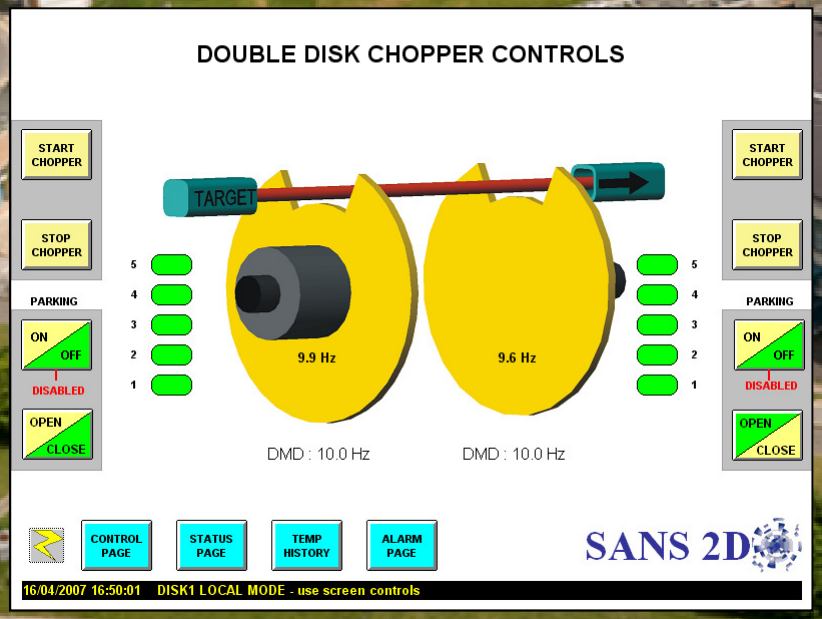

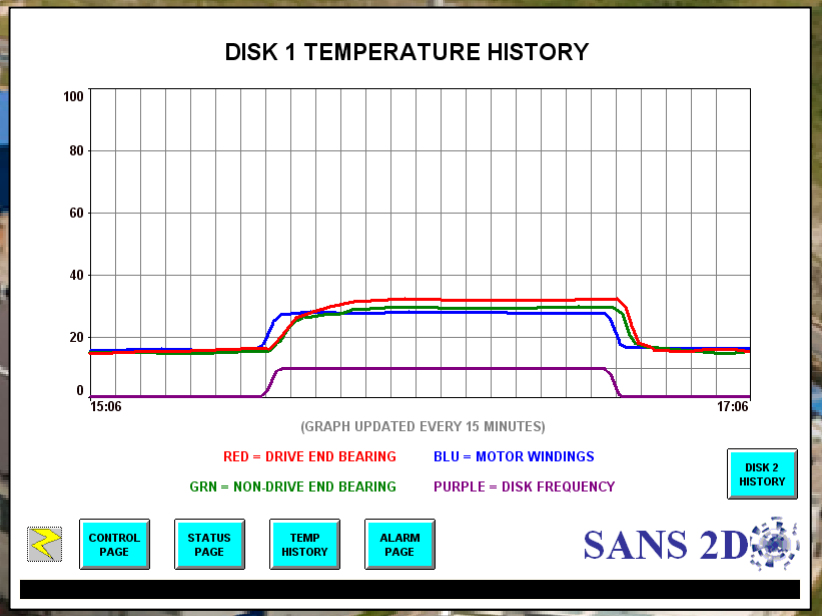

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Power and Control Systems

Drive Pulse

Rotor Pulse

Status / Direction

Chopper Control Crate

Feedback

Position Feedback

Motor

Thermocouples

Disk 2

Disk 1

Flow Switch

Cooling Water

Rotor Pickup

CHOPPER SIDE VIEW

