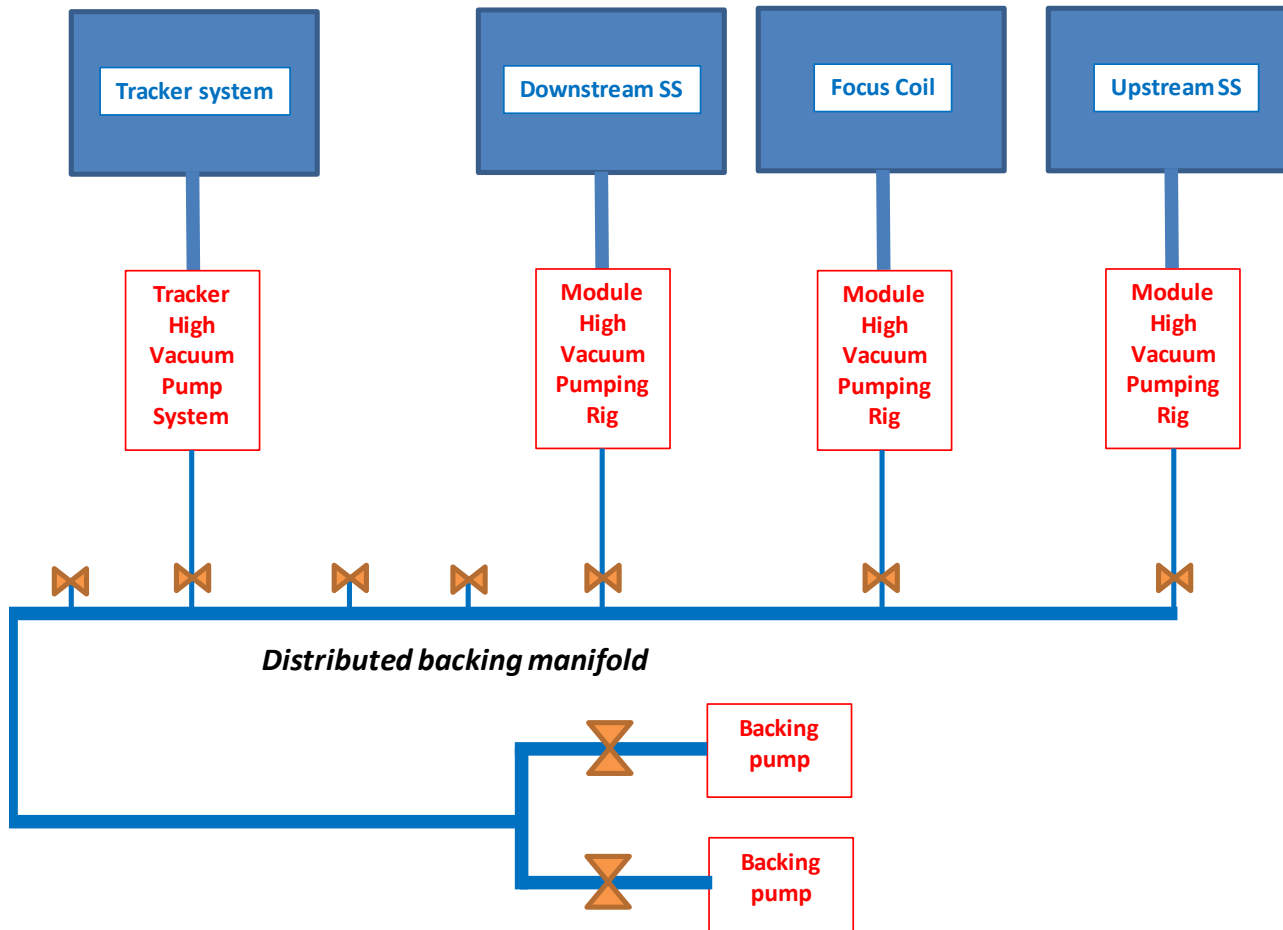# The MICE vacuum system

Presented by Mark Tucker

at

CM-39, 26 June 2014

Schematic diagram

The Distributed Backing Manifold

- A long pipe (100mm internal diameter) to which high-vacuum (HV) systems are connected
- Evacuated by an Edwards iQ pump (500 m³/hr) ROOTS pump backed by a dry pump
- Second iQ pump is spare (back-up when other is serviced or faulty)
- Ultimate pressure of iQ pump is 2×10^{-3} mbar
- iQ pumps are very clean, designed for semiconductor fabrication industry
- iQ pump shaft seals are flushed with nitrogen gas from PEAK Scientific nitrogen generators

