TRIUMF
CANADA'S NATIONAL LABORATORY FOR PARTICLE AND NUCLEAR PHYSICS
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CRYOGENICS CONTROLS IN THE ISAC-II SUPERCONDUCTING RF ACCELERATOR

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ISAC at TRIUMF

- TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics

- ISAC = Isotope Separator and ACcelerator
  - Accelerator of radioactive isotopes
  - Uses Superconducting RF LINAC


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Arctic Ocean
Russia
ASIA
75° N
Beaufort Sea
ARCTIC CIRCLE
Greenland
(Denmark)
60° N
Hudson Bay
Labrador Sea
45° W
Gulf of Alaska
Bering Sea
Canada
TRIUMF
150° W
45° N
Great Lakes
Pacific Ocean
United States of America
Atlantic Ocean
Bermuda
(U.K.)
600 mi
600 km
30° N
75° W
60° W
Gulf of Mexico
Mexico
Bahamas
TROPIC OF CANCER
NORTH AMERICA
CARIBBEAN
Cuba
Dominican Rep.
Jamaica
Belize
Caribbean Sea
Puerto Rico
15° N
Guatemala
Honduras
El Salvador
Nicaragua
Trinidad
Pacific Ocean
CENTRAL AMERICA
Venezuela
Costa Rica
Panama
Colombia
SOUTH AMERICA
135° W
120° W
105° W
90° W

Famous TRIUMF Picture

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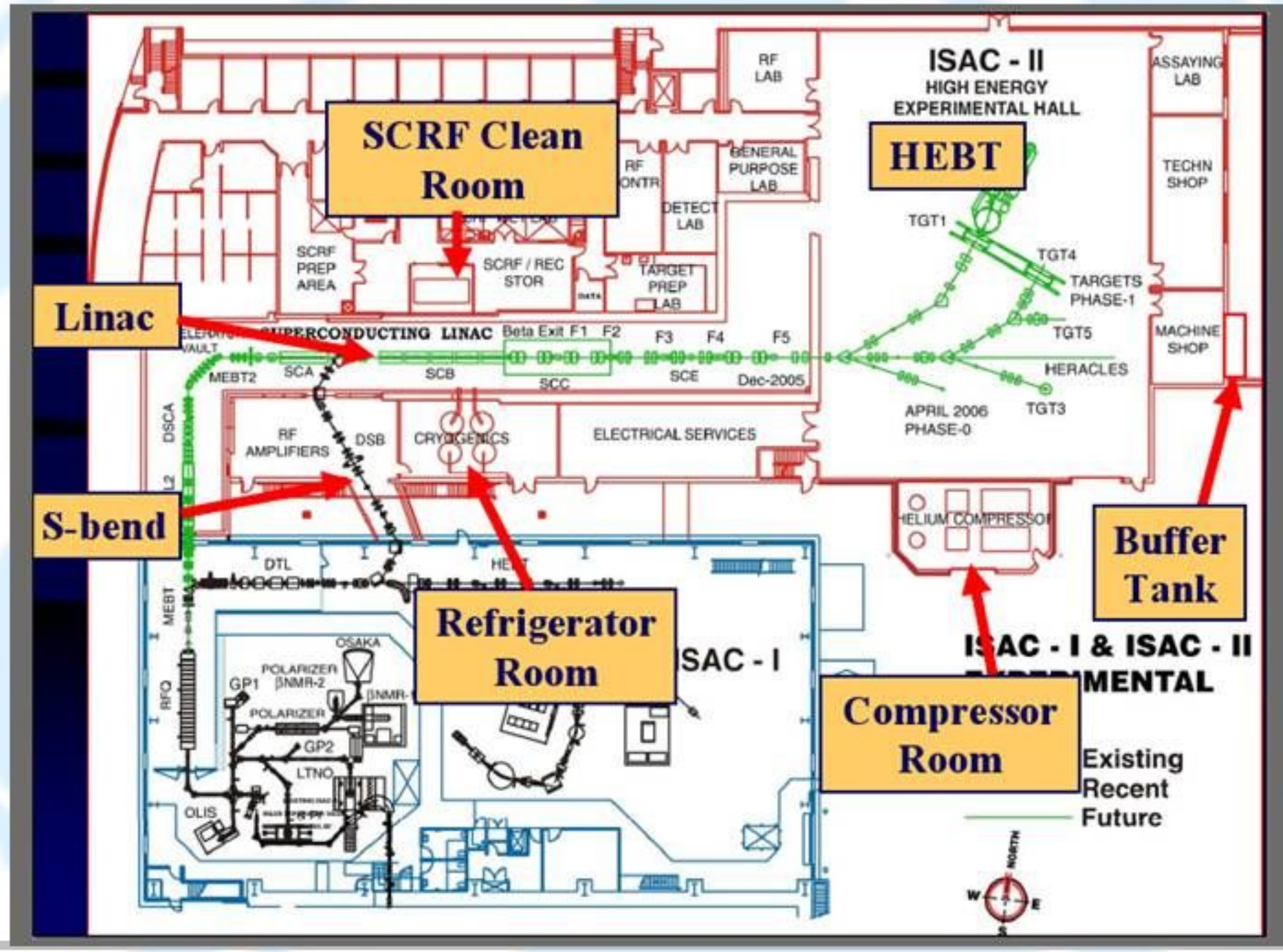
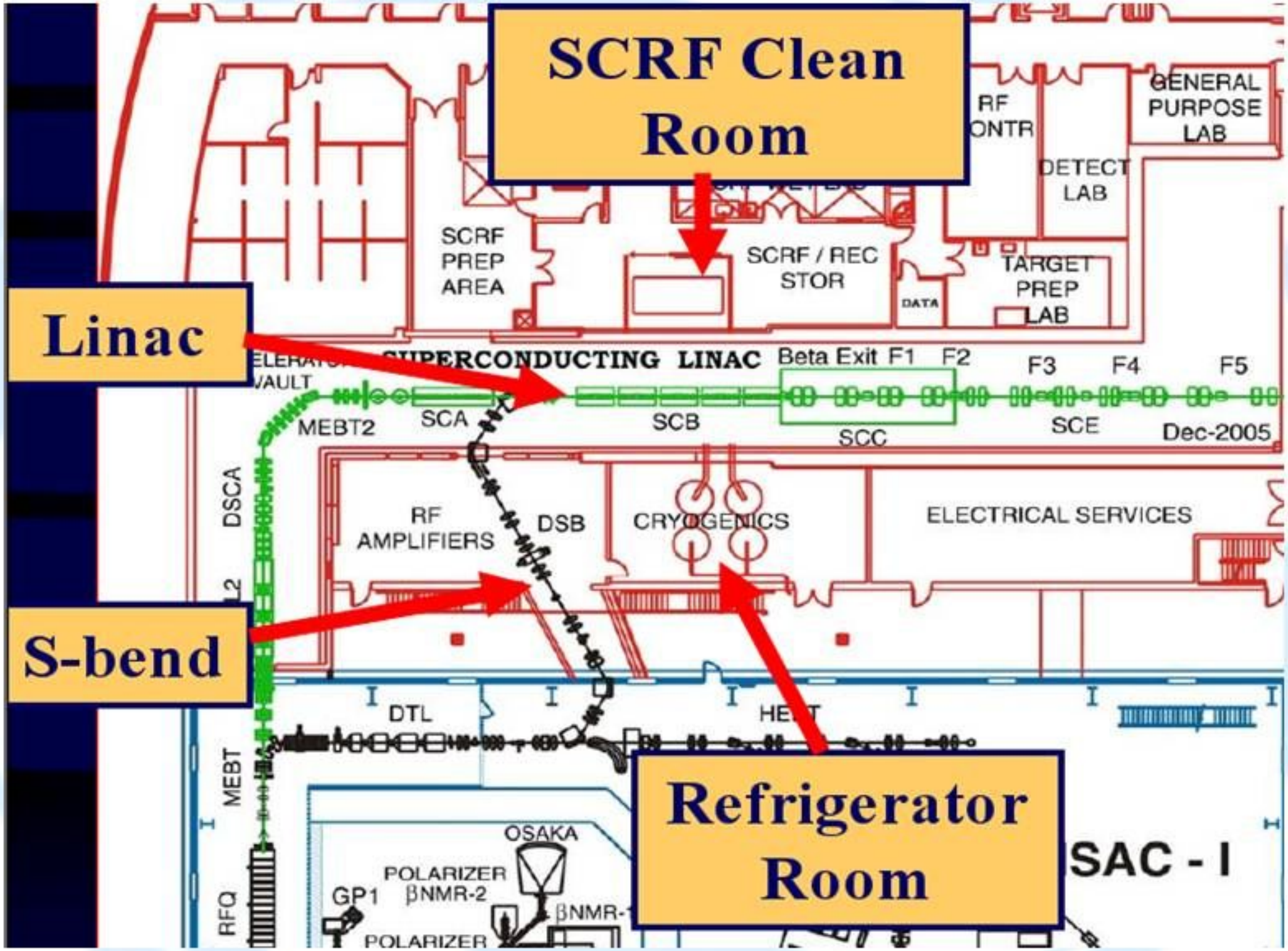
ISAC Beamline Map




