Nuclear Criticality Safety Control Strategy For PDC Conceptual Design Review

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Fundamental Requirements

- Integration with design process consistent with DOE-STD-1189
- NCSEs - consistent with DOE O 420.1B, DOE-STD-3007 (including ANS-8 standards), WSRC-SCD-3 and DNFSB Recommendation 97-2 as well as project requirements in Y-FDD-K-00001, Rev C
- Process Analysis- "Operations are subcritical under all normal conditions and that no credible abnormal condition can lead to an accidental criticality."
- Double Contingency "Process designs should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible."

NCS Strategy for Conceptual Design

- Philosophy and Summary Guidance:
  - "Criticality Safety Strategy for Conceptual Design", M. Brady Raap, D. Wootan, C. Francy, J. Livingston, B. Collins and B. Greenfield, SRB-25.04-10-002, August 12, 2010

- Detailed Guidance:
  - S&P Processes
  - Pit Processing
    - Building/Facility systems (Shipping/Receiving, Waste Management, HVAC, NIM placement, CAAS Evacuation Boundary)
    - Interface with F/H Area Analytical Laboratory
  - Material Storage, Drum Storage concept study/guidance
  - NIM locations and CAAS Evacuation Boundary
  - Collection of fire suppression water

CRITICALITY CONTROL GUIDELINES

- Systematically and comprehensively review and analyze S&P, Material Storage and Pit Processing equipment and operations for criticality safety hazards (using the “what-if” method of hazard analysis)
- Develop controls to so that the possibility of an inadvertent criticality event requires at least two independent and unlikely upsets to have occurred
- Establish criticality control areas (CCA’s) that reflect and support facility operations
- Maximize to extent practical the use of engineered controls
- Where practical, use passive engineered controls in preference to active engineered controls
- Integrate criticality controls as part of the design and safety basis development
- Document analysis and bases for criticality controls as design detail evolves

Future Work Plan for Integration with Design

•Preliminary Design:

•Prepare preliminary NCSEs by process/building system, NIM locations, CAAS Evacuation Boundary, Fire Suppression Water Collection System requirements

Detailed Design:

•Update NCSEs, NIM locations and CAAS Evacuation Boundary

•Develop Criticality Control Review (CCR) document to summarize criticality hazards and controls

- technical reference to the DSA for criticality safety; and
- summarize process NCSEs for the facility into a single document so that identification of commonly important attributes and controls is possible.

Construction Phase:

•Issue NCSEs, final NIM locations and CAAS Evacuation Boundary

Criticality Safety High-Level Strategy

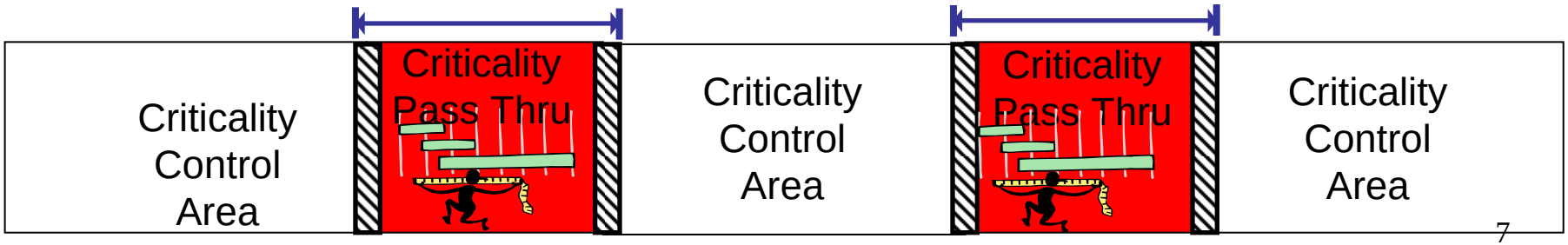
- All transfer, process and storage containers of fissile material are engineered passive-safe by geometry and moderation control to the extent practicable
- All movement of fissile material containers within the process gloveboxes is active-safe engineered by limiting and controlling fissile material accumulation within designated **C**riticality **C**ontrol **A**reas
- Administrative controls are utilized primarily as defense-in-depth controls although in some instances enhanced administrative controls have been introduced to facilitate operational flexibility and maintenance operations.
- The movement of material outside of gloveboxes is primarily based on Administrative Controls (the number of containers outside of gloveboxes is managed by enhanced administrative control).