Expected pressure in backing manifold

- Pipe of diameter d = 100mm has length, L = 20 metres
- Under typical operating conditions (backing TMPs with cryostats at low pressure) expect molecular flow close to iQ pump, where d.p < 0.06 mbar.cm, and Knudsen flow (intermediate between laminar and molecular) closer to the HV rigs
- Conductance increases with pressure so the system is stable
- Under typical operating conditions, expect pressure to be < 2 x 10^{-2} mbar at the end furthest from the pump

Expected backing pressure at TMP

- HV pumping rigs connected to backing manifold by flexible hoses of 40mm internal diameter, approximately 1 to 2 metres long

- Conductance of flexible hose less than conductance of main pipe if hose length > 1.3m

- Expect typical backing pressures at TMP during pump-down to be < 0.15 mbar if hose is 2m long. This pressure will be lower during normal running due to low flow rates.

Tom Weston's drawing
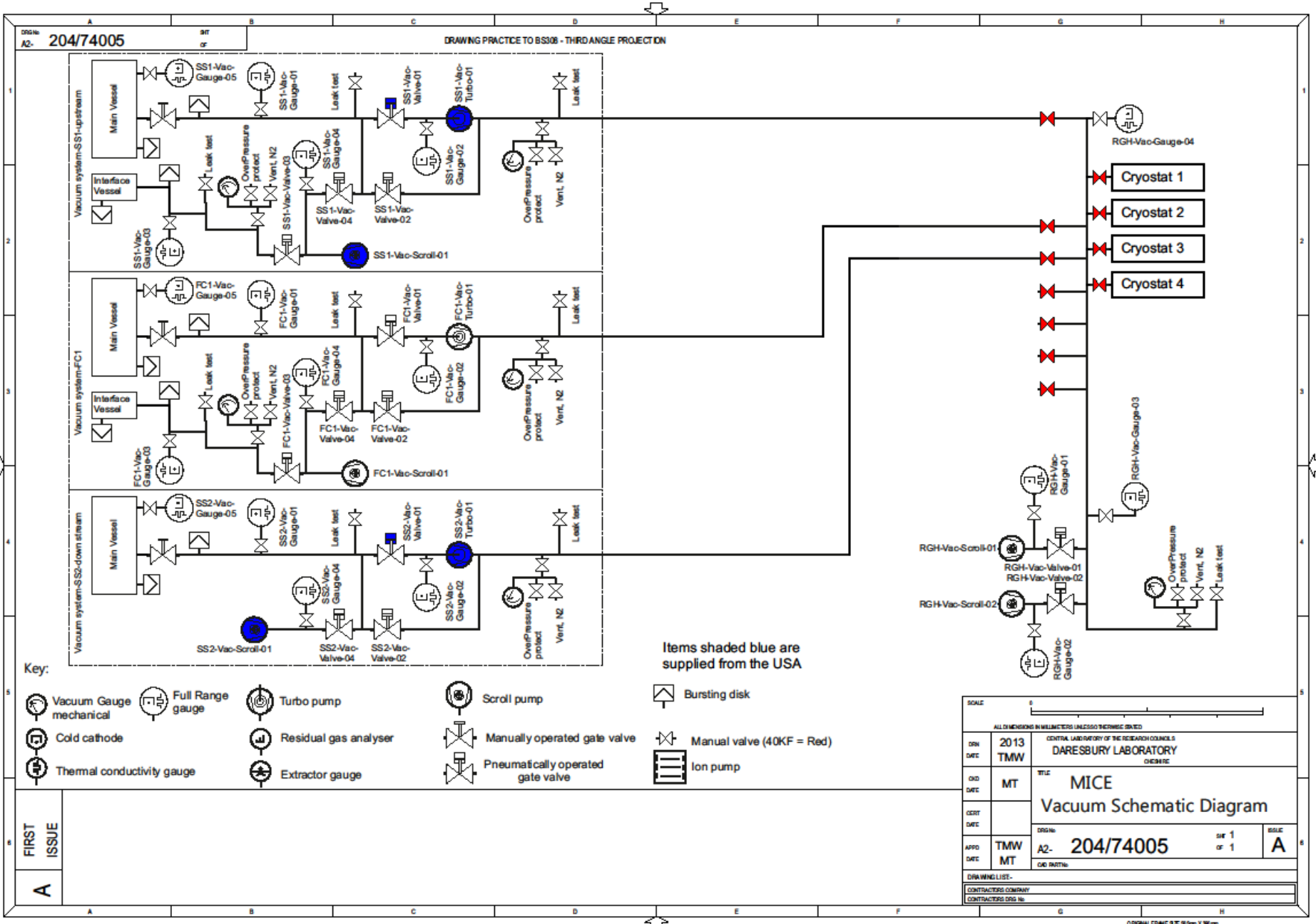
Module Pumping Rigs (pipework)