SCRF Clean Room
Linac
S-bend
Refrigerator Room
SCRF PREP AREA
SCRF / REC STOR
DATA
TARGET PREP LAB
DETECT LAB
GENERAL PURPOSE LAB
RF ONTR
SUPERCONDUCTING LINAC
Beta Exit
F1
F2
F3
F4
F5
SCA
SCB
SCC
SCE
Dec-2005
MEBT2
DSCA
RF AMPLIFIERS
DSB
CRYOGENICS
ELECTRICAL SERVICES
DTL
MEBT
RFQ
OSAKA
POLARIZER
βNMR-2
GP1
βNMR-
POLARIZER
SAC - I

Cryogenics & Controls: Background

What is it?

- Why do we use it?
- Where did it come from?
- How is it controlled?

Cryogenics System Components

- Cryomodules
- Refrigeration Plants
- Cold Distribution System (CDS)
- Helium Recovery
- Related components

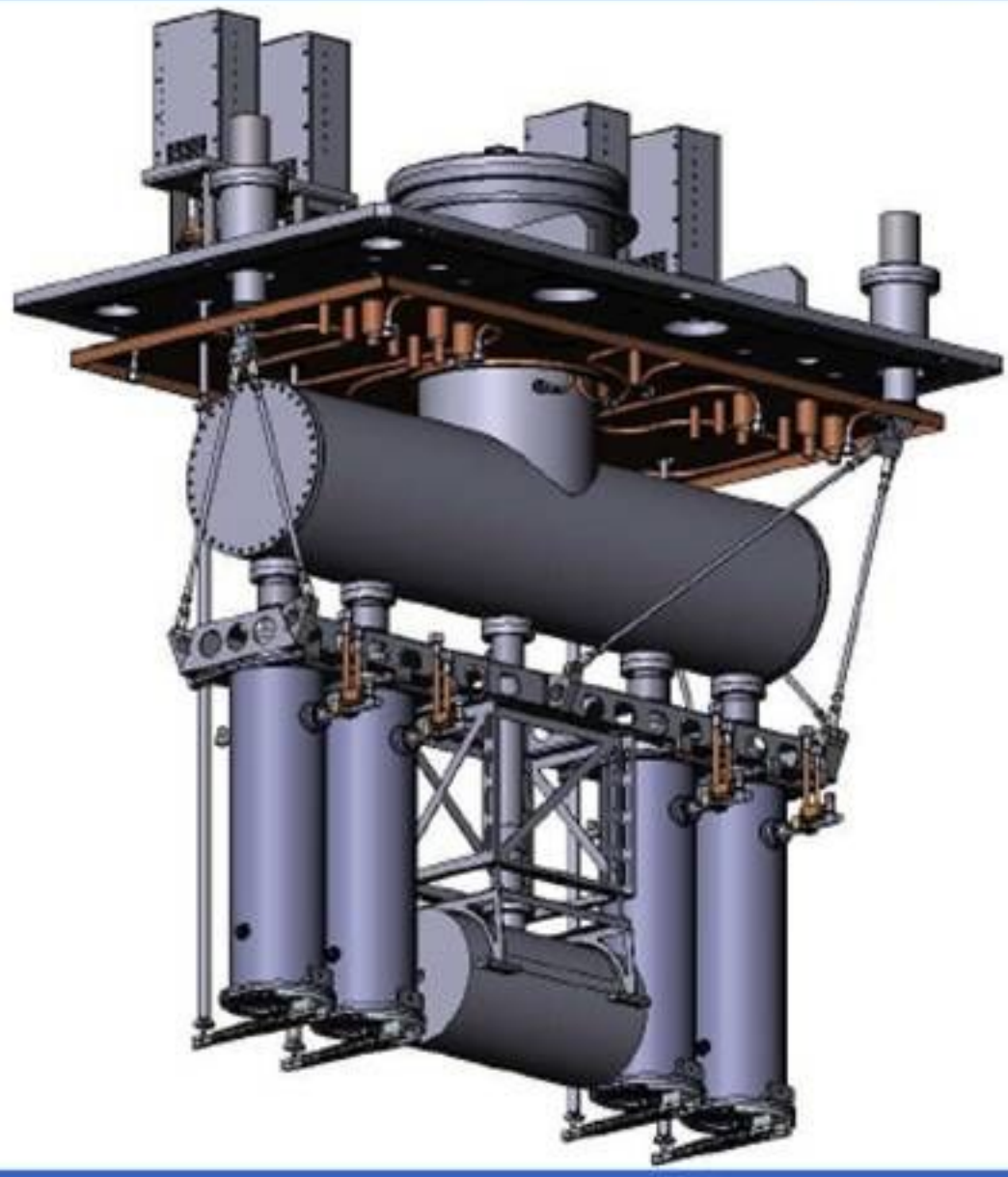
Cryogenics System Components

- Cryomodules: 5 now, 3 more soon
- Refrigeration Plants: 2
- Cold Distribution System
- Helium Recovery
- Related components

