NLC Failure Resistant Sector Design

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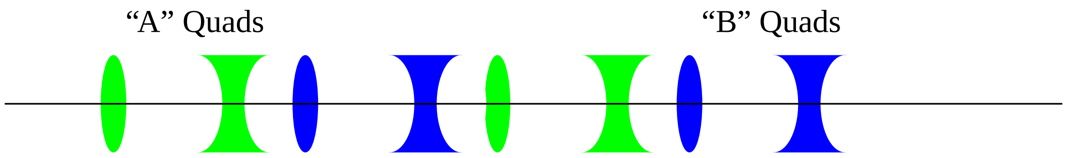
Goal: A design for the NLC sector architecture which is very resistant to single point failures. A realistic design might only incorporate some of the listed features. This design is intended for “standard” X-band linac sectors. Bunch compression, and other special sectors are not covered by this document.

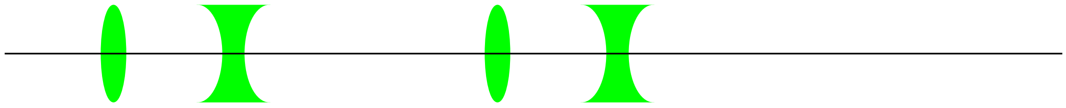
Assumptions:

- The NLC will not be damaged by the sudden failure a a klystron “8-pack”. This is probably true except possibly for some upstream sectors.
- The NLC can operate normally (after energy tuning) with 1/2 of the gradient in a single sector disabled. This relates to the allowance for spare tubes in the linac.
- The NLC can operate with 1/2 of the Quads in a sector (FD pairs) turned off. This assumption is critical to the quad reliability scheme, and must be tested with simulation.
- Radiation levels are too high in the tunnel to allow the use of fiber optics.
- All tunnel electronics must be in shielded enclosures due to tunnel integrated radiation doses exceeding 100KRad.

Quad Failure Doublet Lattice



Lattice before failure



Lattice after failure

Critical Systems - upstairs:

Timing / RF: Uses redundant timing design. Different 8-packs have independent connections to the timing system. The redundant timing distribution system is described in detail in the timing system notes.

Disadvantages: Increased system cost - requires 100 additional receiver and transmitter pairs. Estimated NLC cost increase $3M - $6M.

Control system: Dual networks are maintained within the sector to the 8-pack level. Within an 8-pack a local network (if needed) is connected to both of the networks. Local intelligence at the network connection detects failure of one of the primary networks, and switches to the secondary.

All interlocks are local to an 8-pack, and will only trip that 8-pack.

Disadvantages: Increased system cost - 2X number of “TRIOs”, Micros, and sector networks. Guessed NLC cost increase $1M to $4M.

AC power distribution: It is assumed that the NLC is fed from 3 site mains. All systems at >120V are assumed to be 3 phase. At each sector, a pair of transformers / power centers is used to distribute power at 480V. All devices at 600V or less are assumed to have breakers. High power devices are divided among the two 480V distribution systems so that loss of either system will allow the accelerator to function (see other sections of this document for details). Critical low power (120V) devices are fed from both mains to allow operation if either main fails.

Disadvantages: Added cost and complexity from dual sector transformers and switch gear (each at 1/2 capacity).

Water System: Each sector would have two independent water systems. Equipment would be divided between the water systems to allow NLC operation with one water system failed. This requires the NLC to be able to operate with the “doublet” lattice described above.

Disadvantages: Increased system cost due to dual (but 1/2 capacity) systems.

MPS System: The MPS system has the added complexity of requiring both fault tolerance and fault intolerance. This is probably best achieved by using a 2/3 voting system. RF faults tend to be isolated to a single 8-pack. If a sensor fails, and trips MPS, the entire 8-pack can be taken off line and beam operation continued. Fault tolerance is not required below the 8-pack MPS interface level.

RF fault detection will rely on matching sensor outputs to allowable waveforms. It is very improbably that a sensor will fail so as to still generate an acceptable waveform when the actual RF is bad. In addition, the MPS fault information can be encoded so that sensor processor failures are unlikely to result in a false MPS “OK” signal.

Beamline / critical sensors are 3 way redundant, with voting in the MPS system. For some sensors redundancy may be impossible, and high reliability must be designed into the sensor system.