Power

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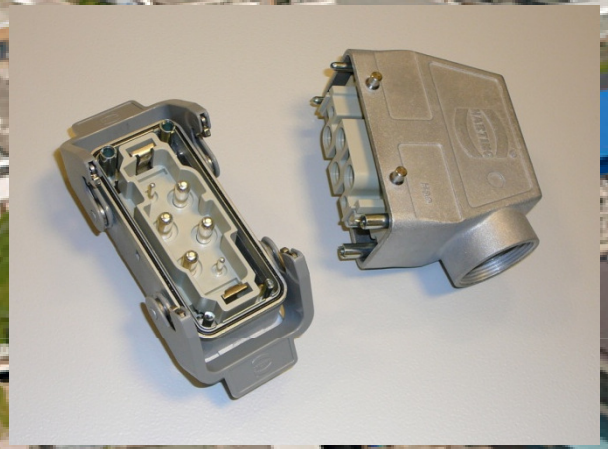
Power and Control Systems



- EMC Versions
- Coded Connectors to prevent incorrect connection
- Padlockable
- Procedural disconnection strategy

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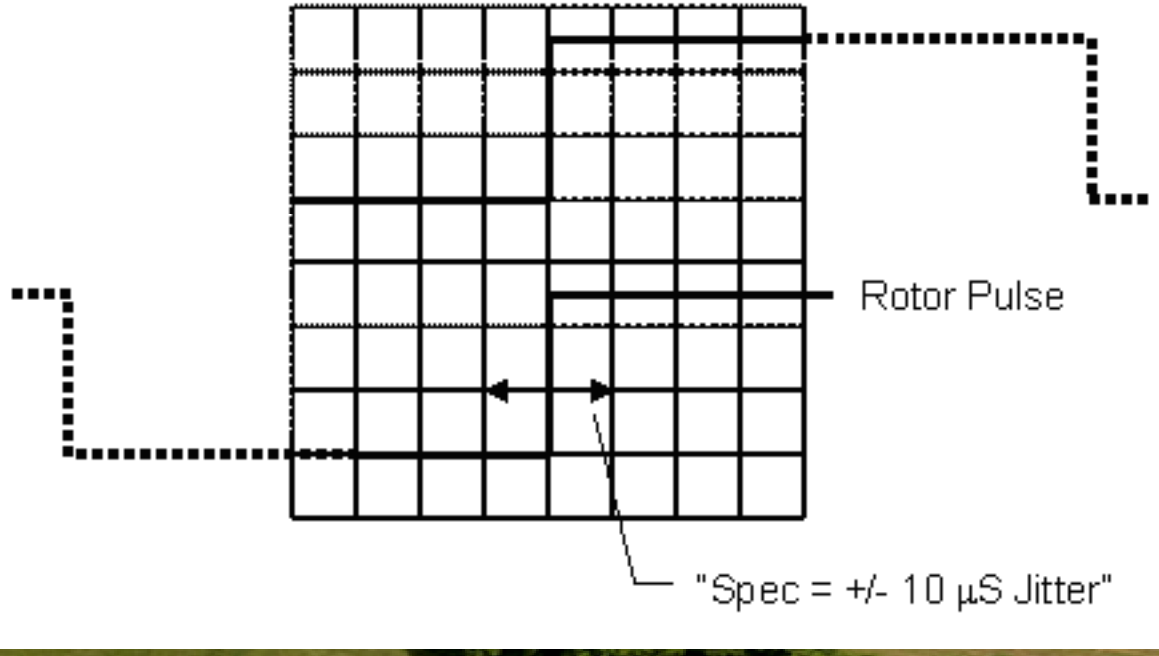
Power and Control Systems