A = DN 40 KF to Interface vessel via flexible hose

B = DN 40 KF to Backing Manifold via flexible hose

C = three DN 25 KF ports for leak-testing
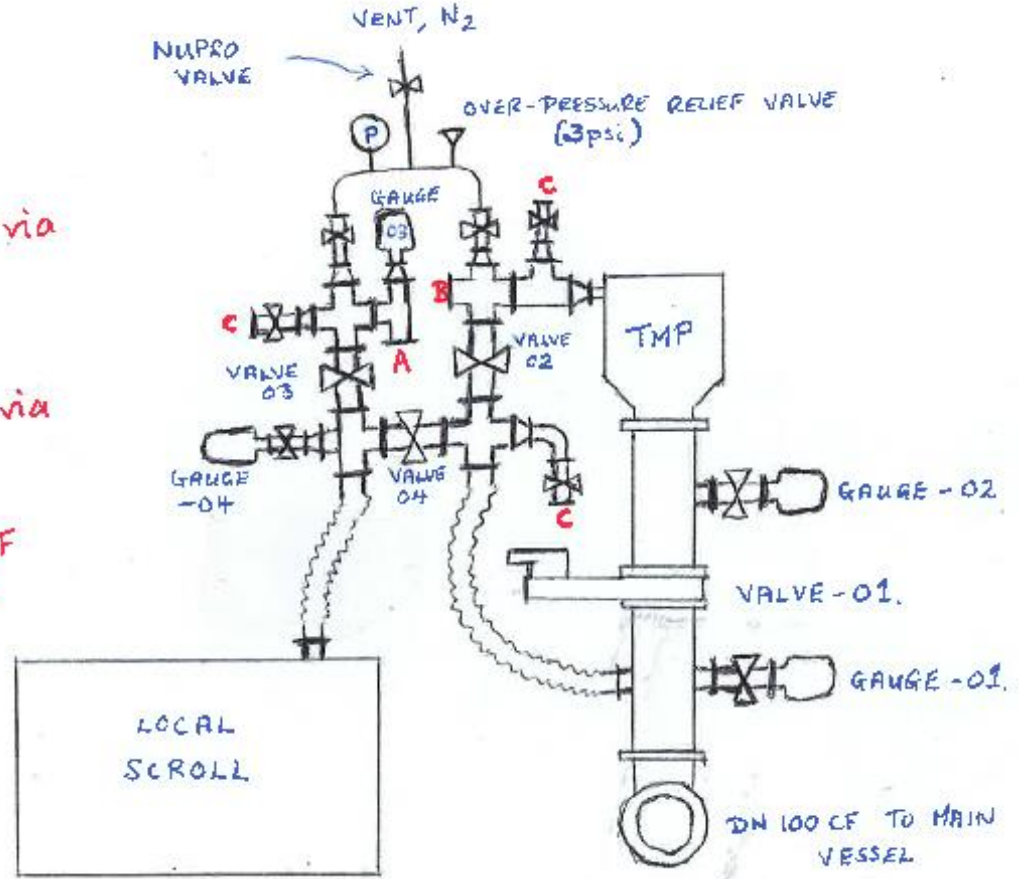
Venting

Venting of the systems must comply with STFC Safety Code No 33 (Safety of pressure and vacuum systems). Hence over-pressure valves, mechanical gauges and dedicated vent valves have been included.