Tunnel RF - S BPM and Phase Detection: The tunnel is expected to have radiation levels on the order of a few Rad/Hour. This requires either electronics capable of operating reliably at dosages of >100K Rads, or electronics located in shielded enclosures. A quick survey of available Rad-Hard components suggests that only a limited number of components capable of withstanding >100KRads are available. In addition, these components tend to be very expensive.

Modeling is required to determine if the accelerator can operate with any of the S-BPMs inoperable. An outline schematic is shown which is fairly resistant to component failures.

All RF signals are brought to the alcoves in waveguide. This allows the alcoves to be located as much as 100M from the structures - probably limited by waveguide costs. In each alcove, a pair of PLLs fed by separate timing receivers generates each of the required down-mix frequencies (11, 13, 16 GHz). A pair of mixers (for redundancy) is used for each input for each frequency. Each digitizer has an input MUX to select the channel to be measured.

Note: This design assumes that low cost “Minicircuits-style” surface mount mixers will be available at up to 16GHz. At the present time these mixers appear to only be available at frequencies below 6GHz.

Disadvantages: Increased system complexity and cost.

Structure Movers: It is likely that we can operate with some number of structure movers inoperative. In the unlikely event that wake fields from a single structure are a major issue, it is possible to steer the beam flat through a small number of failed structures by moving other parts of the linac.

Qauds Q-BPMS, and Quad Movers: If it is possible to operate with 1/2 of the quads in a sector disabled (as discussed above) these system do not require high reliability.

If we cannot operate with failed quads, extreme reliability must be designed into each system. With 1500 quads, movers, and BPMS, and an allowed downtime contribution of 2% for each system, we need approximately 300,000 Hour MTBFs.

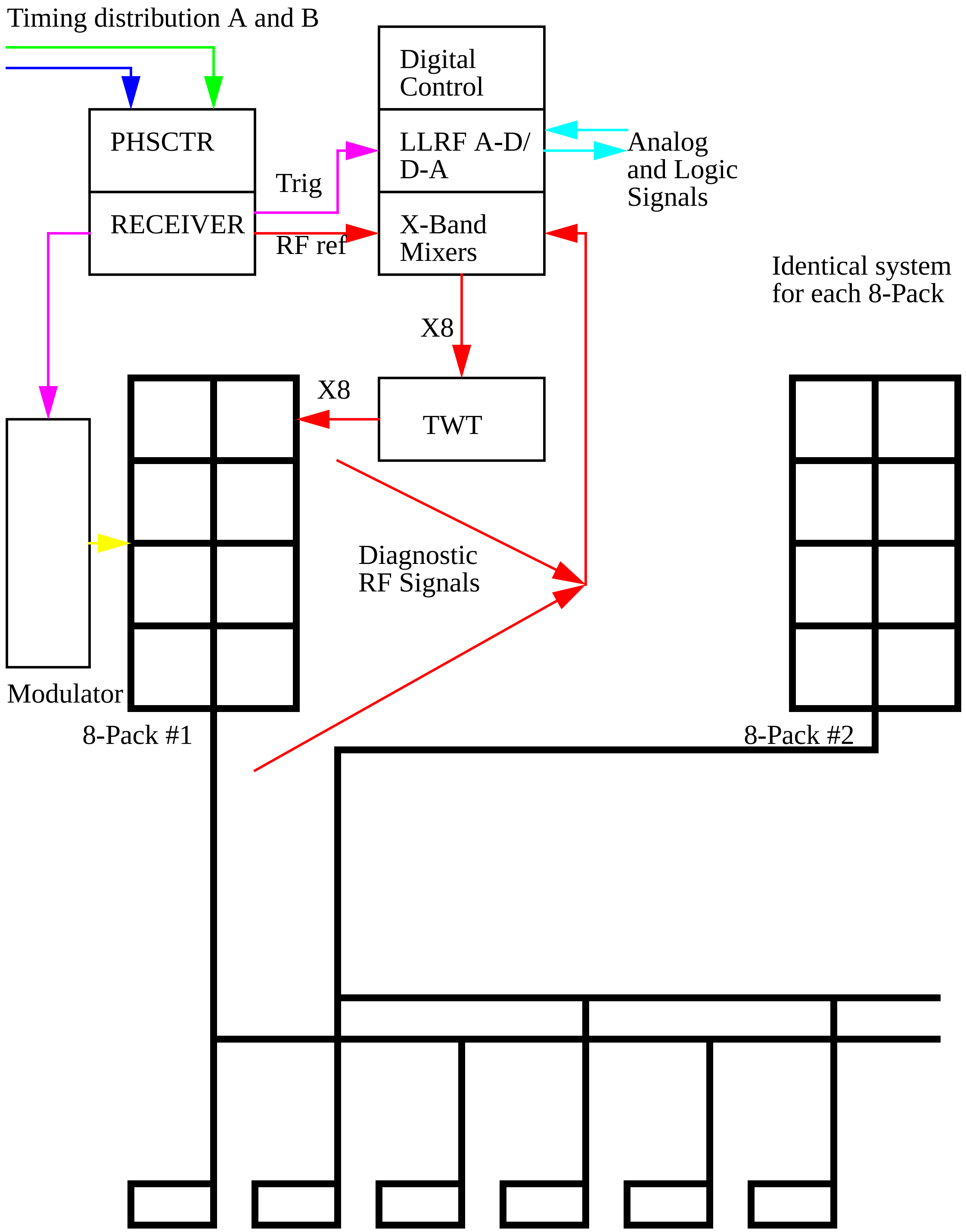
HVAC: Temperature control for the “gallery” buildings and for the tunnel is required. Use of dual redundant systems is straightforward, but adds cost. Note that wighout redundancy, the failure of a single HVAC system will prevent NLC operation.