Accuracy Specification



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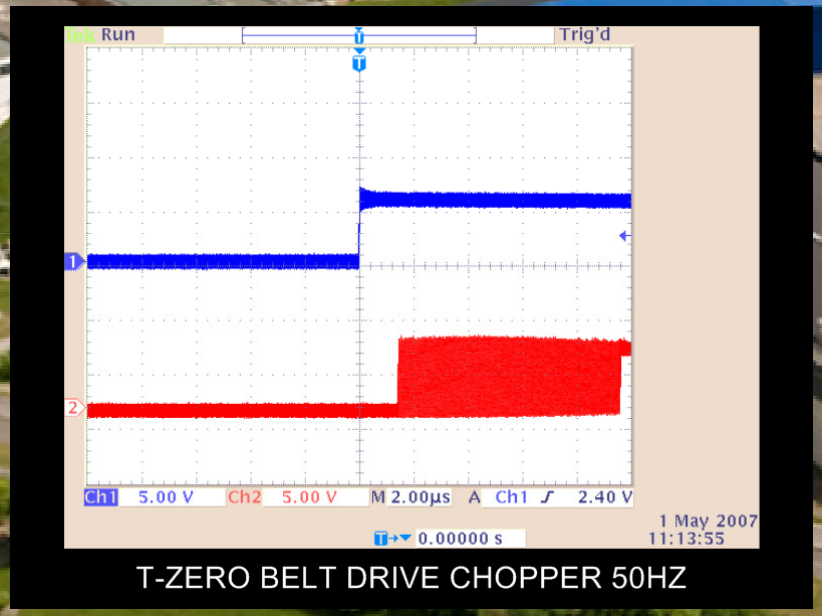
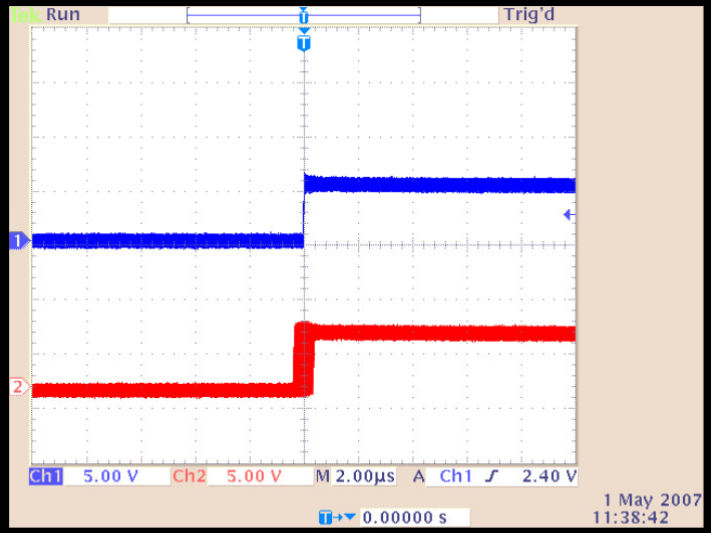
Results – 50Hz