The leak test port is not to be used for venting.

Over-pressure protection is provided by bursting disks connected directly to the main vessels and the pumping line between the vessel and any valve.

Mice Vacuum system venting procedure.

The venting system shown below includes a pressure relief valve, Dial vacuum gauge, permanently connected to N_2 Nupro vent valve. All the afore mentioned are isolated from the main vacuum system by a manual vacuum valve.

The system is to be used in the following manner:

1. Ensure the vacuum valves between the vacuum pumps and vacuum chamber are fully closed.
2. Open the N_2 Nupro vent valve and allow N2 to flow into the vent system, check that escaping gas passes through the vent valve, the vacuum gauge should show a =+'ve pressure of no more than ?? bar.
3. Once satisfied that the over pressure valve is working, close the N_2 Nupro vent valve.
4. Open the main valve to the vacuum chamber.
5. The overpressure valve will now indicate vacuum.
6. Next open the N_2 Nupro vent valve to continue with venting the vacuum chamber.
7. Remain with the system until is fully vented according to the local gauge.
8. Close the N_2 Nupro vent valve. The system is now vented.
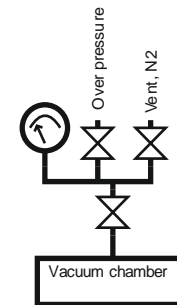
System description

Module (SS/FC) pumping system

- Initial rough pumping of the modules from atmospheric pressure to 0.5mbar is provided by scroll pumps (typically $10m^3$/hr) to avoid damage to vessel MLI by excessive viscous flow. Below 0.5mbar, the system will automatically switch over to the main backing line with the $500m^3$/hr pump.

- Pressure monitoring will be provided by wide range gauges with magnetic shielding.

- At a predefined pressure the turbo pump will be turned on and the isolating valve opened, the by-pass valve will be closed automatically and maximum pumping will have been achieved.

- Vacuum leak detection will be carried using a leak detector which can be connected to one of the many leak detection ports as and when required.

Inter-space pumping system

- Pumping will be provided by a dedicated scroll pump protected by a controlled isolation valve. No turbo pump is required.

- Pressure monitoring and leak detection will be the same as described above.

Quench protection

In the event of a rapid pressure rise to $p > 6 \times 10^{-3}$ mbar:

- The valve SS?-Vac-Valve-01 will close to protect the turbo pump
- The turbo pump will be switched off
- The turbo bypass valve, SS?-Vac-Valve-02, will open to ensure pumping continues via Scroll-02.

When the pressure decreases below 5 x 10-3 mbar:

- Valve-01 will open
- Valve-02 will close
- The turbo pump will be switched on

Pressure interlocks (Main Vessel)

Pressure (mbar)	Plant	Status
> 0.5	SS?-Vac-Valve-01	Open
	SS?-Vac-Valve-02	Open
	SS?-Vac-Valve-04	Open
	SS?-Vac-Turbo-01	Off
	SS?-Vac-Scroll-01	On
	Manual valve isolating distributed backing line	Closed
0.05 < p < 0.5	SS?-Vac-Valve-01	Open
	SS?-Vac-Valve-02	Open
	SS?-Vac-Valve-04	Closed
	SS?-Vac-Turbo-01	Off
	SS?-Vac-Scroll-02	On
	Manual valve isolating distributed backing line	Open
< 0.05	SS?-Vac-Valve-01	Open
	SS?-Vac-Valve-02	Closed
	SS?-Vac-Valve-04	Closed
	SS?-Vac-Turbo-01	On
	SS?-Vac-Scroll-02	On
	Manual valve isolating distributed backing line	Open

- If a TMP fails or is switched off, the associated SS-Vac-Valve-01 is closed
- Gauges remain ON at all times

Pressure interlocks (Interface Vessel)

- If SS?-Vac-Gauge-03 = atmospheric pressure and SS?-Vac-Gauge-04 = less than atmospheric pressure, then SS?-Vac-Valve-03 must remain closed.