System Components: Cryomodules

- Superconducting RF Cavities
- Superconducting focusing solenoid magnet
- Physical housing and cold management
  - Vacuum insulation layer
  - Liquid Nitrogen cooling
  - Liquid Helium cooling

System Components:Cryomodules



Lid Assembly in Assembly Frame

Cryogenics System Components

- Cryomodules: 5 now, 3 more soon
- Refrigeration Plants: 2
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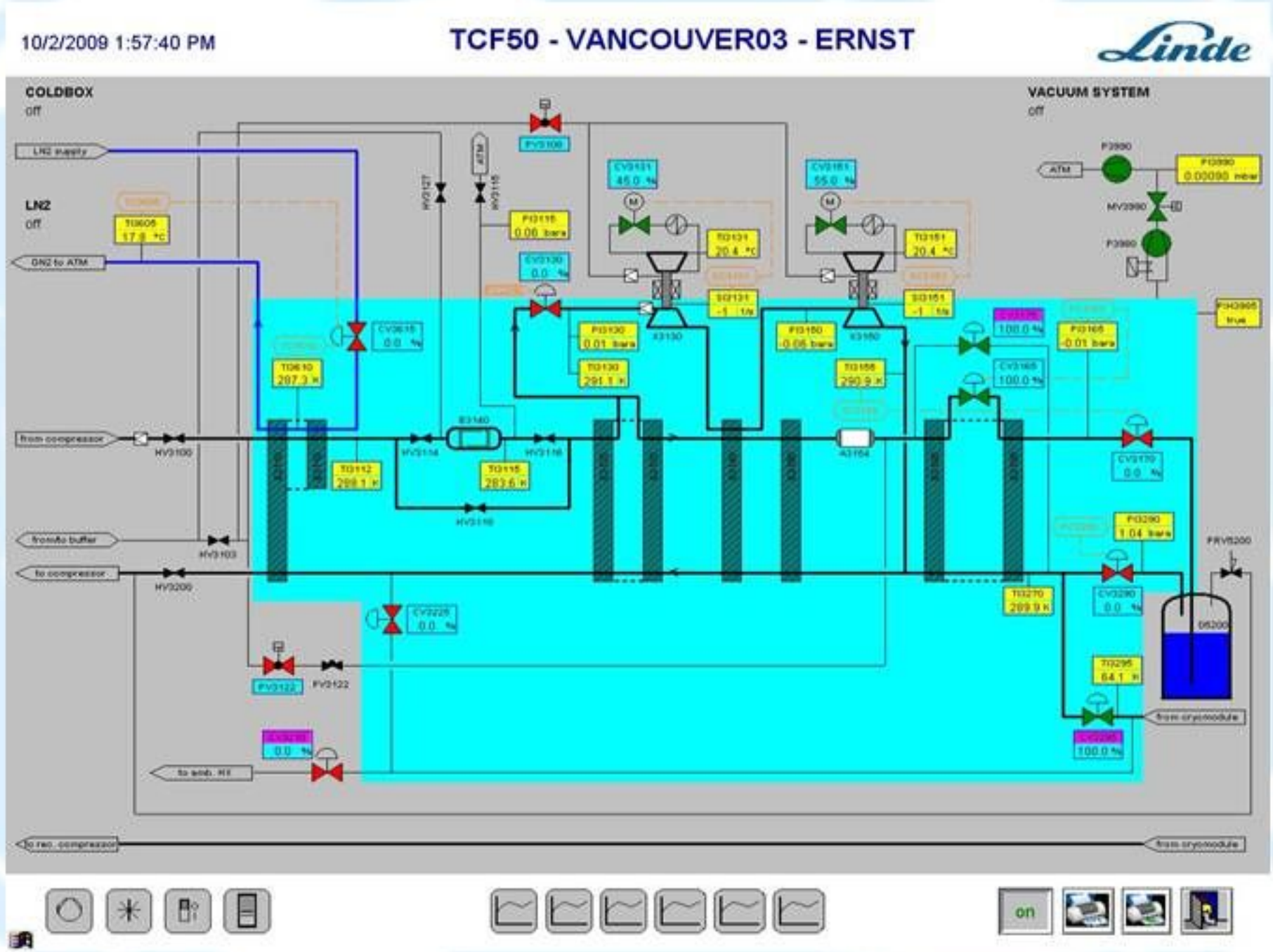
System Components: Refrigeration Plants

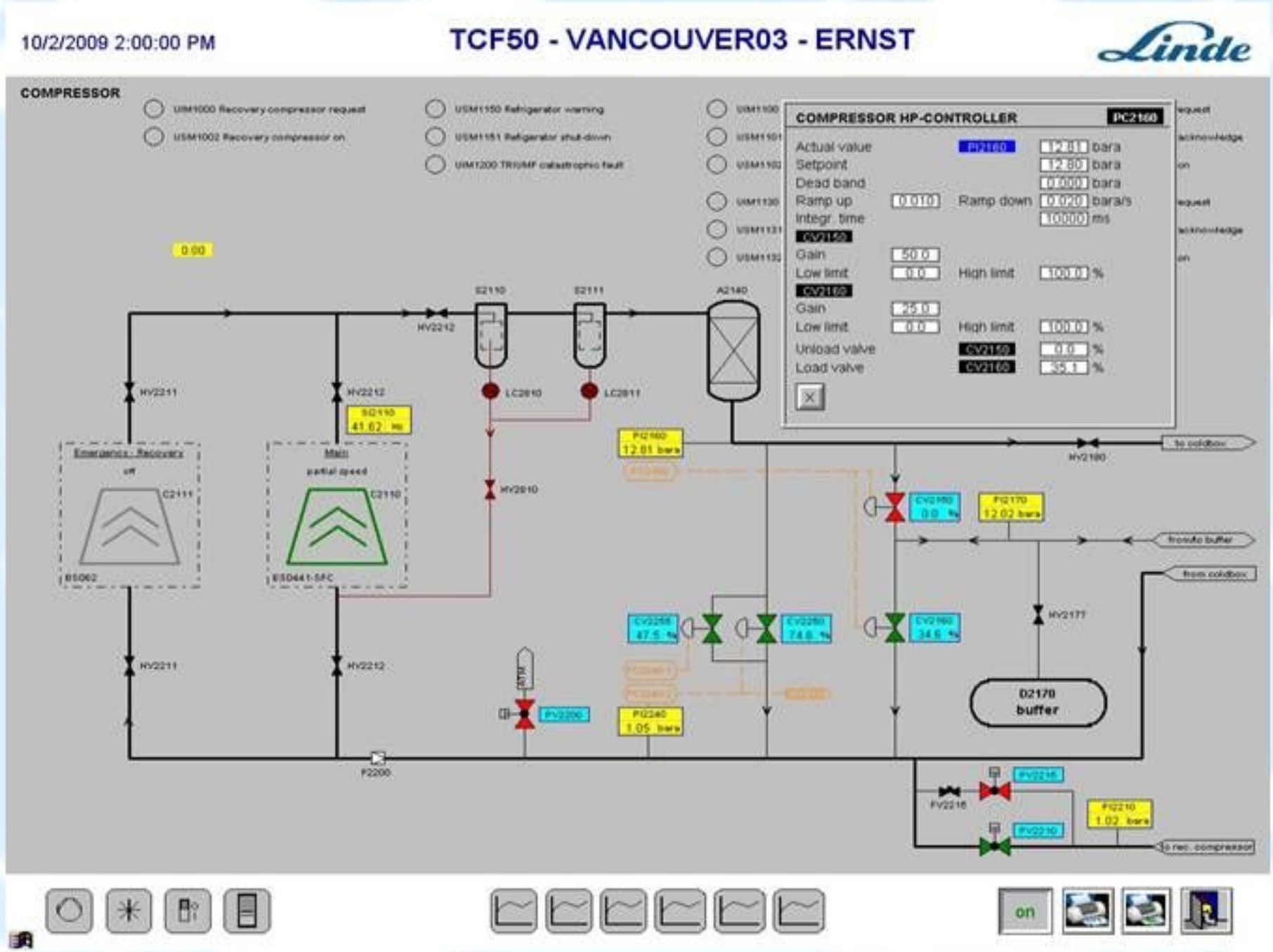
- Furnished by Linde Kryotechnik
  - Supplied in two phases
- Liquefy gaseous Helium up to 860 litre/hour,each
- Self contained turn-key packages
- Uses proprietary PLC-based control system
  - Vendor provided basic interface to ISAC Controls
  - Siemens S7 Series 400 PLC
  - Siemens/Windows based operator GUI
  - Siemens touch-panel operator interface