Diax04 Belt Drive:
±4µS, 5.8 µS Offset



T-ZERO BELT DRIVE CHOPPER 50HZ

IndraDrive Direct Drive:
±400nS, NO Offset



T-ZERO DIRECT DRIVE 50HZ

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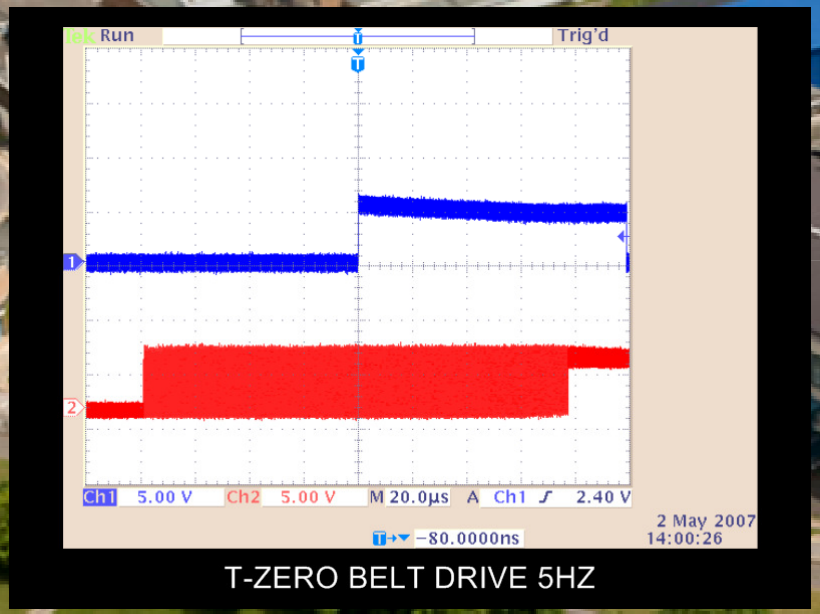
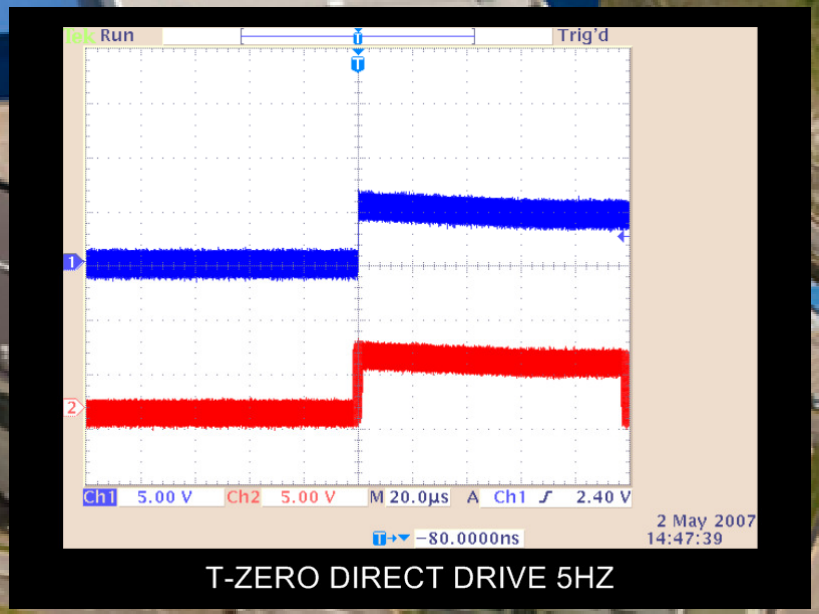
Results – 5Hz