Concept of Criticality Control Areas

•Process lines are divided into Criticality Control Areas (CCAs) wherein either mass or unit counts are controlled.

•Criticality Pass Throughs (CPTs) function to provide:

- ✓Physical isolation between CCAs
- ✓Software-controlled physical interlock to permit/prohibit movement of material from one CCA to another
- ✓Physical measurements (gamma, neutron, and/or mass) to establish a permissive enabling movement of fissile material



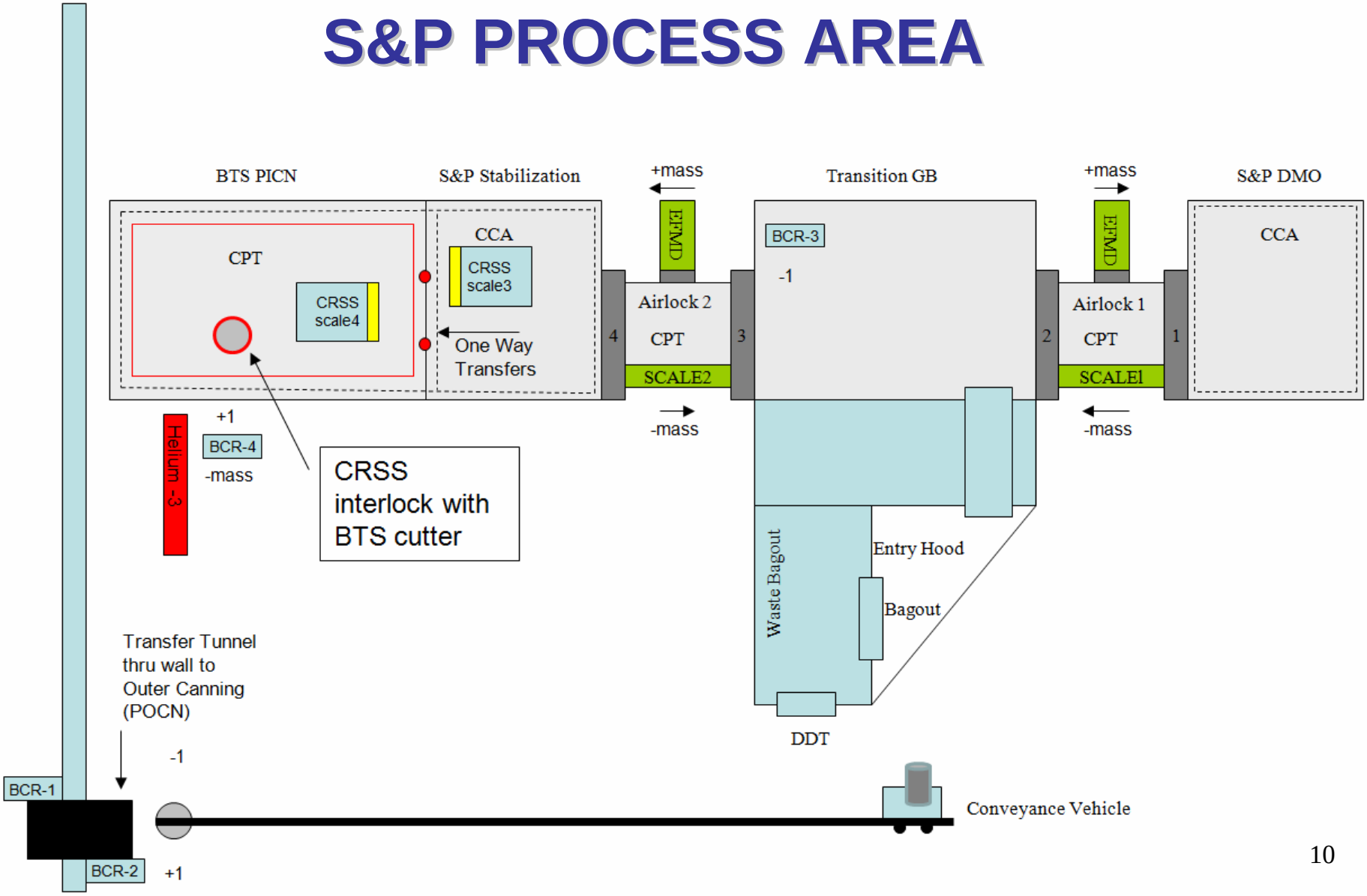
S&P Control Strategy

- All material storage in the K building is assumed to be in certified shipping pacakges (e.g. 9975) for the S&P phase of operations
- Unpacking and packaging of 9975s is assumed to take place in KIS
- Required NDA of S&P 3013 containers is assumed to take place in KIS
- The existing safety basis for KIS assumes one-can-at-a-time anywhere in KIS room, therefore criticality is beyond extremely unlikely. Additional demand of S&P phase on KIS will likely challenge that control (to be verified by a Time and Motion)…impact revise KIS NCS controls and add NIMs
- Material transfers from the Outer Canning Room to/from KIS are permitted only in the approved, engineered transfer cart

S&P Outer Canning Room Summary

Parameter	Control
Mass	Overhead crane/manipulator and transfer cart limited to one-at-a-time movement of fissile material, cart movement tracked by CRSS
Geometry	Approved containers, equipment size-limited to permit only single containers Engineered features control locations overhead crane/manipulator may release containers
Volume	Approved containers
Interaction	Equipment fixed, seismically anchored Transfer cart maintains separation
Moderation	Sealed containers (preclude water ingress)
Reflection	None, Full reflection permitted

S&P PROCESS AREA



S&P Process Room / Glovebox Guidance

- The conveyance vehicle/aid is designed to handle one can at-a-time and not interfere with the gloveboxes or hoods.