Vacuum: No Redundancy is possible against leaks. Multiple pumps provide some redundancy against pump failure. Pumps should be powered by the same AC distribution system that is used for the associated 8-pack.

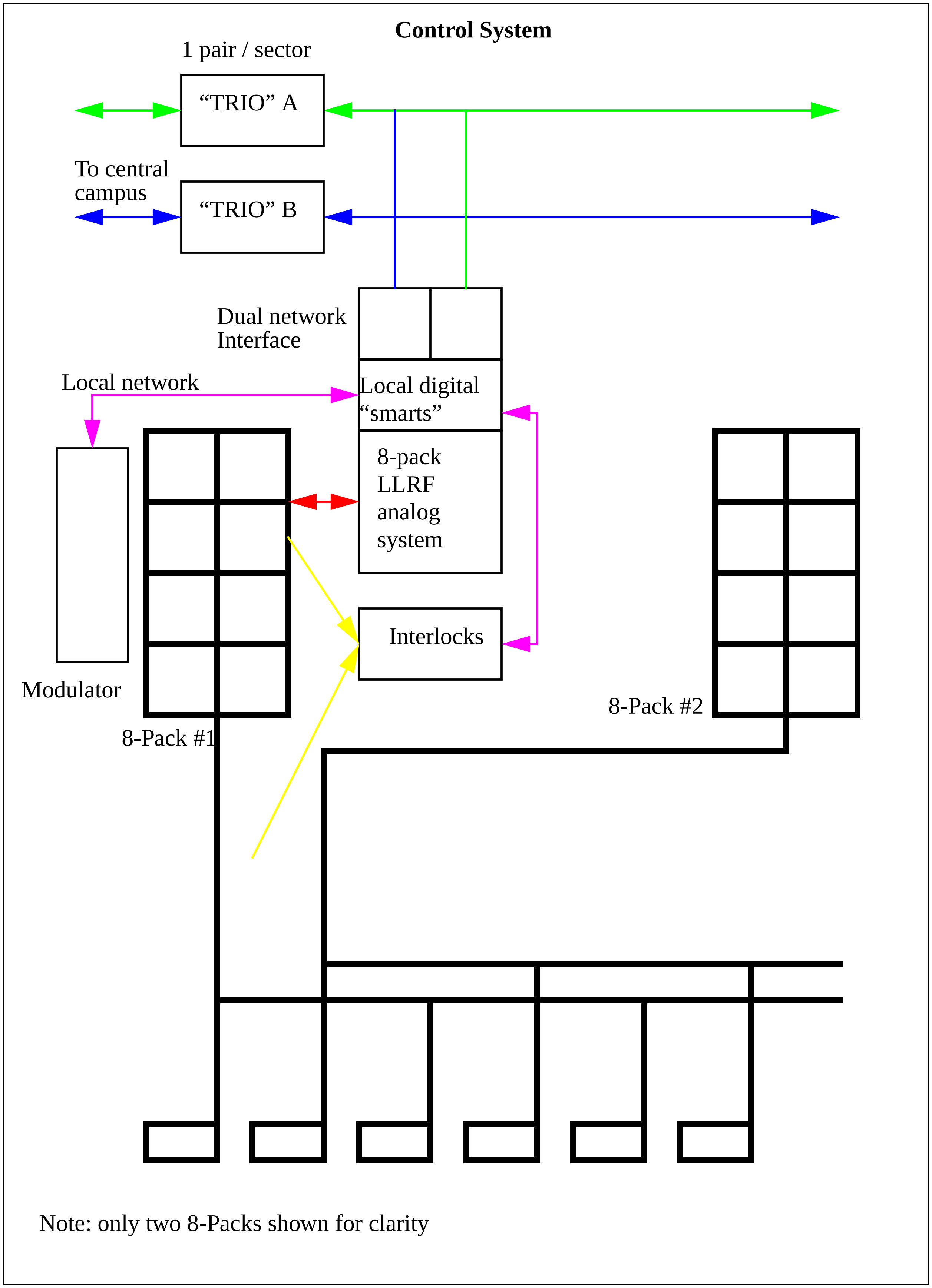
Fast valves can be installed to prevent the venting of large parts of the machine. Note that fast valves must be designed to be very unlikely to trip accidently.