Diax04 Belt Drive:
±80µS



T-ZERO BELT DRIVE 5HZ

IndraDrive Direct Drive:
± 2µS



T-ZERO DIRECT DRIVE 5HZ

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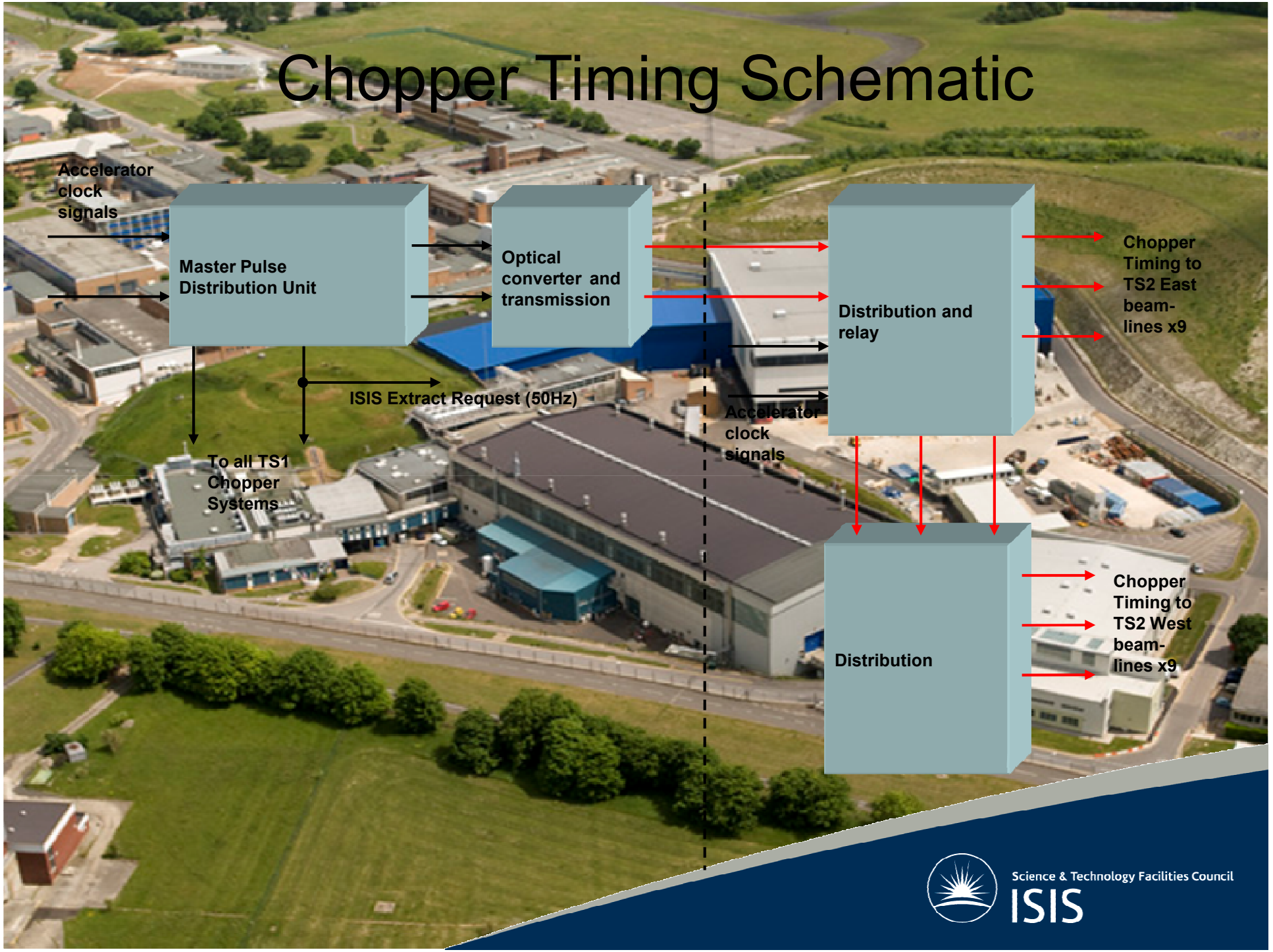
Chopper Timing Schematic



Timing Control Module

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Chopper Timing Control System

ISIS Machine Timing Signals

Master Pulse (M.P)

Earliest Extract Pulse

1MHz

MK3v1 Chopper Control System
19" x 1U High
(TS1/TS2 Hall)

Drive Pulse

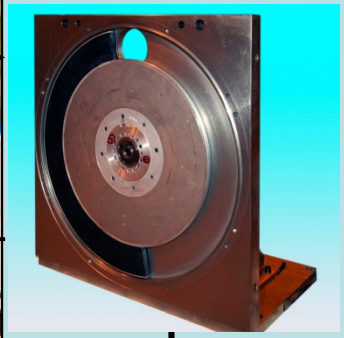
Buffered R.P

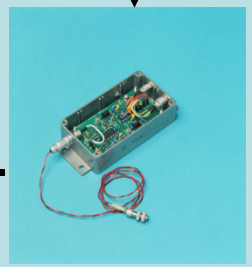
Interlock status and direction control

Drive Power

Encoder Feedback & Interlocks

Neutron Beam Chopper





Position Pick-off. Rotor Pulse

Data Acquisition Unit (Pod)

