Project Title: *UFTR DIGITAL CONTROL SYSTEM UPGRADE*

UFTR-QA1-12, System Description

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1. Introduction

1.1 Purpose

The purpose of this System Description (SD) document is to define the UFTR design and its unique safety features, describe the proposed protection system, and discuss the unique features of the proposed protection system.

1.2 Scope

The SD provides the fundamental data on the design of the UFTR and the TXS protection system. The scope includes discussion on the UFTR design and its unique safety features, the proposed UFTR RPS, and its unique features.

2. References

/1/ UFTR-QA1-103, "Diversity and Defense-in-depth (D3) Analysis"

/2/ UFTR-QA1-14, "Safety System Design Basis"

3. Definitions, Acronyms, and Abbreviations

3.1 Definitions

Defense-in-Depth: The practice of having multiple, redundant, and independent layers of safety systems to reduce the risk that a single failure of a component or system will cause the catastrophic failure of the reactor.

Design Basis Event: Postulate events used in the design to establish the acceptable performance requirements for the structures, systems, and components.

Diversity: In fault tolerance, realization of the same function by different means. For example, use of different signals, processors, storage media, programming languages, algorithms, or development teams.

Nuclear Instrumentation (NI): The portion of a train that directly senses and responds to changes in neutron and/or gamma ray levels in the reactor core and converts the measured interaction into an electric, optic, or pneumatic signal.

Protective Action: The initiation of a signal within the sense and command features or the operation of equipment within the execute features for the purpose of accomplishing a safety function.

Redundant Equipment or System: A piece of equipment or a system that duplicates the essential function of another piece of equipment or system to the extent that either may perform the required function, regardless of the state of operation or failure of the other.

Sensor: The portion of a train, other than nuclear instrumentation, that responds to changes in a plant variable or condition and converts the measured process variable into an electric, optic, or pneumatic signal.

Sensing Equipment: This expression includes both nuclear instrumentation (NI) and sensors.

Train: An arrangement of components and modules required to generate a single protective action signal when required by a generating station condition. A train loses its identity where single protective action signals are combined.

3.2 Acronyms

AQP	Acquisition and Processing
ARM	Ariel Radiation Monitor
BF3	Boron Tri-fluoride detector
CCF	Common Cause Failure
D3	Diversity and Defense-in-Depth
ESFAS	Engineered Safety Features Actuation System
F	Fahrenheit
FM	Fan Monitor

FRM	Flow Rate Monitor
GW	Gateway
HEU	Highly Enriched Uranium
LEU	low enriched uranium
MCR	Main Control Room
MRS	Manual Reactor Scram
MSI	Monitoring Service Interface
NI	Nuclear Instrumentation
PI	Process Instrumentation
QDS	Qualified Display System
RG	Regulating Blade
RTD	Resistive Temperature Detector
RTS	Reactor Trip System
SD	System Description
SU	Service Unit
SW	Software
TXS	TELEPERM XS
UFTR	University of Florida Training Reactor
WLM	Water Level Monitor

4. Description of the UFTR

The UFTR was built in 1959 and was one of the first nuclear reactors on a university campus. Originally designed for highly enriched uranium (HEU) fuel, the UFTR was converted to a low enriched uranium (LEU) fuel system in 2006. The UFTR is currently completing relicensing which requires modification and creation of documents to correct existing errors and to reflect on the changes caused by the refueling and regulatory changes. The current licensed analog protection/control system for the UFTR has not changed since its original design. The existing system has become old and prone to failure, and consequently, in past few years, the availability of the UFTR has reduced significantly. Hence, it is essential to replace the analog system with at least an equivalent digital system. The proposed digital protection system upgrade is designed to make the UFTR more available and relevant to current trends towards digital protection/control in commercial reactors for training purposes.

4.1 The UFTR Design

The UFTR core is comprised of six fuel boxes placed in two rows of three boxes, and surrounded by a graphite reflector. Fig. 1 shows schematic of the UFTR core and its bundles and control blades. Each box contains up to four fuel bundles, and each fuel bundle has up to 14 fuel plates. There are three safety blades (S1, S2, & S3) and one regulating blade (RG). The worth of the three safety blades is significantly higher than the regulating blade. The RG is used for change of power during regular operations, while the safety blades are used to shutdown the reactor. Table I provides a list of important parameters associated with the UFTR fuel plate.