- This ensures that the Main Vessel can be pumped down even when the Interface Vessel is open to atmosphere/vented with N gas.

Pressure interlocks
(Distributed Backing Manifold)

On pump fail, or local power off, the associated valve RGH-Vac-Valve-01/02 will close.

RGH-Vac-Valve-01/02 can only be opened if either:
- RGH-Vac-Gauge-01/02 and RGH-Vac-Gauge-03 are both at atmospheric pressure, or
- RGH-Vac-Gauge-01/02 and RGH-Vac-Gauge-03 are both at $p < 0.5$mbar

Whilst pumping from atmosphere to operational vacuum the pump's associated valve RGH-Vac-Valve-01/02 should be open provided that RGH-Vac-Gauge-01/02 is less than RGH-Vac-Gauge-04

scenarios for system control

1) pump from atmosphere for complete step IV in beamline position.

- Request status of all plant. Reset all plant to known initial conditions.
- Ensure all pneumatic valves are open. Manual gate valve is open.
- Ensure manual valves to backing lines are closed and distributed backing line is under vacuum.
- Start scroll pump 01.
- When pressure less than 0.5 mbar, open the manual valve to the distributed backing system. Close SS?-Vac-Valve-04. Leave Scroll-01 running to pump the interface vessel.
- Wait until pressure in main vessel < 0.05 mbar, then close SS?-Vac-Valve-02, start turbo pump.
- System is now under normal running

1a) **In maintenance position (out of beam)**

- Manual gate-valve to the vessel will be closed
- Connect to a portable pumping rig

1c) **Interface vessel open to atmosphere**

- As 1), but with SS?-Vac-Valve-03 closed

2) Normal operation

- Distributed backing system running continuously
- If SS?-Vac-Valve-01 < 8 x 10-8 mbar, close SS?-Vac-Valve-01 (cryopumping mode)
- Switch off turbo after 30 minutes, unless…
- If SS?Vac-Valve-01 > 2 x 10-7 mbar, SS?-Vac-Valve-01 is closed, and turbo is off: switch on turbo
- If SS?-Vac-Valve-01 > 2.5 x 10-7 mbar, turbo at full speed, and gauge-02 within a decade of gauge-01, open SS?-Vac-Valve-01

3) Failure modes

- If computer failure occurs, the control system carries on as indicated by the pressure interlocks

- If the control system fails, the computer will be unable to obtain status updates – alert operator of potential failure

