Identifying and addressing processes and failure modes that impact across subsystems

Subsystems are generally responsible for identifying their vulnerabilities. The FMEA is a standard method of identifying potential vulnerabilities, as well as identifying the mitigations. Examples of documented FMEAs:

Mu2e-doc-#	Title	Author(s)	Topic(s)	Last Updated
7304-v8	HAB Cryogenic System Faliure Mode and Effect Analysis	Robert Sanders	Safety	09 May 2017
8372-v2	Mu2e 475.04.07.03 Cryo Controls FMEA	Ian L Young	Cryogenics Solenoids Distribution Box Vacuum	05 Dec 2016
6489-v7	Muon Beamline Vacuum P&ID & FMEA & Input to the control system design	Dave R. Pushka	Muon Beamline Safety Vacuum	20 Sep 2016
7527-v3	DAQ Pilot System FMEA	Richard Kwarciany	DAQ Hardware	14 Jun 2016
4520-v19	Cryogenic Distribution System P&ID (including MC-1 and A0)	Yuenian Huang *et al.*	Cryogenics Solenoids	24 Apr 2017
7180-v3	Mu2e 475.04.07.03 Cryogenic Controls What-If Analysis	Ian L Young	Cryogenics Solenoids Vacuum Vacuum	05 Dec 2016
4497-v6	Mu2e Solenoid Risk Analysis	Marc Buehler *et al.*	Solenoids	16 Oct 2014

The interface control documents are intended to identify and document features that have the potential to impact other systems, or that cross boundaries. So, when an FMEA identifies some potential feature that crosses boundaries between subsystems, it should generally be included in the interface document, and highlighted in discussions at integration meetings. Where necessary implementation of mitigations or solutions to situations identified via FMEA which cross subsystem boundaries are negotiated between those subsystems (and the topics are frequently documented in interface control documents). In addition, the relevant interfaces are specifically reviewed at integration meetings prior to Construction Readiness Reviews.

The integration team attempts to identify and monitor topics that are likely to cross subsystem boundaries via participation in subsystem meetings, and typically discuss such topics at integration meetings or in other targeted discussions with the representatives of the relevant subsystems. Such topics are generally also raised in Tech Board meetings, and we anticipate that this will continue as the various systems mature.

A recent example is the evaluation of the impact of loss of cryostat insulating vacuum on the integrity of the cryostats, and the mitigation of those circumstances, which could cross the subsystem boundary between solenoids and muon beamline (see risk MUON-226). Other examples include:

- Loss of HVAC in the DAQ room—in response to NOvA experience, the rating on the sprinkler heads in the DAQ room were re-evaluated, and the sprinklers heads were replaced with heads rated at ta higher temperature to provide larger margin. In addition, temperature sensors and interlocks to the power in individual racks are being built into the rack monitoring system using in each rack in the DAQ room (docdb 9954).

- Requirement that the tracker and calorimeter HV distribution system must be capable of operation in the pressure range 10^{-4} to 10^{-2} torr as well as at atmospheric pressure to provide operating margin (see muon beamline interface document docdb 1168 interface 105.2.2.1)
    - Pressure measurements will be available for interlocking detector high voltage (see muon beamline interface document docdb 1168 interface 105.2.2.1)
- Constraint on the rate of change in pressure in the muon beamline vacuum volume, which is intended to protect the straws in the tracker (see muon beamline interface document docdb 1168 interface 105.2.2.1)
- Inner bores of cryostats must be capable of sustaining 5 psig to accommodate backfills pf the muon beamline vacuum volume (see muon beamline interface document docdb 1168 interface 105.2.2.1)
- The temperature of the warm bores of the PS and TS cryostats must be maintained (or instrumented) by WBS 4 to facilitate timely and reliable backfill of the muon beamline vacuum volume without significant risk of condensation (see muon beamline interface document docdb 1168 interface 105.2.2.8)
- Implementation of ground on conductors (either safety ground or detector ground docdb 7254)
- During the conventional construction design phase, there was discussion of the backup power systems to be implemented in the Mu2e hall. There is a generator, and the process controls system will also be powered by a battery backup to ensure continuity of process controls. As additional requests for use of the remaining margin on generator power, we anticipate that the integration team will be involved in the process.

Regarding the particular example of the response to a quench, evaluations of the sensitivity of subsystems to a quench, have been performed, including the HRS, collimator (docdb 7481) stopping target (docdb 5570, 6825, and 6878), antiproton window (docdb 7379) tracker, and the integration team has also asked the calorimeter team to ensure that their support structure will sustain forces resulting from a quench.