- Integrate features into the BTS design to enable the BTS glovebox/hood to function as a CPT
  - CRSS would control a physical permissive that precludes operation of the BTS cutter if the S&P room limit would be exceeded by a can exiting the BTS hood
  - CRSS would control a physical permissive that precludes the operation of the isolation door at the inlet to BTS glovebox

- Controls for the S&P DMO glovebox based on the analysis of the PDCF DMO evaluation >Limited volume cooling water system

- HVAC – HEPA filtration primary control, surveillance program required to detect potential accumulation. Assume that required ventilation flow rates DO NOT REQUIRE AUTOMATIC FIRE SUPPRESSION IN THE HEPA FILTER PLENUM

S&P Process Room NCS Summary

Parameter	Control
Mass	Room has a can limit, enhanced admin control with CRSS
Geometry	Only approved containers allowed
Volume	Can geometry
Interaction	Equipment fixed, glovebox seismically anchored, mechanical assist for single can movements
Moderation	No water-based fire suppression (i.e. no sprinklers*) in room or HVAC filter plenum
Reflection	No water-based fire suppression (i.e. no sprinklers*) in room or HVAC filter plenum Nominal reflection assumed

*Fire Suppression will be FM-200 (gaseous) during the S&P phase of operations. Conversion to water-based fire suppression is expected during the Pit Processing phase, as such these features should be integrated into the design

S&P DMO Glovebox NCS Summary

Parameter	Control
Mass	CCA has mass limit, mass controlled by CRSS
Geometry	Only approved containers allowed (i.e. 3013s and convenience cans with milk bottle lids)
Volume	Limited volume cooling water system, vacuum canisters
Interaction	Equipment fixed, CPT structure, glovebox seismically anchored
Moderation	Limited volume cooling water, no water-based fire suppression (i.e. no sprinklers*)
Reflection	Limited volume cooling water, no water-based fire suppression (i.e. no sprinklers*) Nominal reflection assumed within GB