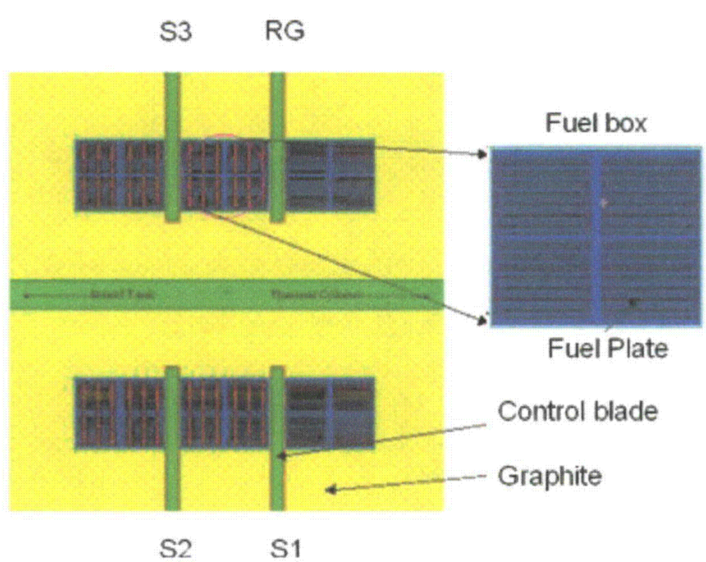


Figure 1 - Schematic of UFTR Core, fuel boxes, and fuel bundles

Table I – Important parameters associated with each fuel plate

Parameter	Value
Fuel type	U_3Si_2-Al
<u>Fuel Meat Size</u> Width (cm) Thickness (cm) Height (cm)	 5.96 0.051 60.0
<u>Fuel Plate Size</u> Width (cm) Thickness (cm) Height (cm)	 7.23 0.127 65.1
Cladding material	6061 Al
Cladding Thickness (cm)	0.038
Fuel Enrichment (nominal)	19.75%
"Meat" Composition (wt% U)	62.98

The UFTR cooling system includes both primary and secondary loops, however, currently the secondary loop is open, i.e., the water is dumped into the sewer. Fig. 2 depicts the primary loop.

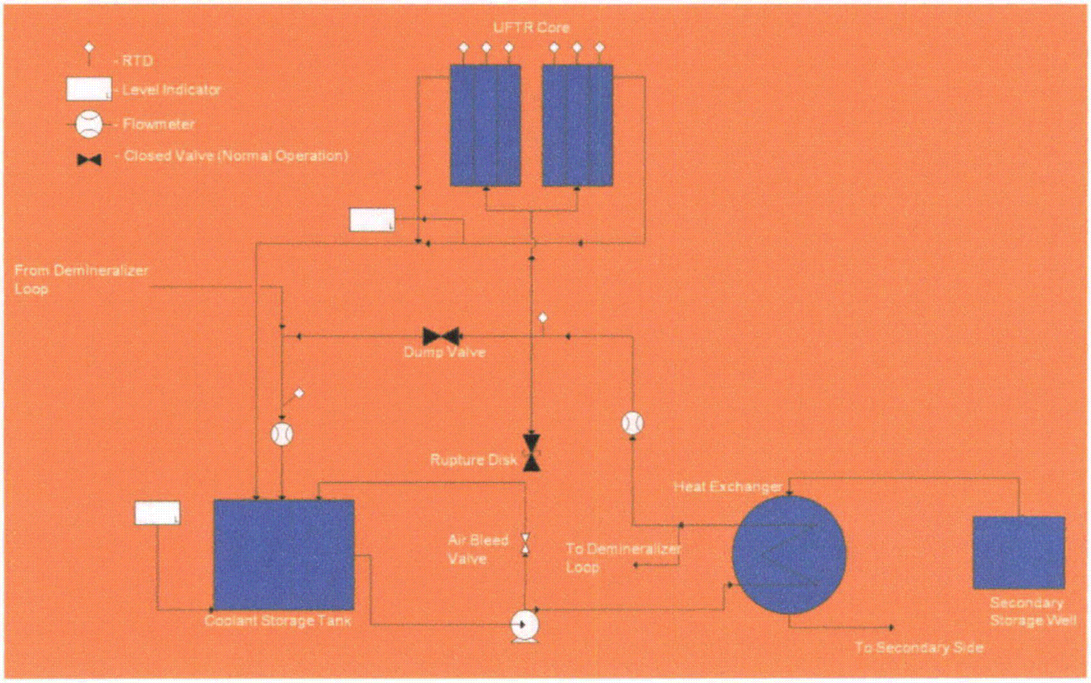


Figure 2 - Schematic of the UFTR Primary coolant loop

The primary loop starts from the lower left-hand side of the above diagram; water is pumped out of 'coolant storage tank' to the 'heat exchanger,' then the reactor core. The water flows from the bottom to the top of the core, and then returns back to the 'coolant storage' tank. This completes a closed loop. The above figure also shows all the Process Instrumentations (PIs) or sensors, and Nuclear Instrumentations (NIs) including:

- i) six RTD's which measure fluid temperature on the top of the six fuel boxes,
- ii) one RTD, which measures the temperature of the inlet water,
- iii) one RTD, which measures the temperature of the outlet water;
- iv) one flow-meter, which measures the inlet flow rate;
- v) one flow-meter, which measures the outlet flow rate;
- vi) a sight glass indicator for the water level in the 'coolant storage tank,'
- vii) a level indicator measuring water level in the core relative to the top of the core, and
- viii) the Nuclear Instrumentations (NI's) including BF3, Fission Chamber, and Ion Chamber, which measure reactor power over the whole range.

All temperature variables will be measured with RTD's, and water level will be measured in the core and coolant storage tank.