Data Veto

Conditioned R.P

Panel PC TS1/TS2 Hall

LAN

Host PC

UPS 2U x 84HP

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Comparison: MK2v2 v MK3v1 Systems

	MK2v2	MK3v1
Chassis Height.	3U	1U
Manual Mode Controls.	Chassis Front Panels.	Panel PC GUI.
Computer Mode Controls	Controller – Cabin PC. RS-232 connection.	Panel PC – Pod PC. LAN connection.
Control Parameters.	Speed, Phase Delay, Phase Error Window, Stop/Start.	Speed, Phase Delay, Phase Error Window, Direction (Discs only).
Inverter Drive Interlocks.	Interlock Indication & STOP.	Interlock Indication only.
Data Veto O/P.	Open Collector.	1. Differential. 2. Open Collector.
SMP O/P.	Open Collector.	1. Differential. 2. Open Collector.
RP O/P.	TTL Test Point.	1. Differential. 2. Open Collector.
MP, EEP, 1MHz Inputs.	Electrical differential.	1. Electrical differential. 2. Optical inputs.

Operation

- SANS2D, POLREF, INTER, OFFSPEC and WISH
  - Excellent operation and performance
  - Over 3 years operating without problem
  - First choppers just removed for routine bearing change
    - determined by condition monitoring
- LET
  - All choppers perform well
    - including 2 × 150Hz, 2 × 300Hz
  - Instrument technically highly complex
  - Choppers meet challenging specifications
  - Compromised access and interface arrangements
  - Mechanical, electrical and software issues were resolved
  - We relied on supplier expertise to fault find

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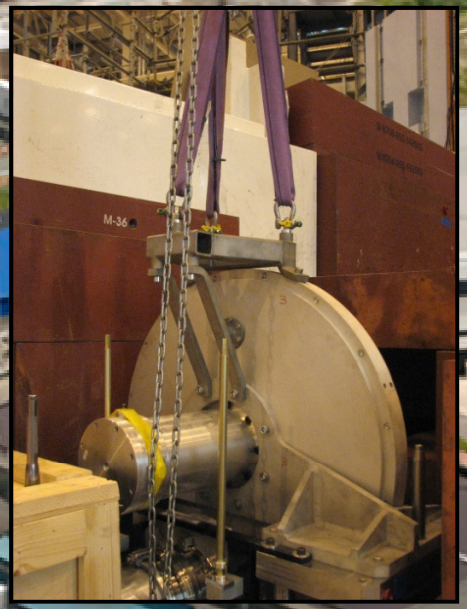
Installation



- In-house choppers have bespoke interface and access designs
- Bought-in choppers needed to be "accommodated"

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The Team

- Multi-disciplinary Engineering
  - Mechanical, Electrical, Electronic, Process, Operations
- Multi-functional
  - Development
  - Design and manufacture
  - Assembly
  - Installation and testing
  - Operational support
  - Project management
- From different management groups
  - Design Division
  - Instrument Operations Group
  - Accelerator Engineering Group
  - Technology Dept.

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Key Points for ISIS

- Modular design in all respects
- Flexibility to meet specification detail
- In-house development
- Specialist collaborations
- Condition monitoring
- Obsolescence programmes
- Dedicated, established team

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The ISIS Chopper Team

Erik Johnson
Tim Carter
Doug Whiting
Paul Chorley
Adam Davis
Peter Dawson

Clive Smith
Mike Brind
Kevin Allen
Simon Rutter
Steve Wakefield
Peter Galsworthy

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The Future

- Target Station 2 Phase 2
  - 3 of 4 new instruments have choppers
    - ZOOM Double Disc + Si window
    - LARMOR combined T_0 & Double Disc assembly
    - IMAT 2 x Double Disc + T_0, fully vacuum integrated
- Fermi
  - Material and package design
- Blocking materials
- Drive obsolescence (Cortinas + Bosch-Indramat)
- Timing control obsolescence
- New MPDU

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