Software: Software is a common failure point and is very difficult to make fully redundant. For example a bug in the RF drive code could send the wrong RF waveform to ALL klystrons in the NLC - possibly causing severe damage. This remains an unsolved problem.

RF / Timing System (upstairs)



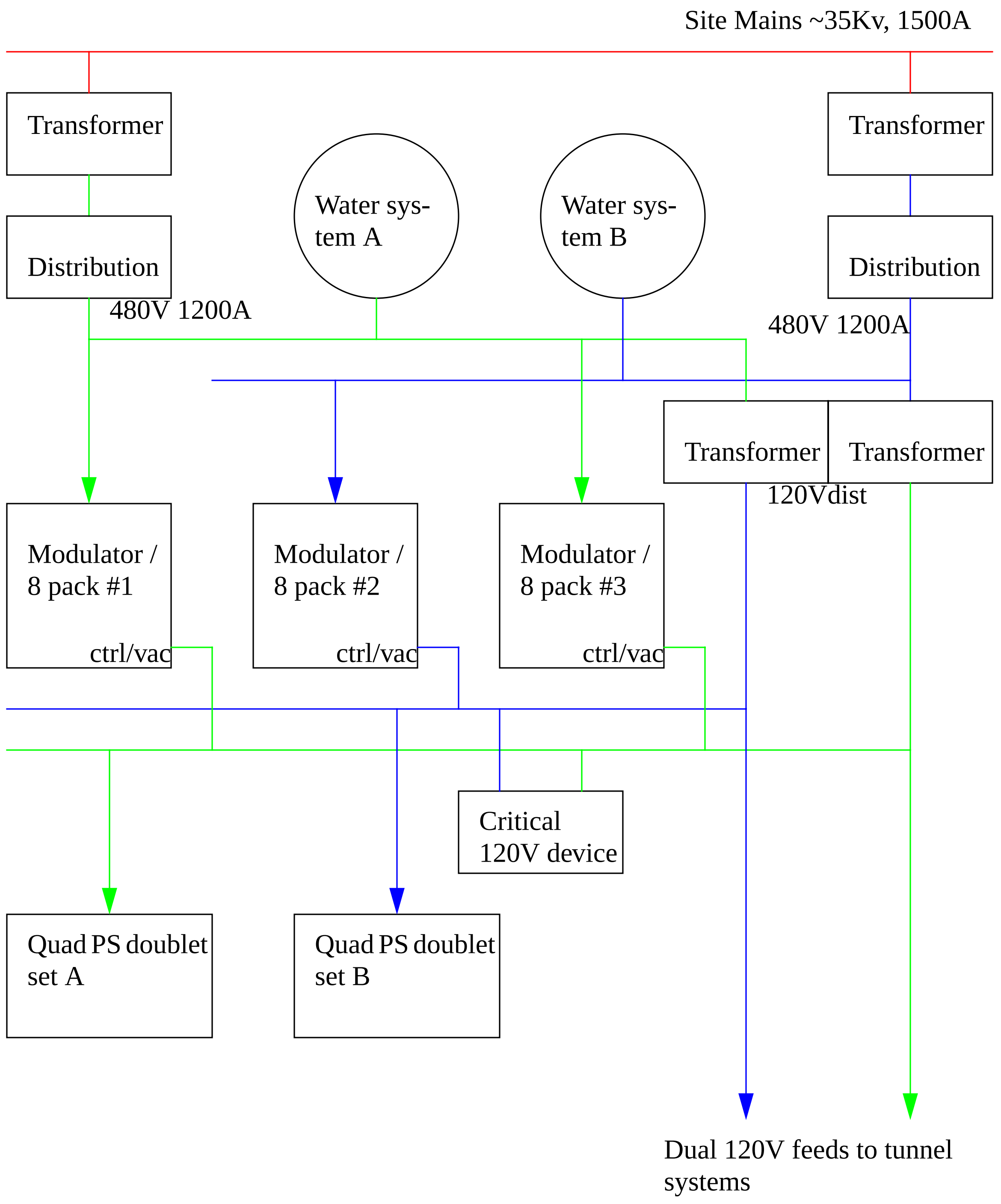
Note: only two 8-Packs shown for clarity
Note: Triggers may be direct cables, or embedded