*Fire Suppression will be FM-200 (gaseous) during the S&P phase of operations. Conversion to water-based fire suppression is expected during the Pit Processing phase, as such these features should be integrated into the design

S&P Furnace Glovebox NCS Summary

Parameter	Control
Mass	CCA has mass limit, mass controlled by CRSS
Geometry	Only approved containers allowed (i.e. 3013s and milk bottles)
Volume	Volume limited furnace boat, vacuum canisters
Interaction	Equipment fixed, isolation door, glovebox seismically anchored
Moderation	No water-based fire suppression (i.e. no sprinklers*) Limited volume moderator permitted in GB
Reflection	No water-based fire suppression (i.e. no sprinklers*) Nominal reflection assumed within GB

*Fire Suppression will be FM-200 (gaseous) during the S&P phase of operations. Conversion to water-based fire suppression is expected during the Pit Processing phase, as such these features should be integrated into the design

Pit Processing - Systems with PDCF NCSEs

The **evaluation process** included the following steps

- **Identify differences** between the Pit Processing layout and the corresponding "green field" (aka Pit ProcessingF) design
- Identify any new hazards/conditions that could result in **new or changed process upsets**
- **Develop/revise criticality control guidance** for Pit Processing operations

The criticality controls for **Glovebox, PITD/SRL, PCAN, HEUM, SAN, Product NDA , and Hydride** are basically unchanged from PDCF (other than the logic to implement the engineered mass control). The primary change is the use of a single conveyor/airlock for material transfer both in to/out of the process gloveboxes. The total number of airlocks has also been reduced. **HVAC** during Pit Processing operations relies on sand filter as in PDCF, therefore criticality concerns/controls unchanged.

Pit Processing Systems with PDCF NCSEs

- **Compatible PDCF NCSEs relied upon for:**
  - PITD, SRL, DMO, HEUM, OPH and ISM, HYD, SAN, Product NDA, Canning (PCAN), HVAC and Glovebox
- **KAC-specific criticality hazard identification, evaluation and development of controls needed for:**
  - Shipping/receiving, Unpacking and packaging, internal transport system, Waste Handling, Fire Suppression Water Collection, interface with Analytical Laboratory, KIS operations

Guidance for Systems Unique to PDCP

•**Ship/Receive** – no open shipping packages in Receipt Staging or Ship/Receive NDA, number of packages limited by package Criticality Safety Index (or Transportation Index whichever is more limiting)

•**Pack/Unpack**- MD-2 unpacking limited to processing one SI at-a-time, 9975 packaging limited to processing one 3013 at a time

•**Waste Handling** – No HAW/LAW tanks, HEUM electrodecon waste transferred to favorable geometry tanks (i.e. pencil tanks) for assay prior to transfer to mobile waste tank for transfer to WSB; mass limits for SWHS gloveboxes

NCS Guidance for Systems Unique to PDCP

•**Internal Transport** – engineered to limit to one-at-a-time movements, water ingress is precluded by design and by CRSS constraint on CPT doors to open only one-at-a-time

•**Fire Suppression Water Collection -** Engineered SS water collection system including glovebox criticality drains, curbs/ramps, weirs, floor drains, collection basins with areal distribution system (addressed as an independent control strategy).

•**ALAB –** engineered controls including the use of double-door-transfer (DDT) containers fit with sample trees to control the number of sample vials, and sample vials of fixed size shall be used

Pit Processing Operations NCS Summary

Parameter	Control
Mass	CCA mass and/or item count controlled by CRSS, design for single can storage, grippers for single can operations
Geometry	Only approved containers. Favorable diameter tanks. Piping sizes. Equipment (calciner tube, blender shape, catch trays), drain design
Volume	LVCS, vacuum canisters, waste can volume, filter size
Interaction	Equipment fixed spacing, CPT structure, glovebox seismically anchored, transportation packages
Moderation	LVCS, no water fire suppression in HEPA filter plenum, passive backflow prevention
Reflection	LVCS, Criticality drains, CRSS beryllium controls

