HENEX RAM Analysis

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The HENEX Reliability-Availability-Maintainability (RAM) analysis is an attempt to estimate the HENEX availability for NIF shots based on the instrument's expected reliability and maintainability. The analysis draws on the experience gained with the Hard X-Ray Spectrometer (HXS) that was built by the HENEX team and fielded at LLE. The HENEX design philosophy is similar to the HXS design, and HENEX implements some of the same components as HXS. The HENEX RAM analysis is closely related to the HENEX Risk Mitigation Plan, where the probability of instrument component failure is estimated.

HXS Experience

The HXS mechanical hardware in general functioned very well. The front end Be debris filter (5 mil thick) survived all OMEGA shots. The x-ray attenuation filters, covering the pinhole and the cross-over slit, also survived all shots. The method of easily changing the filters functioned well. The transmission crystal was undamaged. Finally, based on the pinhole image, the pointing of the instrument (by means of a mechanical pointer) was accurate and stable.

The HXS fiber optic trigger did not function on some shots. The problem was traced to unexpected OMEGA facility trigger levels and poorly coupled FO connectors. When these problems were corrected, the HXS triggered on subsequent shots. As a result of this experience, HENEX electronics will monitor and display the FO signal levels. If the signal levels are too low, they will be red-flagged so the operator can take corrective action.

The HXS battery pressure vessel functioned well, and the HENEX battery pressure vessel is identical to HXS. However, the charging of the HENEX battery was not always done in the proper manner. This originally resulted from an incomplete description of the charging procedures in the HXS operator's manual. After the operator's manual was updated, battery charging problems resulted from not following the procedures in the manual. In any case, the HENEX electronics will monitor and display housekeeping information on the state of the battery and also voltages and currents in the electronics box.

On several occasions, the HXS electronics responded to OMEGA DAS facility signals in an unexpected way during data download after the shot, and a portion of the data were lost. One problem was traced to the RID number that was sent before the shot and also under some circumstances between shots. This was corrected by having HXS discriminate between valid shot RID numbers and DAS signals that are not shot precursors.

HENEX RAM Analysis

In the HENEX Risk Mitigation Plan, a number of possible component failures are listed. These failure modes are of two types: (1) Failure mode has minor impact; would not severely affect the performance of the instrument and the quality of the recorded data.

These include slight misalignment of the instrument resulting in small shifts of the spectral images on the sensors, and sensor overexposed in some filter regions and good exposure in other filter regions. (2) Failure mode would detrimentally impact the instrument performance and would need to be corrected before the next shot. Depending on the type of failure, the corrective action could be extensive and time-consuming. The latter type of failure is considered to be relevant to the RAM analysis, and these failures are listed on the following page. For each relevant failure mode, the estimated probability of the failure occurring during the first year of operation is listed in the first column, the time to correct the failure is listed, and the assumptions are listed in the last column.

We shall assume that the time between NIF shots is sufficiently long so that at least one hour is available for corrective action. That is, if the failure can be corrected within one hour, then the failure does not impact the NIF shot schedule and is not significant with regard to the RAM analysis. Failures that take longer than one hour will delay the shot schedule and must be further considered in the RAM analysis.

The calculated parameter is the time to correct the failure minus one hour times the probability that the failure will occur during the first year of operations. By summing up these times for all of the relevant failure modes, the result is 0.1 hours. Thus based in these assumptions, HENEX is estimated to delay the NIF shot schedule by 0.1 hour during the first year of operation. This possible delay is expected to decrease in later years since reliability should increase with experience.

Assumptions

There are many assumptions that form the basis of the HENEX RAM analysis. These are grouped into several categories:

(1) The spare HENEX components listed in the last column of the table are available on site and can be quickly brought to the HENEX DIM. In some cases, such as the replacement electronics, the costs of these spare components are considerable and must be added to the budget for the construction of the HENEX instrument.

(2) We assume that the instrument can be withdrawn into the DIM, vented, evacuated after refurbishment, and re-deployed into the NIF chamber in less than one hour.

(3) Off-line NIF facilities are available for the set-up and complete testing of the instrument. This includes the availability of NIF DAS signals for testing the triggering of the instrument.

Probability % in 1st Year	Event	Effect	Corrective Action	Time to Correct	Assumption
20	Entrance filter bursts.	Additional x-ray flux and visible light reach the sensor. Filter must be replaced.	Withdraw the instrument in the DIM and replace the filter.	1 hour.	Replacement filter is available.
10	Crystal breaks.	Crystal must be replaced.	Withdraw instrument in DIM and replace crystal and holder.	1 hour.	Replacement crystal and holder are available.
5	Sensor filter bursts.	Additional x-ray flux and visible light reach the sensor. Filter must be replaced.	Withdraw the instrument in the DIM and replace the filter.	1 hour.	Replacement filter is available.
10	Sensor fails because of EMI.	Destruction of the sensor.	Withdraw instrument and replace sensor module.	1 hour.	Replacement sensor module is available.
<<1	Battery pressure vessel fails.	Dispersal of contaminants into the target chamber.	Withdraw instrument in DIM and replace battery pack. Assess damage to the target chamber.	1 hour to replace battery pack. Additional 2 hours to assess damage to the target chamber.	Replacement battery pack is available and damage to target chamber is minimal.
5	Battery discharges before shot.	No data are recorded.	Withdraw instrument in DIM and replace battery pack.	1 hour.	Replacement battery pack is available.
10	Electronics fails because of EMI.	Destruction of the electronics.	Withdraw instrument in DIM and replace electronics box.	1.5 hours.	Replacement electronics box is available.
5	Electronics fails because of high temperature or voltage.	Destruction of the electronics.	Withdraw instrument in DIM and replace electronics box.	1.5 hours	Replacement electronics box is available.