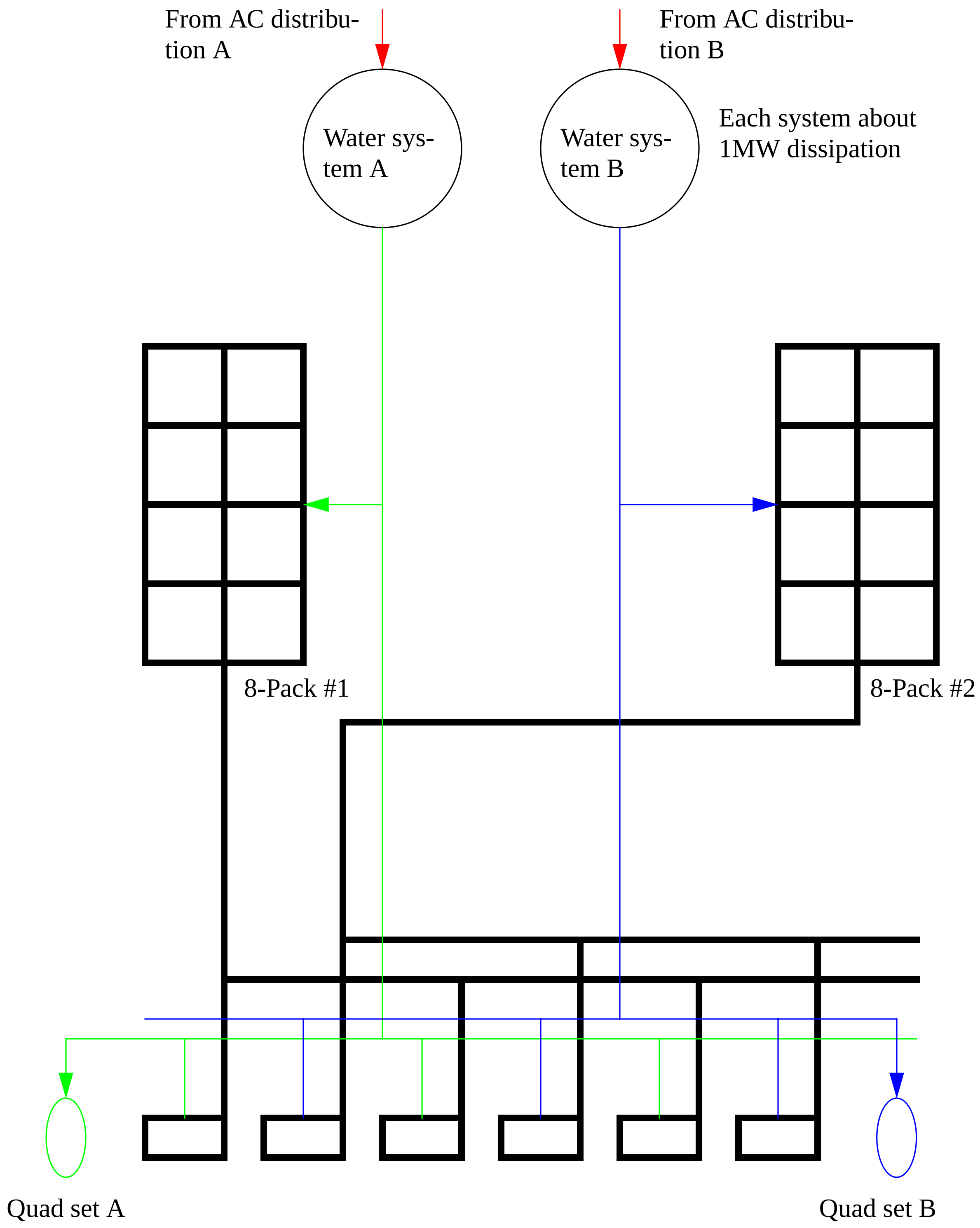
Control System

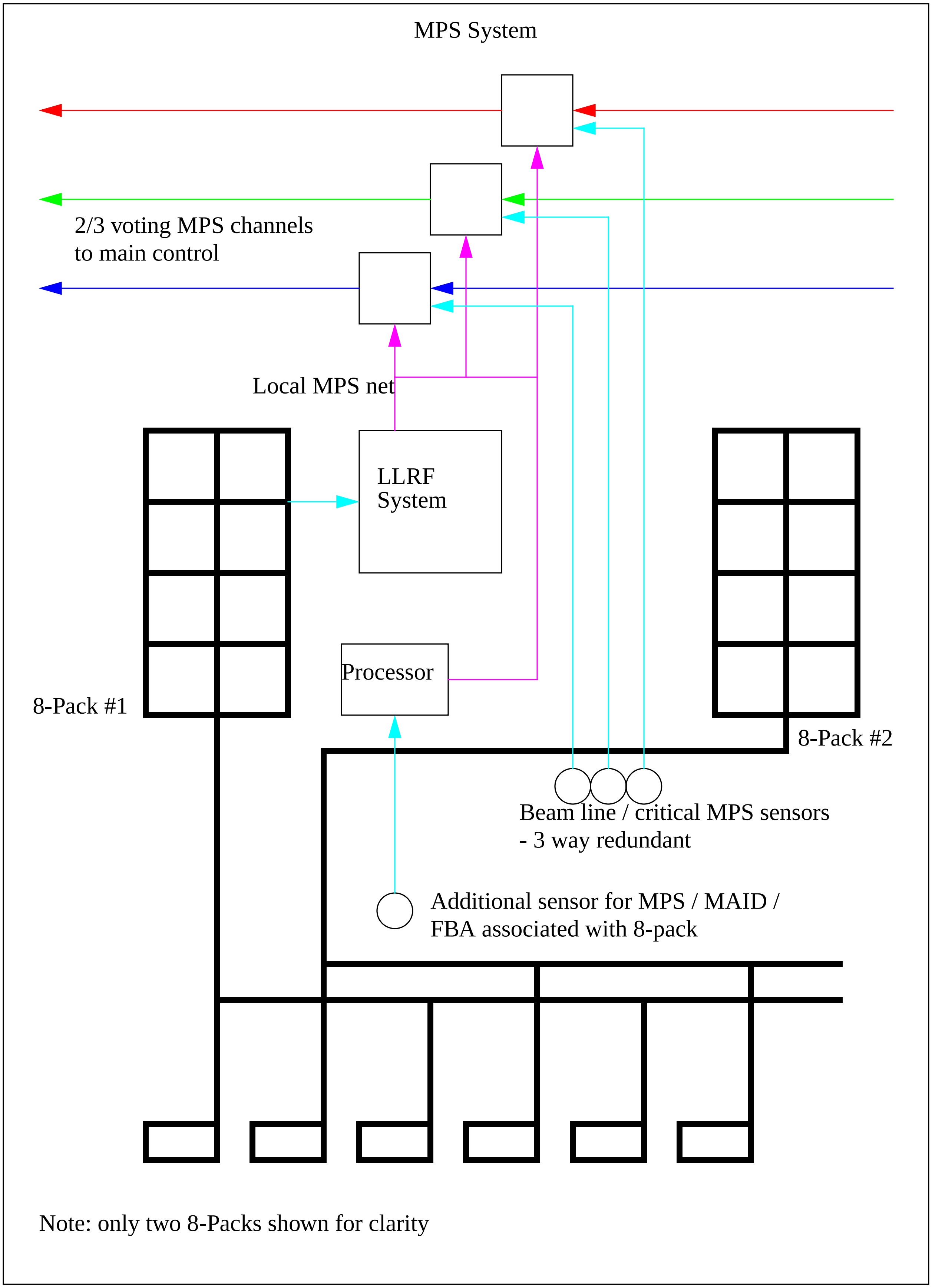
Note: only two 8-Packs shown for clarity

Electrical Distribution



Water System





Note: only two 8-Packs shown for clarity

Tunnel S-BPMs and RF Phase