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INTERNAL DOCUMENT
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To: WEA
From: MEZ

Subject: Zeroth pass at "Receiver/Facility Interface" questions.

1. Introduction

Discussions in May between WEA and MEZ attempted to elucidate the actual definition of the term "Receiver/Facility Interface." Since this nebulous category denotes a boundary between two undefined domains, I think we decided not to define it at all until we had some more examples of topics we would like to include in the category. Following is a list of some topics we briefly considered.

2. Mechanical Interface

This interface could be defined, for example. as the boundary between the general--purpose laboratory buildings and foundations and the receiver--specific supports and antiseismic systems. This might be a good boundary because the builings and foundations are likely to be handled by external contractors while antiseismic and other receiver systems might be designed in--house. An early standardization of the characteristics of the boundary may be necessary to get external people going.

WEA suggested we think for the moment in terms of "plinths" (concrete piles or bases) provided on either side of each experimental chamber. In this possible scenario there are several obvious considerations:

a) Height. Room must be allowed for as-yet unspecified antiseismic systems. but for at least some experiments little or no such equipment may be used; how much space is enough?

b) Loading. Both static and dynamic (earthquake) loads should be estimated.

c) Access. It is desirable to have access to as much as possible of the experimental chamber surface; the area directly surrounding the suspended test masses is premium real estate, so the plinths may have to be split or staggered. By how much? The area below the chamber may also be needed; can workspace be provided below as well?

d) Vibration. Thinking about the divided--floor system in use in the 40 m prototype lab, we realized that these systems probably increase the effect of natural seismic noise while reducing anthropogenic contributions. We thus need to consider two sources of vibration energy and two distinct transfer functions, since we may have to compromise between good isolation from natural noise and good rejection of man-made interference. The natural seismic spectrum can be measured; the artificial noise produced by people walking, forklifts forking, and champagne corks popping may be more difficult to figure.

The vibration transfer functions for each type of input will probably have to be modeled for any given concept before specification of the interface can be made sensibly. For example, such a specification could be organized as "Transfer coefficient between any point of experiment area floor and plinth surface not to exceed XXX dB at frequencies between A Hz and B Hz in X,Y, or Z directions" and similarly (with different numbers, of course) for vibrations originating in the ground or the nearest stand of trees. This may be easier and better than trying to specify the maximum allowable seismic noise. The output of exercises like this will guide decisions about what kind of human activities are acceptable during observing periods (if any).

e) Independence of separate experiments. The question of whether plinths supporting different experiments should be joined rigidly, joined implicitly (e.g., through the earth or the building), or deliberately isolated from each other may be sensitive.

f) Effects of settling. The amount of settling, and especially possible settling effects on angular orientation of the platforms, has to be estimated; this will affect receiver design.

3. Electronic (Signal) Interface

I think we agreed to consider actual electric power needs and things related to the so-called "housekeeping data" systems separately; work already done on these topics seems to show no insurmountable problems so far. The main question here is what to do about actual receiver signals which need to be sent 2 and 4 km along the pipes. Some examples of what I mean: pointing servo signals (if used), antiseismic interferometer signals, test mass position servo signals, monitors of transmitted light, etc. The housekeeping data will probably need to be transmitted along with these "internal" reciever signals, maybe using the same path, but the receiver signals will probably make the most stringent demands on the communication channels and will thus drive the bandwidth, SNR, etc.

We considered the possibility of just running RG-58 or something; that might be very costly (WEA has made some estimates that I don't recall). Also, each line would probably need to be opto-isolated or something to avoid ground loop problems; and finally, the cost of routing new cables is so high that the maximum possible demand would probably have to be provided for at the very outset. These considerations pushed us toward thinking about high--speed digital optical fiber links with multiplexed A/D's and DAC's at each end; no firm estimates are in hand but WEA's intuition is that this could be cheaper and more flexible, IF it will do the job. A digital replacement for RG-58 might not work if we need too much bandwidth or dynamic range; I'd like to stimulate some thought on those questions by showing some rough limits.

a) Real-time servo bandwidths greater than 19 kHz are ruled out by the round-trip delay to the 4 km end stations; this probably means we won't need to consider digital sample rates higher than 40 kilosamples/second for servos (and I can't off hand think of any other fast signals we'd need).

b) Delays in conversion and multiplexing are also important, and aren't typically addressed in standard communication applications (indeed many types of data link deliberately introduce random delays).

c) Dynamic range is still an open question. I'll take a simple example; suppose we use quadrant diodes for orientation controls as we do in the 40 m. Suppose further that we use 10 mW of light on the diode (we now use less than one mW usually). That means at a quantum efficiency of 80% there will be 2x10^16 photoelectrons/sec or 2x10^13 pe/millisecond, meaning that the maximum signal (all light on one quadrant) is sqrt(2x10^13) = 4x10^6 times bigger than the minimum discernible (shot noise limited) change in the beam position over a millisecond time interval. That implies a dynamic range of about 130 dB for kilohertz fluctuations (for slower fluctuations you average more photons and can discern a smaller angle for the same power). If the sample rate is 40 kHz you have 40 samples per millisecond so the digitization noise per sample (1 LSB) can be sqrt(40) = 6.3 times or 16 dB bigger than the minimum discernible millisecond change (assuming perfect linearity--for now we are discussing just the problem of transmission, conversion is discussed in (d)). That leaves about 124 dB per sample or 21 bits for a 10 mW, shot-noise limited (at 1 kHz), 20 kHz bandwidth, one--diode--width dynamic range servo system. From this baseline we can consider what we really need; from the transmission standpoint 21 bits x 40 ksamples/sec x N channels may not be bad (depending on N).

d) Of course, the number of channels to be provided at any given bandwidth needs looking at; to quote WEA, we should count everything we can think of and double it. I haven't thought this through yet. We also need redundancy to allow for failures, and since the housekeeping data will almost certainly share the system we probably need to take a closer look at those needs before we can give this even rough numbers.

e) Data compression may be applicable for these links.

f) Other transmission means besides baseband coax and digital fiber exist: we might want to consider CATV-type UHF analog or digital systems, microwave transcievers or free--space laser transmission through the tube or alongside it (we have a controlled uninterruptible path, unlike the phone company; I think this could potentially be very cheap, and you can add a channel any time you need one.)

g) A transparent "virtual cable" type interface at each end would be nice; an experimenter should be able to just plug in an analog signal to a BNC panel and pull it out of a socket with the same number at the other end. WEA and I agreed this was a worthy goal for any system. This (finally) defines a sort of interface: a big panel of BNC's with virtual connections to the other stations, each of which looks (within limits) like a length of coax (although maybe without capacitance or inductance).

3. More categories will be added later.