Material Storage

- During S&P
  - K-Area Material Storage Area (KAMS) (WSRC-SA-2002-00005)
  - approved transportation packages only
  - controls and limits will be maintained
- During Pit Processing Phase
  - authorized material loadings will be expanded
  - AL-R8SI and ES3100 packages will be added

Material Storage

- Existing analyses reviewed to develop CD-1 NCS for Material Strategy
- 9975 and ES3100 are licensed transport packages with NRC Certificates of Compliance (CoC)
- K-Area Material Storage Area (KAMS) (WSRC-SA-2002-00005)
  - Pallets restricted to single package type
  - Pallets permitted to be mixed
  - infinite planar array of 9975 packages stacked 4 high, no restriction on ES-3100
  - Stack limit to 3 high limiting potential damage
  - AL-R8SI package is not an NRC approved transportation package
  - AL-R8SI approved for transportation and storage of pits at Pantex
  - Pantex criticality evaluations reviewed for AL-R8SI limits

Nuclear Incident Monitor (NIM) Placement

Currently not required for KIS function (basis establishes the criticality is not credible in KIS, KIS pack/unpack area, 910A based on limit of only one can outside of a shipping package)

Required in S&P room
Required in Outer Canning
Based on PDCF analyses, NIMs will be required:

- at +31-Level for HEU process rooms (est 4 sets)
- at 0-Level for all rooms with gloveboxes (est 20 sets including S&P)
- at -40-Level, NDA room requires NIMs (est 2 sets)
- at -40-Level for Material Storage (no NIMs when no AL-R8SIs present)

Additional analyses required in Title I to determine if presence of AL-R8SIs will require NIM installation (dependent on number and configurations of AL-R8SIs) and if modifications to KIS operations will require additional NIMs to be installed there.

Criticality Accident Alarm Evacuation Boundary

- Assume maximum accident same as PDCF
- Based on PDCF calculations (N-CLC-F-00381) with a minimum 1m-thick shield wall and a distance of 17.6m would conservatively define the boundary for 12-rad
- The method reasonably well bounds plutonium and uranium metal systems and uranium solution systems.
- Based on current wall thickness and interior door placement, the evacuation boundary will extend beyond the building walls
- Results of the preliminary analysis indicate that the evacuation boundary:
  - Will clearly encompass areas under construction at 0-Level (PITD) and construction of/work at +31
  - May extend to drum storage area at -40 Level from the NDA room at that level

Design Requirements for FSW Collection

- maximum credible flow rates into gloveboxes
- maximum credible flow rates into room drains
- minimum credible flow rates into basin
- maximum credible volumes into basins
- maximum credible fissile mass to basins to establish appropriate dispersal mechanism
- maximum piping sizes and spacing
- Glovebox and floor drain systems to promote settling
- Consider features/requirements to recover water after accident
- Identify contingency for water volumes beyond design basis (i.e. 300,000 gallon sump capacity in K-building)

Reference MMW-2-10-016

Design Challenges

- Piping Runs
- Structural interferences
  - Particularly drains from Hydride appear to penetrate shear wall (Backup for Hydride is to use S&P fire protection strategy)
  - Also number and separation distances for drains
- Provide drain path for water from rooms with only contamination (Canning, SAN and SWHS gloveboxes do not have criticality drains)
- Concurrence on reasonable design basis volumes
- Concurrence on maximum flow rates
- Establish minimum flow rate and pressure differential to qualify specific distribution device