System Components: Coldboxes and Cold Delivery

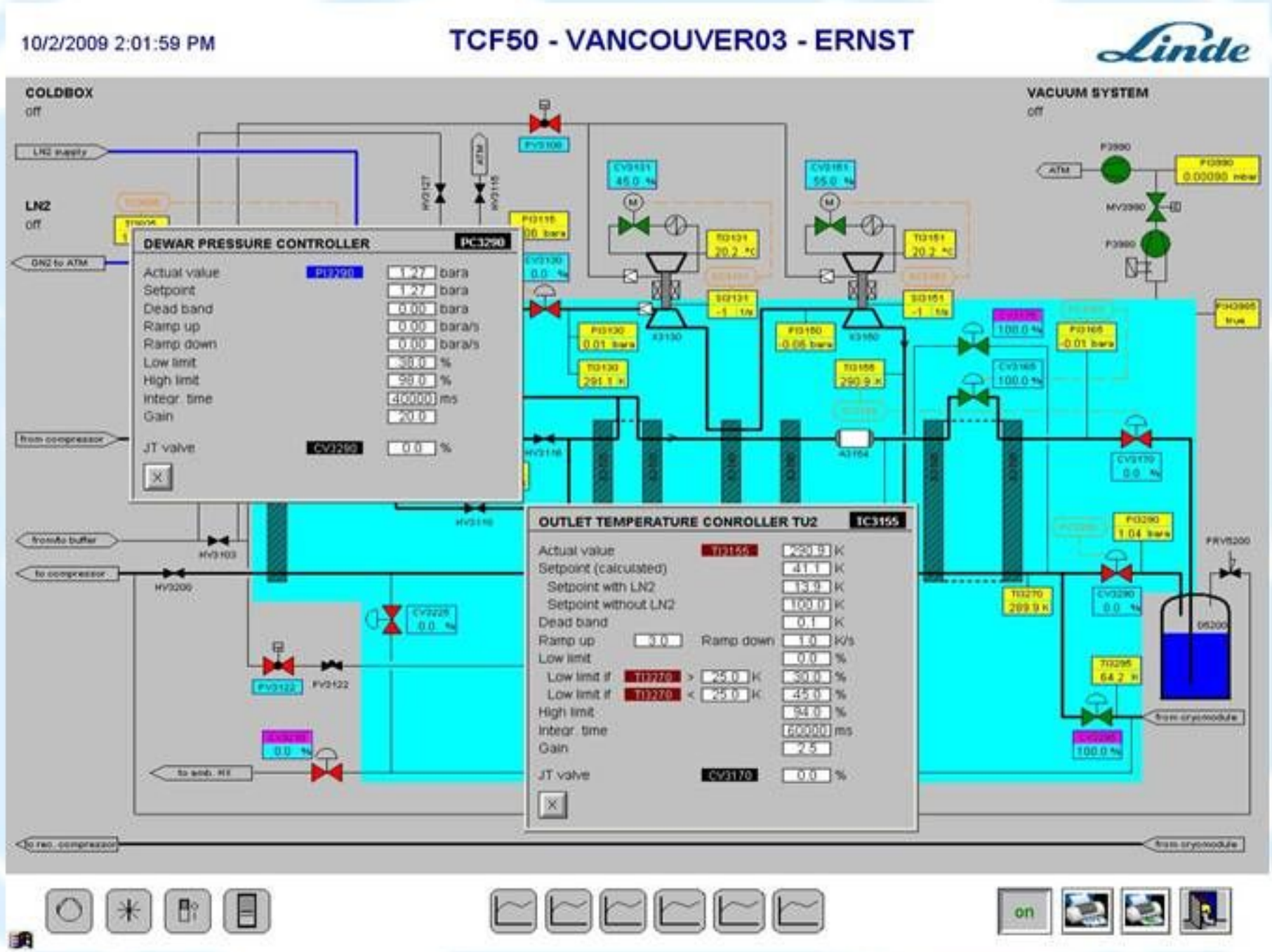
Linde-Supplied GUI



Linde-Supplied GUI



Linde-Supplied GUI



Cryogenics System Components

- Cryomodules: 5 now, 3 more soon
- Refrigeration Plants: 2
- Cold Distribution System
- Helium Recovery
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System Components:
Cold Distribution System (CDS)

- Infrastructure for distributing liquid Helium and liquid Nitrogen to the cryomodules
  - 5 cryomodules commissioned, 3 more soon
- Plumbing to and from cryomodules
  - Valves, pressure and temperature monitors, heaters

Cryogenics System Components

- Cryomodules: 5 now, 3 more soon
- Refrigeration Plants: 2
- Cold Distribution System
- Helium Recovery
- Related components

System Components: Gaseous Helium Recovery & Related Devices

- Storage of Helium during warm downtime
- Controls similar to CDS
- SCRF Test stand
  - Throttling Butterfly Valve
  - Stand-alone Temperature monitor
  - Other conventional devices
- Helium purity monitor
  - Monitors Nitrogen in recycled Helium

