Review of issues relevant to 300-ft collapse. 22 December 1988

Internal committee has three main scenarios still under review.

There now seems to be little doubt that telescope failed while being driven north of Dec 74d at about 2.5 deg/min by the variable speed drive. This is consistent with:

(a) commands expected to have been issued by H316 control computer
(b) present position of limit switch tripper arms relative to switches
(c) present configuration and state of chain
(d) continuing decline of total power level after end of north-going slew scan.

The three failure scenarios still worth considering are:

1. Prime cause of collapse was failure of a bearing at about 75d Dec while the chain continued to drive to about 85d Dec.

   Sequence of events: Bearing sticks, so unusual forces and moments applied to structure near both bearing and to towers, triggering failures of structure.

   Evidence FOR: East bearing readout is still at 75d Dec, despite large twist of bearing as tower failed. But - could this be an indication that encoder stopped functioning at 75d Dec ?

   Lee King has calculated that failure of bearing provides forces to tower members that exceed elastic limit of steel by a factor of 2, and are up to 10 times normal gravitational loading.

   Questions: Could bearing stick so hard that siezure triggers failure of structure as chain keeps driving ?

   Although forces and moments about vertical axis are of right sense to move telescope and twist towers as seen, moments of drive forces abount horizontal axis would displace towers toward north, in conflict with wreckage ?

   If chain was driving north for 4 full minutes after bearing froze, is it reasonable that operator heard nothing unusual for so long ?

   Did operator ever see Dec readout go above 75d ?

   Action: Inspect both bearings. Are they stuck or free ? If either or both is free, is there unusual wear near the turn-around points of previous slewing surveys ? (Includes S4 survey turn-arounds).

   Talk to operator. Was control room noisy that evening, e.g. was radio on ? Was pit microphone working ? Could unusual noises have been masked for 4 minutes ? Did he go to lunch room when he thought he heard telescope start moving ? If so, what did he hear that made him think telescope motion had changed ?

2. Prime cause was a major structural failure while telescope was driving north.

Sequence of events: Failure of member deforms structure near bearing and starts "chain reaction"; possibly impeding telescope motion while driving, or triggering brittle fracture (or other failure modes) of other members of dish or of towers.

Reason to suspect: Poor quality and age of steel, history of minor structural failure near bearings.

Questions: Do any major members show evidence of fracture that was not caused by collapse ? Especially in box girder near points of attachment to bearings ?

Can a computer model suggest which major members were stressed when gusset plates broke in the past? (Problem here is that no detailed record was kept of where broken plates were located, so we know only general areas where failures occurred, not member-by-member history).

Could structural failure have caused East bearing to stick at 75d Dec ? I.e., can we distinguish #1 from #2 by any examination of wreckage ?

If failure begain near 75d Dec, why did operator hear so little for 4 minutes (same problem as in #1 above)?

Action: Locate as much of box girder structure as possible and document where breaks have occurred (?) Can we distinguish sudden fractures from slower semi-plastic deformation ?

If external team builds computer model, can we learn whether a major member was being stressed when joints failed, and if its later failure could have provoked collapse ?

Talk to operators who went outside on Nov 14/15. D. Westphal has told me that at least one of them saw *deformed* (rippled) members in backup structure from the ground.

3. Prime cause was failure of feed leg guy wire attachment on West side while telescope was driving north.

Sequence of events: Failure of structure near attachment point of west guy wires releases these wires and their attachment hardware. Feed swings east and south and this motion provokes further structural failures.

Reason to suspect: Feed legs probably unstable if guy wire attachment points failed.

Argument against: If failure *started* only 10-15 seconds before feed hit control building, why is East encoder

now reading 75d (i.e. is it just a coincidence that this readout is close to the value at the end of the last slew scan?)

Questions: Can condition of hardware still attached to west guy wires give us any clues ? Can we tell whether guys pulled the attachment yoke out of structure, or whether the yoke failed first and was then pulled out ?

Can condition and geometry of feed legs give any clues. I believe south leg is still attached, but North leg eventually detached (this is consistent with the feed ending up on top of the control building, but does it give any additional information?).

Action: Document final state of all joins between feed legs, guy wires and the rest of the structure (but I'm not sure how much we can get from this).

Generally: As the structure continues to warp under daily thermal stresses, snow loads, long-term settling. etc. local evidence (geometry, condition of breaks, etc.) that might bear on the structural failure possibilities is presumably being corrupted. I'm concerned that we do not know how much of the wreck was photographed clearly in the first few days or weeks. Will the photographic record be of any help if we later need to verify the condition of key members, e.g. in box girder, around the bearings, feed legs and guy wire supports, soon after the collapse? (I would expect photographs to be hard to interpret unless taken explicitly to document the state of important members, and the members ended up near the ground).

I'm also concerned that we have not directly interviewed the operators. Is there a simple explanation for why nothing unusual was heard for 4 minutes (e.g., a radio or TV playing in the control room?) If not, does the lack of premonition support scenario #3? I'm bothered that Dave Westphal has heard some reports from operators that were not included in Fred Crews' account to us, e.g. about visual evidence for deformed members. The duty operator might still have recollections that could rule scenario #3 in or out, and I'm bothered that a month has passed and we still have only Fred Crews' verbal account of the interview with this operator and nothing in writing beyond my own notes of our interview with Fred.