- If magnets quench, expect a fast pressure rise. Open SS?-Vac-Valve-02 if SS?-Vac-Gauge-01 pressure > RGH-Vac-Gauge-04. Turn turbo off.
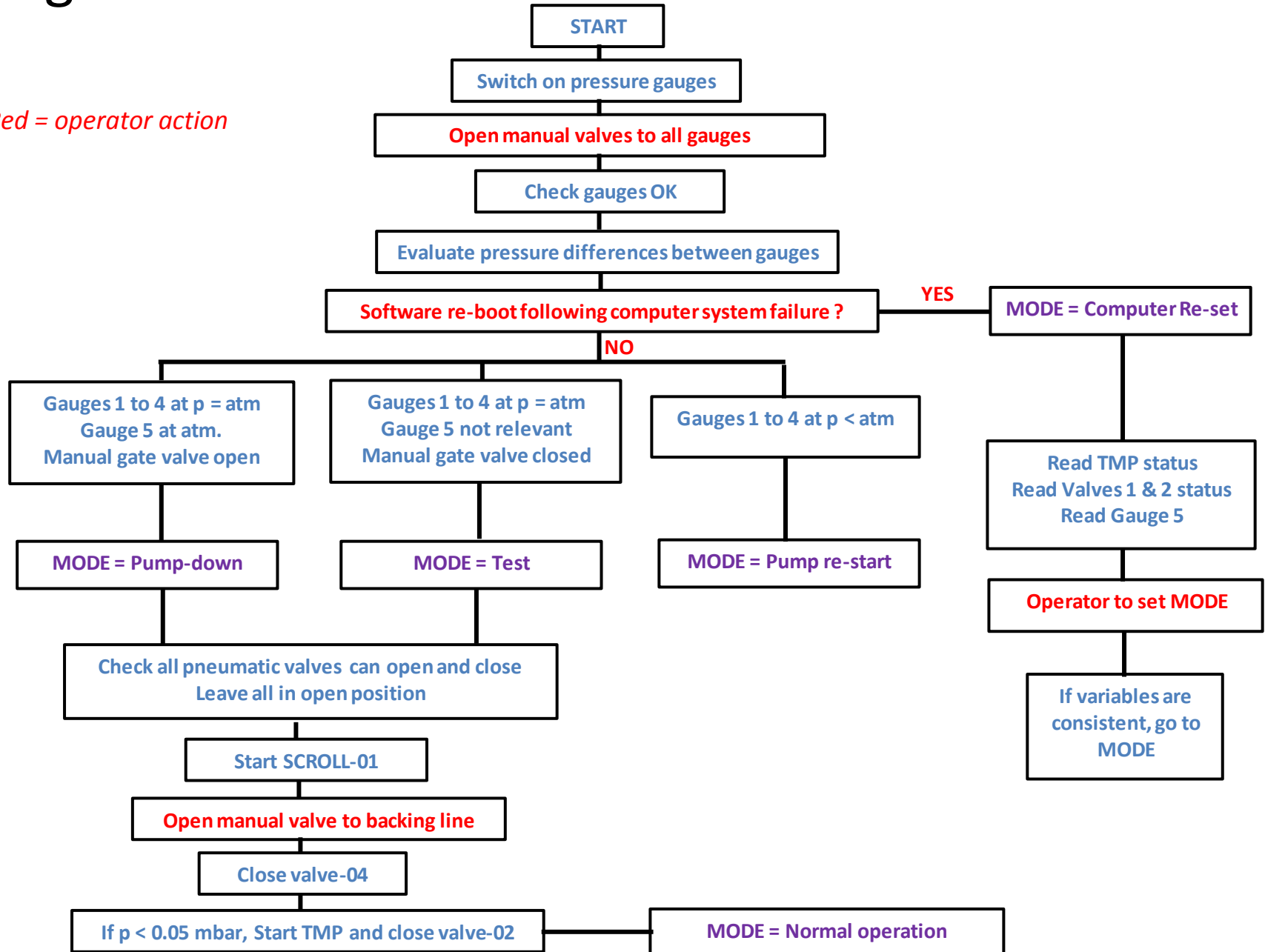
4) Planned vent

- Operator selects "Vent" mode on computer
- Close SS?-Vac-Valve-01
- Stop Turbo
- Close manual valve to distributed backing system
- Open SS?-Vac-Valve-02
- Vent using manual venting procedure given in earlier slide

Computer software procedure

- Check gauges are ON, no faults.
- Check pressures and determine start-up procedure
- Check of initial status and set MODE =
  - Pump-down from atmosphere
  - Test (pump-down of pumping system only, not vessels)
  - Pump re-start (system under vacuum)
  - Computer re-set (re-establishment of computer control on re-starting software – monitors only, until operator resets ability to control)
- All text outputs written to the GUI, and all operator responses via the GUI, are written to a log-file complete with date and time of each entry.