Control System & Integration

- ISAC uses EPICS
- CDS requirements similar to existing vacuum controls
  - Cold Distribution System and He Recovery Controls built in-house
  - Modeled on existing beamline vacuum controls
- Turn-key systems use proprietary control system
- Integration is major part of control system effort

ISAC Standard Already in Place

- PLC based vacuum controls
- EPICS supervisory role
- ISAC-standard EPICS-based applications
  - EDM
  - Capfast-based runtime DB design
  - Alarm-handler, StripTool, Backup/Restore tool, Channel Archiver, others
- Standard includes design methods, programming models, look and feel

ISAC Standard PLCs used for CDS and Recovery

- ISAC standard model for beamline vacuum controls

- Some elements of cryogenics system are vacuum
  - Existing model expanded to control cryogenics
  - Similar device types; model is a good fit

- Modicon PLCs
  - Initially Modsoft, now Concept
  - Programming model expedites EPICS connectivity

ISAC Standard PLCs used for CDS and Recovery

- EPICS IOCs
  - Now hosted on Linux,
    - Previously vxWorks on VME, then PC/104
  - EPICS modtcp device support by R. Keitel
  - One IOC per PLC
  - Multiple IOCs co-hosted on Dell rack-mount Linux hosts
    - Scientific Linux 4.x, moving to 5.x

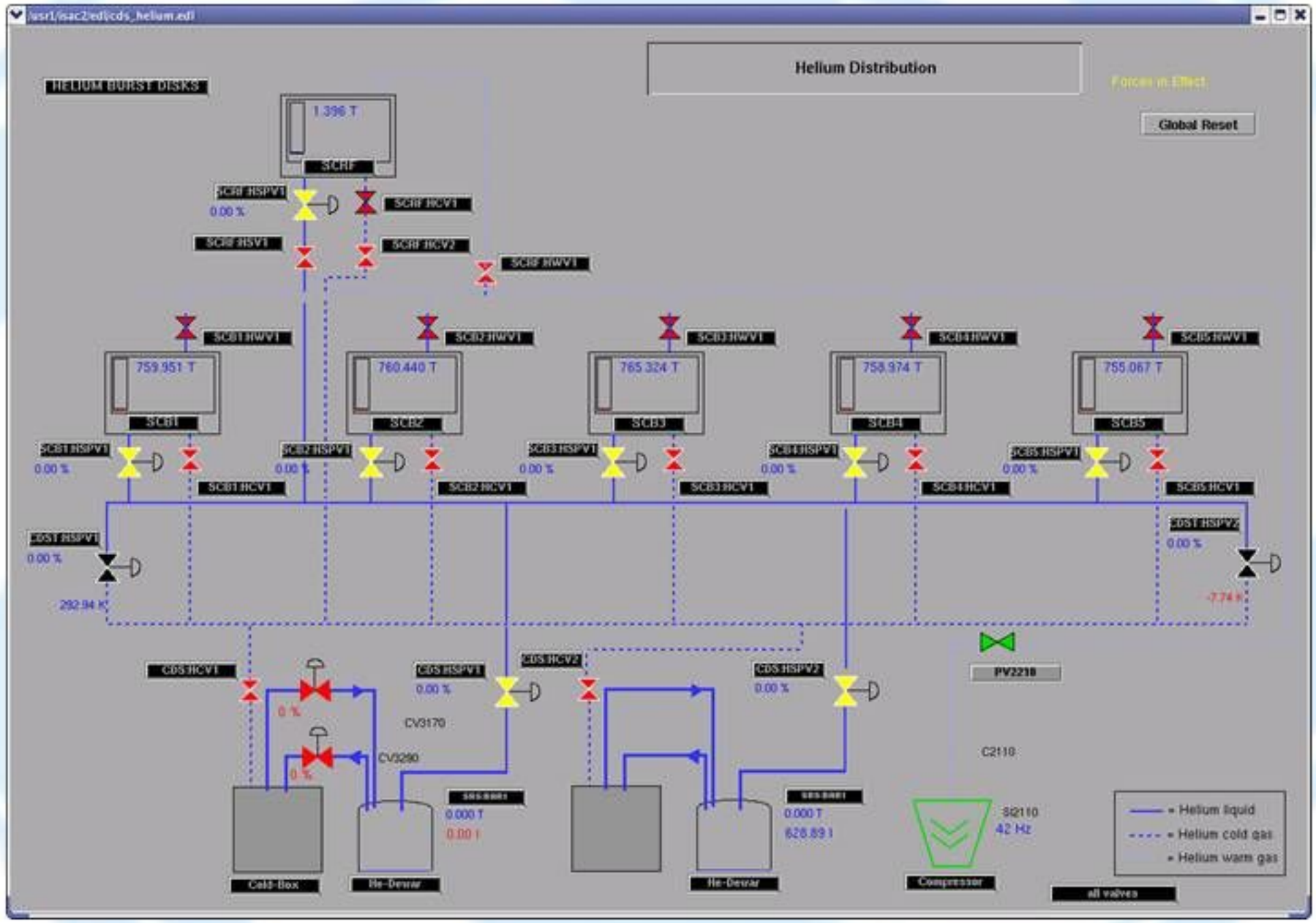
CDS PLC Programming Model

- Uses function-block-like model
- Coded for compatibility with EPICS modtcp
  - Data read and written in blocks via TCP
  - Standardized data structures
- Exports data for generation of EPICS displays
  - Interlock logic displayed on operator interface always matches PLC code implementation