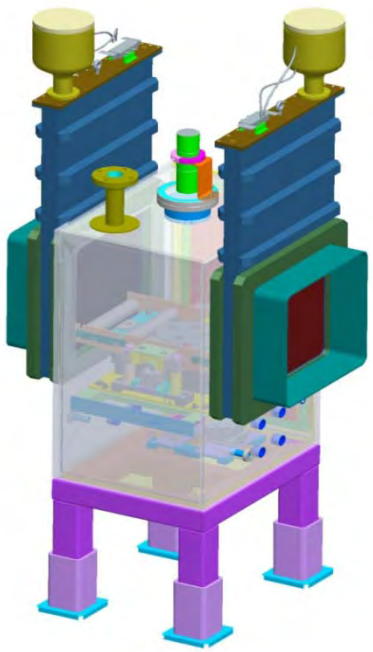
CRSS Safety Function* includes:

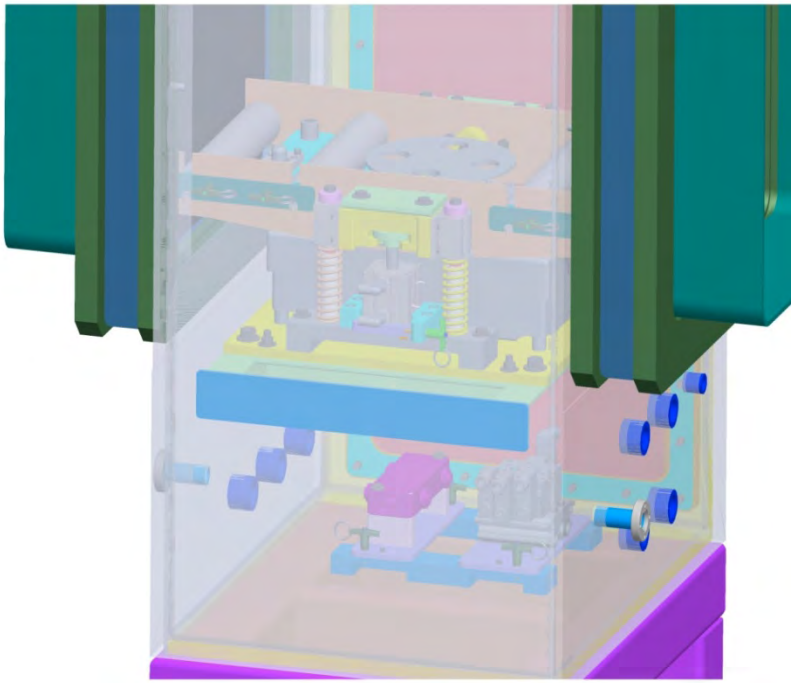
1. Decision Logic to Permit Transfers
2. Actuation of solenoid valve
3. Reliable measurement data
4. Multiple position sensors

*The CRSS must meet the design features and quality attributes of nuclear qualified, commercially available instruments and electronic components.

Pass Thru / Airlock Design Features

Interior View





Airlock Function and Performance

- Carriage with the MTC enters the Airlock --
  - Through open entry door
  - Via motorized drive rollers
  - Positioned by raised stops
- Door is closed and sealed, position confirmed by sensors
- FMD sequence is initiated.
- Weight is taken --
  - Shuttle is pneumatically lowered
  - Carriage plug, MTC, and material is supported by pedestal
  - Weight is obtained by scale
  - Shuttle is raised to original position
- Atmosphere exchange is initiated
- Carriage with the MTC exits the Airlock
  - Through open exit door
  - Via motorized drive rollers