Logic network

Red = operator action

START

Switch on pressure gauges

Open manual valves to all gauges
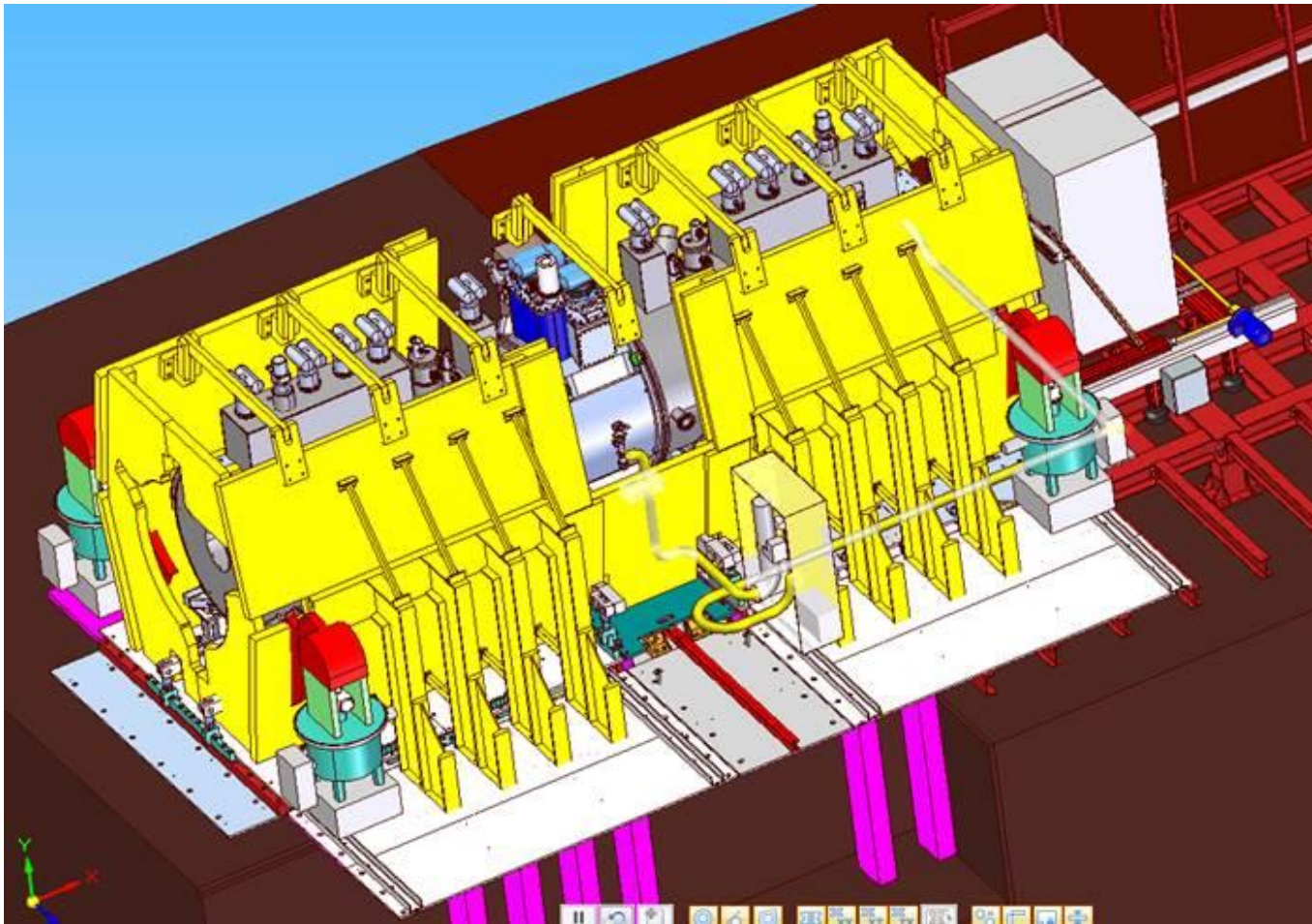
Check gauges OK

Evaluate pressure differences between gauges

Software re-boot following computer system failure ? — **YES** → **MODE = Computer Re-set**

NO

- **Gauges 1 to 4 at p = atm**
  Gauge 5 at atm.
  Manual gate valve open
  → **MODE = Pump-down**

- **Gauges 1 to 4 at p = atm**
  Gauge 5 not relevant
  Manual gate valve closed
  → **MODE = Test**

- **Gauges 1 to 4 at p < atm**
  → **MODE = Pump re-start**

MODE = Computer Re-set →
Read TMP status
Read Valves 1 & 2 status
Read Gauge 5
→ **Operator to set MODE**
→ **If variables are consistent, go to MODE**

Check all pneumatic valves can open and close
Leave all in open position

Start SCROLL-01

Open manual valve to backing line

Close valve-04

If p < 0.05 mbar, Start TMP and close valve-02 → **MODE = Normal operation**

Jason's drawing 1

Jason's drawing 2

Timescale to completion

Distributed Backing Manifold: end of July
Individual pumping rigs: end of August
High-vacuum pipes to vessels: end of September
Control system   ?
Computer control software   ?
Services:

- Electricity (single phase)   ?
- Electricity (three phase)   ?
- Water   ?
- Nitrogen gas (for venting) ?
- Compressed air   ?