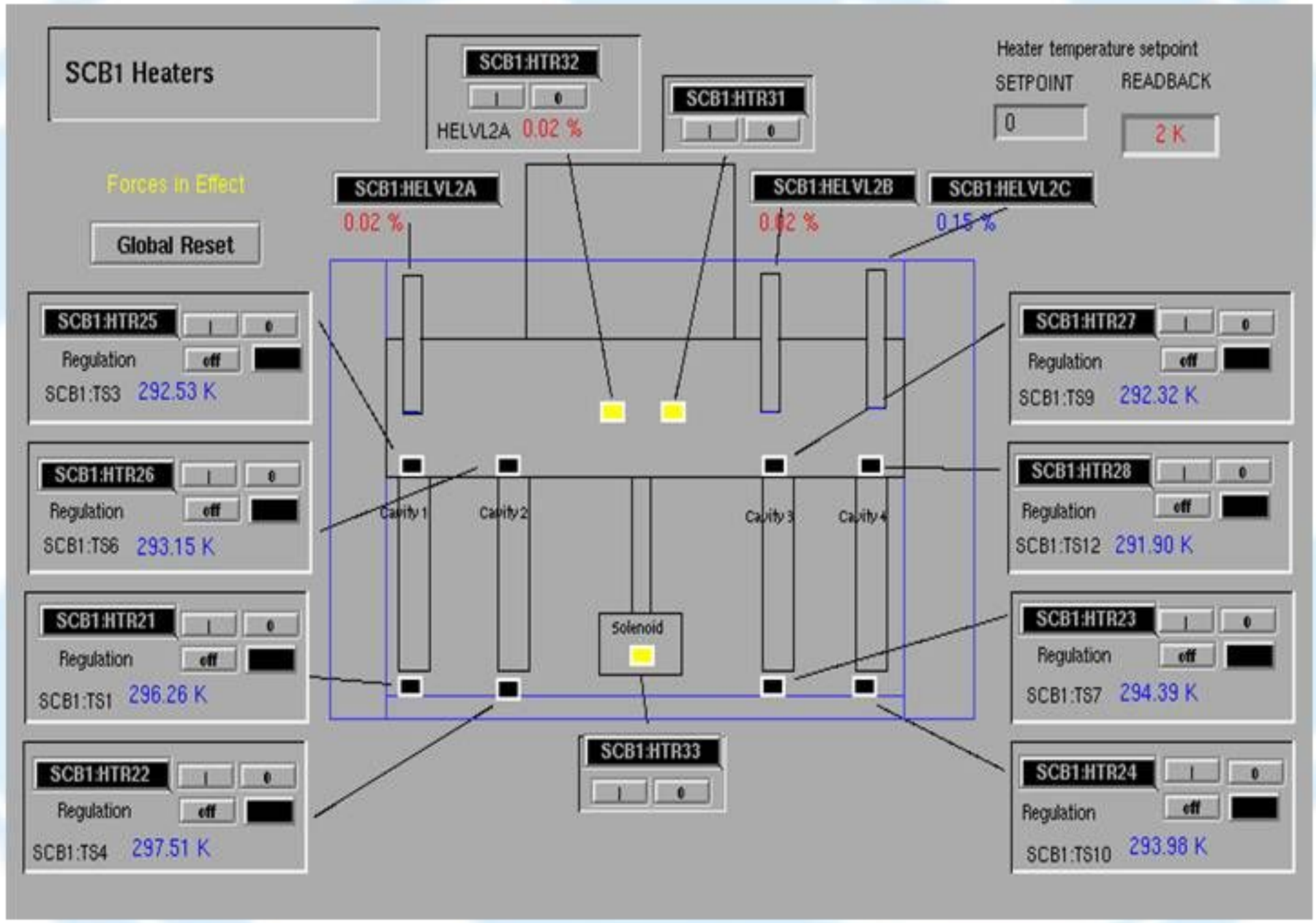
CDS Controls, General

- Cryogenics controls are a proper subsystem of ISAC
  - Consistent behavior and look & feel
  - Uses same development tools
  - Efficient deployment
- Seamless integration with ISAC Control system achieved

