EVLA Memorandum 107
Failure Pathology of EVLA WIDAR Correlator Support Systems

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INTRODUCTION

The WIDAR correlator being developed for the EVLA project will be located at the VLA site in a shielded chamber on the second floor of the Control Building. Multiple electrical, fire protection, and HVAC systems support the basic functionality of this correlator.

The correlator will be central to the functioning of the VLA, therefore it will be important to keep it running. Strategies for dealing with the operation and possible failures of these systems can increase reliability, speed recovery from failures, and extend the useful life of the correlator system.

This document describes the sequence of events for the WIDAR correlator, correlator room HVAC system (fans, water pumps, etc), correlator 48V PS system, and correlator room UPS, and electrical power feed for a reasonable subset of possible failures (for example, dinosaur rampage or direct meteor impact are not discussed).

BRIEF SYSTEM DESCRIPTIONS

This is a basic overview of the correlator, the ancillary and supporting systems, and their interactions.

WIDAR correlator - a special-purpose computer consisting of about 27 racks at 7kW power consumption per rack. A Central Power Control Computer (CPCC) can independently modulate the power consumption and airflow to each rack and enable/disable the four shielded room HVAC unit blowers. The WIDAR correlator will automatically avoid a damaging overheat condition, but should be protected from over cooling to maximize life and reliability.

Correlator room DC power - A 48 Volt 4000 Amp DC power supply fed from a dedicated 480 Volt three-phase filtered power feed. The power supply parallels a 4000 Amp-hour battery string. The output provides most of the power to run the correlator. The output can be disconnected (shunted) by an electrical signal.

Correlator room AC power - Four, filtered, AC, three-phase power feed-throughs into the shielded room. Two 480 Volt 400 Amp, one of which feeds the 48 Volt DC power plant, one 480 Volt 100 Amp from the Control Building Correlator UPS, and one 208 Volt 100 Amp from the Control Building 75KVA Computer UPS.

Correlator room HVAC - Four units that intake from the general room air and output into the raised floor. Two units are 30 ton each using internal refrigeration compressors (DX) with condenser coils outdoors behind the Control Building. The two other units are 60 ton max capacity each but use the control Building chilled water (CW) loop to cool the air and thus are limited by pipe size to 30 tons each.

Correlator room Fire system - The correlator room has a three stage alarm and suppression system.

> Stage one: an extremely sensitive "sniffer" system continuously samples the room air for smoke particles and notifies the VLA operator if any is detected. The sniffer is many orders of magnitude more sensitive than conventional smoke detectors.
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> Stage two: Standard smoke detectors activate a chemical suppression system that disconnects all power feeds into the room and releases a gas that extinguishes the fire.
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> Stage three: A standard preaction dry-type sprinkler system, enabled after stage two.

Control Building chillers - The Control Building has two 120 ton water chillers. These cool the chilled water loop to 45F.

VLA site power system - The VLA site is fed from the commercial power supplier (utility) via a dedicated line from a substation roughly 26 miles away. The VLA has a backup power system consisting of a generator plant that is activated with the loss of utility power. The Control Building has two 480 volt three-phase UPS systems with approximately 10minute runtime at full load, one 150kVA feeding the existing correlator and one 75kVA. These UPSs will be replaced with a single 150kVA unit before the WIDAR correlator is installed.

COMMON FAILURES

Power Failures: The most common event at the VLA is the loss and restoration of Utility electrical power. The VLA is a remote site with occasional strong winds, snow, flooding, and frequent thunderstorms. Power events can be categorized into three general failures depending on duration of the event and therefore the impact on operations.

> **Shorter than ~0.2 seconds** (glitches): Some antennas may drop out but come back in a minute or two, there is likely data available to be correlated. At the same time, one Control Building chiller may drop out causing a 6 minute increase in chilled water temperature. The existing load causes a peak temperature rise of 4F.
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> **0.2 seconds < t < 20 seconds** (power hits): Most or all antennas drop out for a minute or two, which means that there is no incoming data to be correlated. Also, the Control Building chillers drop out for 300 seconds (internal anti-recycle timer), causing a 15-minute rise in chilled water temperature. The existing load causes a 10F peak. The DX units in shielded chamber drop out for 3 minutes (unless put on UPS), but the CW units continue to operate off the chilled water loop.
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> **Longer than 20 seconds**: The following sequence of events occurs:
> 00:00:01 VLA antennas have all dropped out, Control Building chillers have

tripped, CW and DX units drop out (unless put on UPS)
00:00:20 Utility vacuum breaker opens in primary switchgear, releasing the VLA site from utility power feed and the chilled water pumps have spun down (unless put on UPS)
00:00:46 Generators start and warm up
00:02:05 Generator breakers close and VLA site power is restored
00:05:00 VLA antennas can be re-pointed
00:07:05 Control Building Chillers start
00:15:00 Chilled water back to normal temperature

If the generators fail to restore site power within 5 minutes, the WIDAR correlator must take steps to shut down gracefully while avoiding a thermal cycle. A likely shutdown sequence in response to a power failure is as follows:

1. The CPCC-Ps get an indication of mains power failure by talking to the -48 VDC power plant and, if possible, by talking to the secondary AC UPS.
2. Once a power failure condition is detected, a "Toff" timer is started that, at various configurable epochs, causes a sequence of events to occur as described in the remaining bullets. If, at any time, an indication from the power plant and the secondary 110 VAC UPS is that main power is restored, appropriate start up action will occur.
3. Toff=TSLEEP. Once this epoch is reached, it is time to put the correlator into a sleep mode to conserve power and maintain heat capacity. At this point all correlator processing will cease. CMIBs are told (either directly or via the MCCC) to go into sleep mode, temperatures are monitored, and fans are slowed down considerably to maintain heat capacity. HVAC blower fans are likely turned off as well. If desired, CBE computers and switches can be turned off to reduce main 110 VAC load to the minimum.
4. Toff=TPDWN. This epoch is reached automatically when the -48 VDC power plant shuts down because battery capacity is exhausted. Thus, correlator boards and fans automatically shut down, and therefore automatically retain as much heat capacity as possible. This condition is determined when the -48 VDC power monitor lines indicate that power is lost and confirmed by the inability to contact the power plant via the network. All CBE computers are shutdown.
5. Toff=T_CNTRL_PDWN. This epoch is reached when the 110 VAC (secondary) battery backup is about to run out of power. The CPUs gracefully shut themselves down before battery power is lost.

If mains power is restored at some point in time prior to the T_CNTRL_PDWN epoch, then the system, under control of the CPCC-Ps as described above, goes through the startup procedure, starting at the appropriate point. For example, if mains power is restored before the TSLEEP epoch has been reached, then no action is required since the system is still fully operational.

The CW, DX, and chilled water pumps can all be put on UPS if needed and budget allows.

Correlator shutdown (w/ HVAC & utility power power still available):

HVAC system shutdown (w/ correlator & utility power still available): The HVAC system will have no redundancy when the WIDAR correlator and existing VLA correlator are operating at full load. We will require both DX units, both CW units, both CB chillers and ancillary equipment running. A failure will force the WIDAR correlator to reduce capability to reduce the load.

At less than full load, the DX and CW units can be controlled by the WIDAR correlator in a lead/lag configuration to maintain the required air temperature. The CB chiller have an independent lead/lag control to regulate the chilled water loop temperature. Thus a failure will simply necessitate the activation of another unit.

Emergency shutdown: There are three types of emergency shutdown, manual shutdown from large red mushroom head emergency stop buttons near exits, water flow in the sprinkler pipes, or fire alarm smoke detector activation. Any of these conditions kill all power to the equipment in the room immediately, except for emergency lighting. Equipment outside the room, including fire alarm panels and the control building chillers and pumps, continue to operate.

STARTUP SEQUENCES

A likely startup sequence for the WIDAR correlator, following the reset of a manual emergency shutdown or after power is restored after an extended power failure, is as follows:

1. -48VDC power plant self-starts. After batteries are sufficiently charged (or right away, depending on system capability), the battery disconnect is re-engaged to energize -48 VDC power to the system. All correlator modules and rack Ethernet switches are turned off at this point since the CPCCs are configured for all output controls to be OFF or high impedance on startup, and are clearly OFF if the CPCC (i.e. the CPCC-S) has no power.
2. At the same time as step 1., main 110 VAC is restored and the Control Rack UPS starts up, generating 110 VAC to the computers in the Control Rack (Figure 5-1). The CPUs boot from on-board hard drives.
3. The CPCC-P (in each Control Rack) tries to establish network communications with the EVLA M&C system, with the CPCC-S, and with the CPCC-P in the other Control Rack.
4. Once contact amongst CPCCs is established, each one verifies that -48 VDC is present in each correlator rack by reading the -48 VDC status lines. If there is disagreement between them, then the disagreement is reported to the EVLA M&C system, if communications has been established.
5. Both sets of CPCCs go through the same timed sequence of starting up modules in correlator racks and the CBE and switches, communicating to each other sequencing and status information. It does not matter if timing between the CPCCs is not exact, since the redundant nature of the RPMIB will easily handle timing discrepancies, provided modules are not powered up too quickly. This power-up procedure happens independently of whether or not communications with the EVLA M&C system has occurred or not.
6. Once power is on to all modules, power status is ok, and some time has elapsed to allow the CMIBs and CBE computers to boot, the CPCC-Ps go into the steady state condition where they are independently monitoring and controlling the system--checking power status lines, checking module voltages and temperatures, adjusting fan speeds, polling processors to determine if they are alive or not, checking the status of the -48 VDC power plant etc. Also in this state, the MCCC functions are started, communications are established with CMIBs, BIST tests are run etc.

APPENDIX A, CHILLED WATER LOOP THERMAL MASS:

The water loop contains a little more than 1000 gallons of plain water. Each gallon weighs 8.34 lbs, and it takes one Btu to raise one pound of water 1 degree F. Thus:

water loop = 1000 gal * 8.34 lbs/gal * 1 Btu/lb/degree F = 8340 Btu/degree F

The shielded chamber will be roughly 27,000 ft^3. Air takes 0.24 Btu/lb/degree F and there is about 0.06 lbs air per cubic foot at 7000 feet elevation. Thus:

air volume = 27,000 ft^3 * 0.06 lb/ft^3 * 0.24 Btu/lb/degree F = 1620 Btu/degree F

So the total thermal mass presented to the correlator, assuming the fans and pumps run, is

air volume + water loop = 8340 + 1620 = 9960 Btu/Degree F

Assuming that the correlator pulls 200kW,

1 Btu/min = 0.018 kW => 200kW = 11,111 Btu/min

=> temp rise =9960 Btu/Degree F / 11,111 Btu/min
= 0.9 degree F/min

or 16.2 minutes to rise 10 degrees C.