Point-to-Point Verification

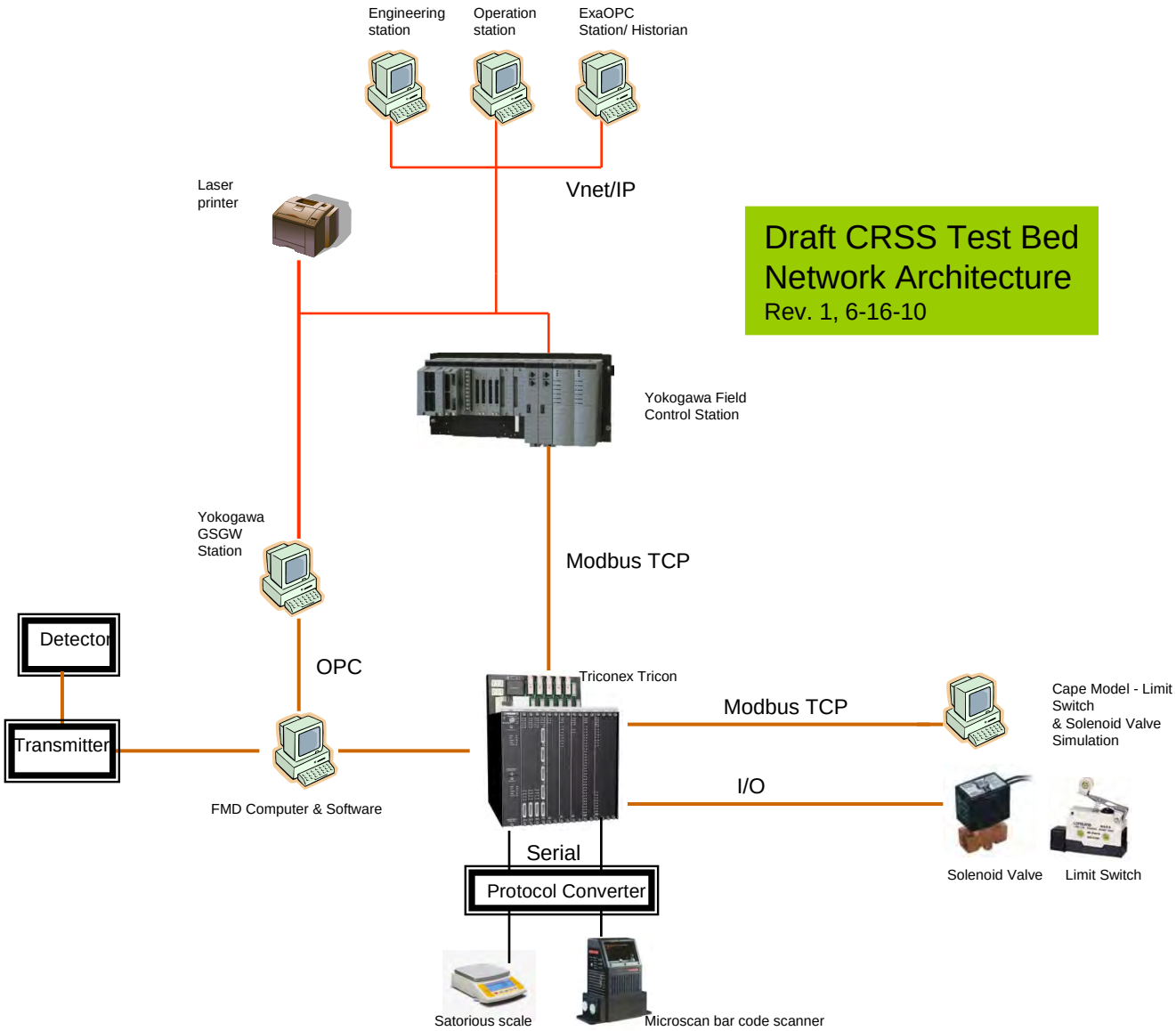
The Criticality Safety System shall include a means to independently verify FMD measurements at multiple locations. A comparison of measurements provides assurance that the FMDs have not drifted (gamma component) or failed, and also provides assurance that the correct package in a given transfer container arrives at the correct process input drop box.

Lower Limit of Detection (FMD Function)

The neutron and gamma detectors shall be capable of detecting fissile mass to a lower limit of detection of 10 grams.

This is required to identify items containing a small amount of fissile material to be properly identified as fissile and to be incorporated into the criticality inventory and not exceed the fissile material limits for a given criticality control area.

The value of 10 grams will provide sufficient margin such that box clean outs should coincide with the 60-day inventory period per Calculation X-CLC-F-00553 - Airlock FMD Error Accumulation. *(Needs to be verified for PDC Time and Motion.)*

PDC Project – Conceptual Design

Formal Design Review, August 2010