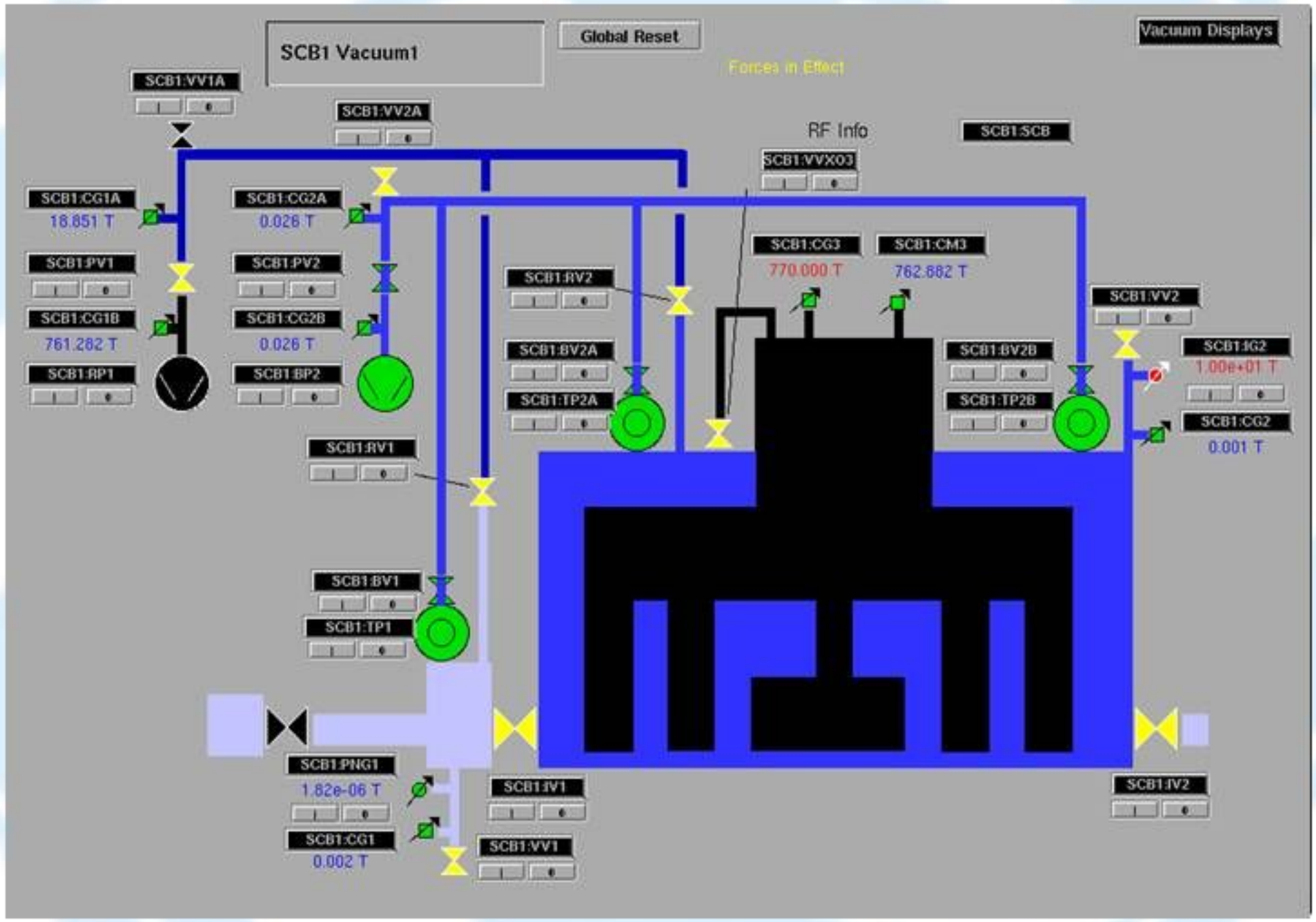
CDS Controls: EDM



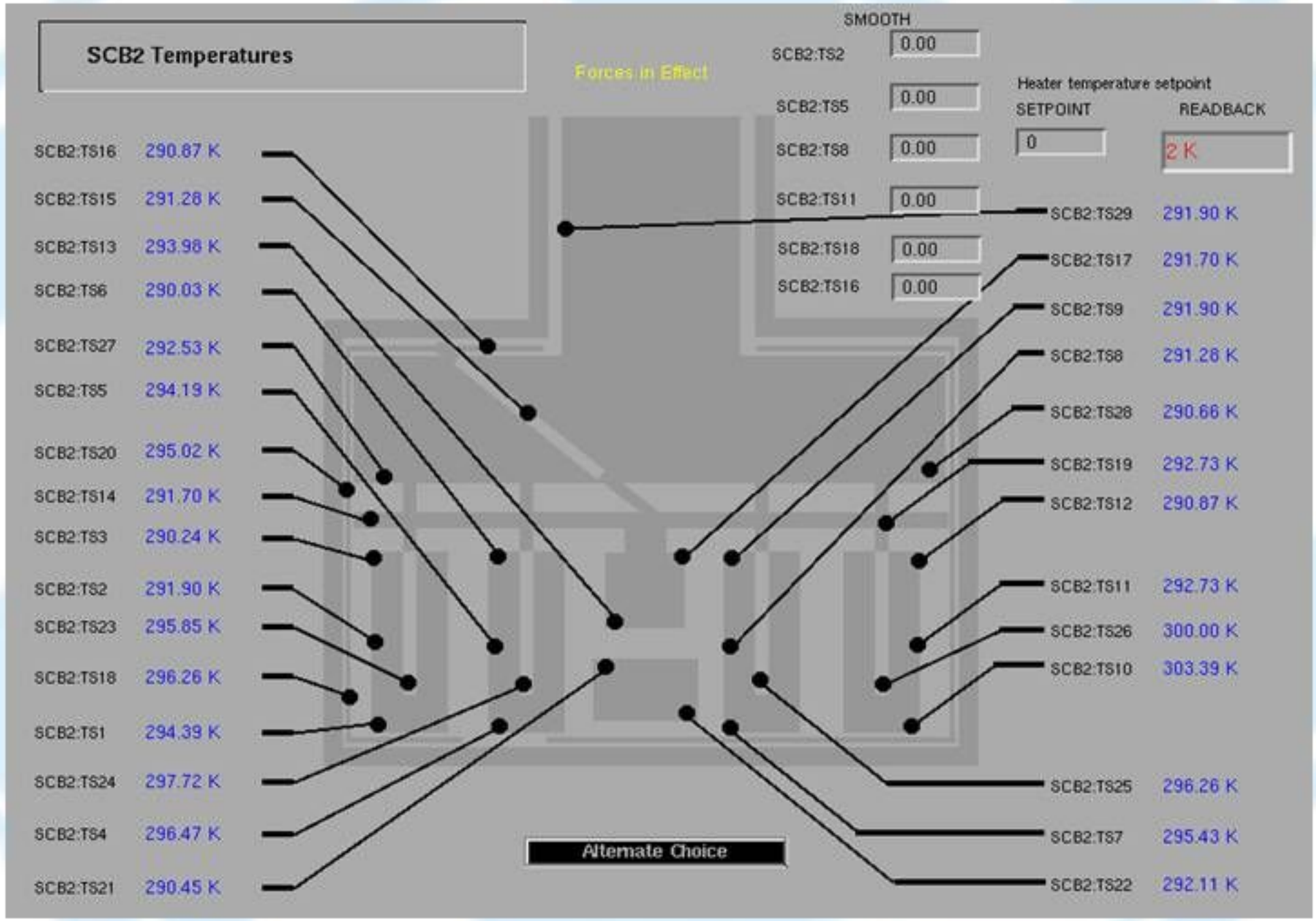
CDS Controls: EDM



CDS Controls: EDM



CDS Controls: EDM



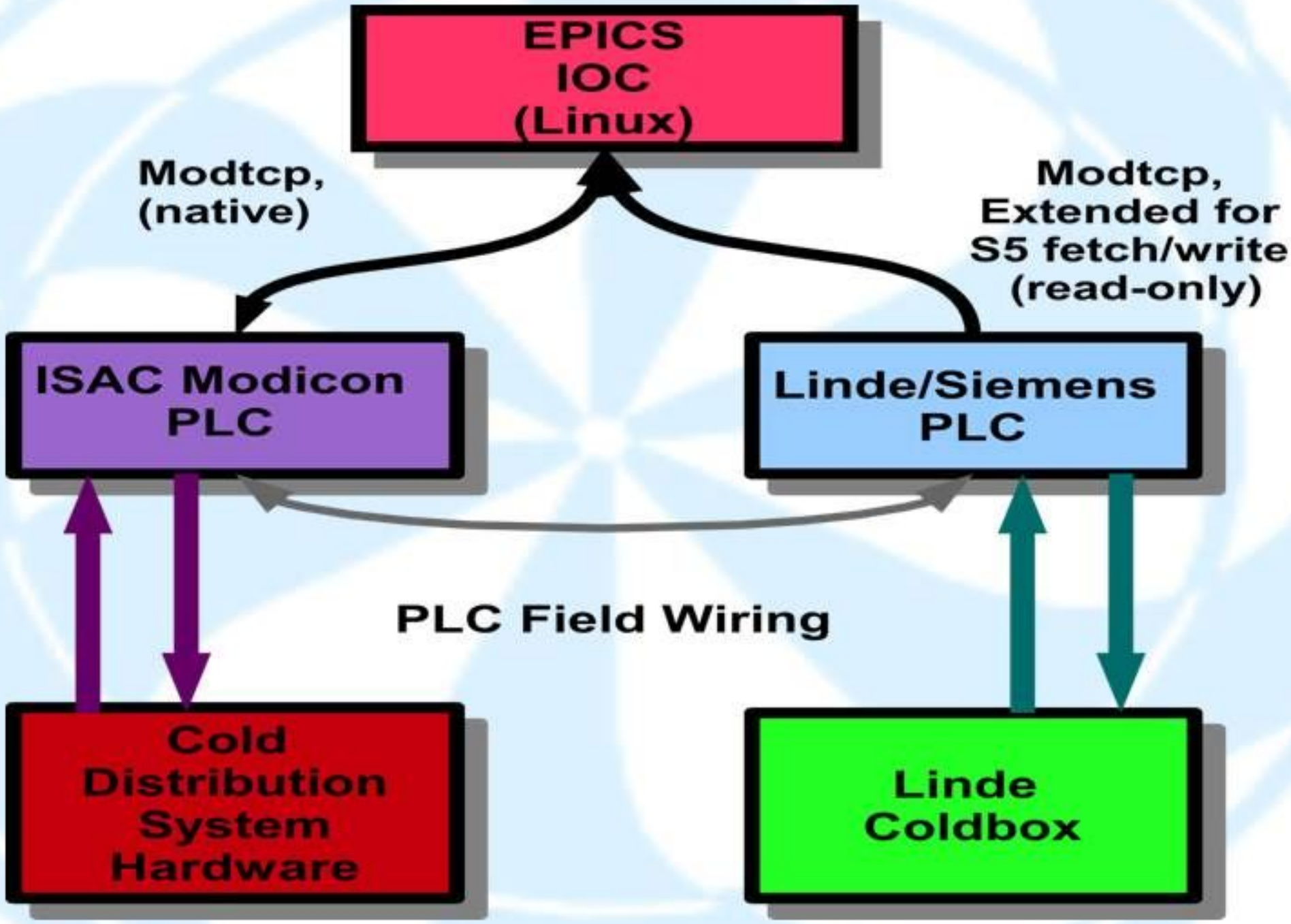
Integration With Turnkey System, Phase I

- Hoped for Modicon-based controls
  - Quote tendered was too much additional cost
- Vendor provided hardwire interface to initiate major control modes
  - Cool-down, warm-up, two run modes
- CDS PLC provides contact closure to drive refrigeration modes

Controls Integration, Phase I

- In-situ PLC program modification by vendor during first system commissioning
  - Allowed reading blocks of key data by EPICS
  - No write capability
- In-house EPICS device support for Siemens PLC
  - Modification of modtcp device support

Phase I Block Diagram



Control System Integration, Phase II

- More complete EPICS Device Support for Siemens PLC

- CDS: more of the same
  - Cold Distribution System controlled by PLC + EPICS

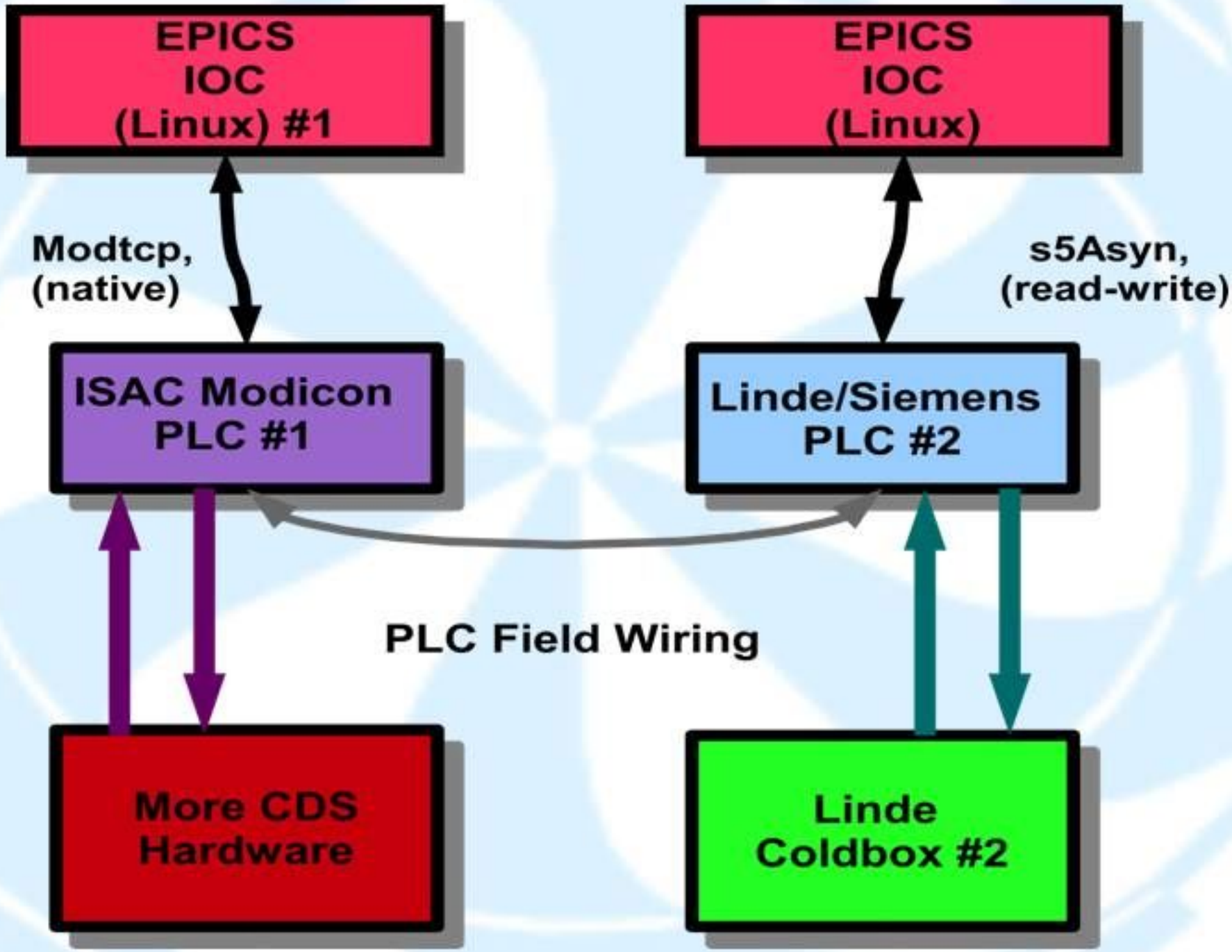
EPICS Support for Siemens PLCs

- Full read-write access to all data spaces
- Uses Siemens S5 Fetch-Write protocol
- Software based on EPICS Asyn driver
  - Code modeled on M. Rivers' modbus support
- Required cooperation of Linde to provide map of key process variables
- Not as efficient as existing Modicon standard

EPICS Support for Siemens PLCs

- PLC holds master copy of all process variables
  - Requires read polling of EPICS output Process Variables for synchronization
- Address spaces of interest are not in contiguous blocks
  - Many small blocks, less efficient to read
- Process variables are of mixed sizes
  - Requires knowledge of PLC address map for correct interpretation
- Difficult to match ISAC standard deployment model

Phase II Block Diagram



Other Devices

- Helium Purity Monitor
  - Embedded HTTP Server
  - EPICS Device Support via StreamDevice + Asyn
- SCRF Test Stand
  - Many conventional CDS devices and controls
  - Now includes Throttling Butterfly Valve
    - Automatic Pressure Controller
    - Setpoints and Readbacks on RS-232 via StreamDevice + Asyn
    - Another ISAC standard method adopted

Integration: Motherhood Issues

- Vendors unaccustomed to needs of accelerator labs
  - Exposing internal functionality
  - Don't have personnel familiar with levels of detail we need
  - Expect to provide the 'master' control system

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  - Allows us to help ourselves

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  - Allows us to help ourselves
- Cooperation of vendors
  - Only they can provide some crucial information

Summary

- Success!
- Not as perfect as we would like
  - Not a perfect world, some aspects don't fit the mold
- Reliable
  - Phase I in service since 2005
  - Phase II controls in service since February 2009
  - No hiccups so far
- Thanks to
  - Mark Rivers (modbus)
  - Marty Kraimer & Eric Norum (asyn)
  - Dirk Zimock (StreamDevice)

The real reason for cooling

Thank you!

Merci!

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