To make sure that there is no local boiling over the whole range of power allowed (i.e., 0.0 – 100 kW), minimum flow rate for different inlet flow temperatures are identified by performing detailed thermal hydraulics analyses. Fig. 3 shows the operating range of the reactor for three different inlet temperatures including 86 F, 100 F, and 110 F.

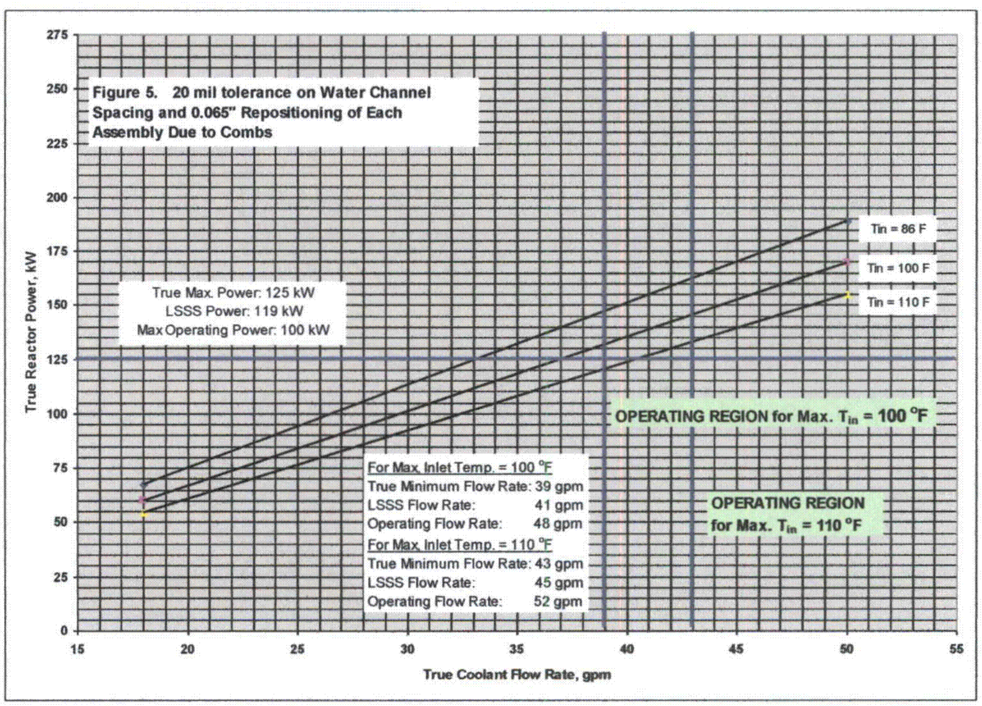


Figure 3 - Operations region for the UFTR for different inlet flow temperatures

Based on operating experience over the past 50 years, the inlet water temperature is consistently about 86 F, and does not exceed 100 F; therefore, the maximum allowed temperature of the inlet flow is set to 99 F, considering an uncertainty of 1%. Note that the region to the right of the vertical blue lines (indicating the flow rate) and the region below of the temperature line identify the 'operating' region of the reactor. As expected, the allowed region for operations decreases as the inlet water temperature increases.

Considering the above 'operation' region with no local boiling, very thin fuel plates, and high thermal conductivity of Al metal, it is shown that following the reactor shutdown, the residual heat in the fuel plates is so low that there is no need for cooling, and therefore, there is no need for an active heat removal system.

Fig. 4 shows the computed total neutron flux distribution throughout the six fuel boxes at full power of 100 kW. As indicated in the diagram, the maximum total flux is ~4.5×10^{12} neutrons/cm^2-s, and as expected it occurs at the middle of the two central boxes.

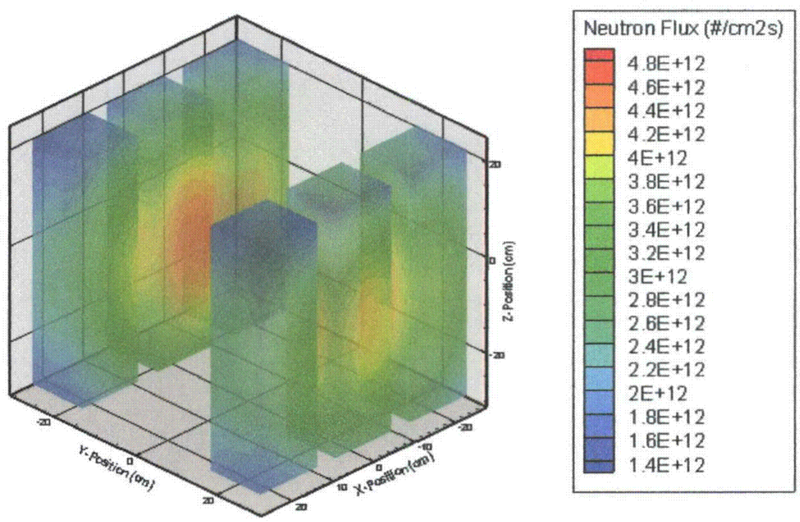


Figure 4 - Total neutron flux distribution throughout the six fuel boxes at full power

Also, as shown in Fig. 5, the UFTR has six beam ports, one thermal column, on rabbit system, and three vertical columns.

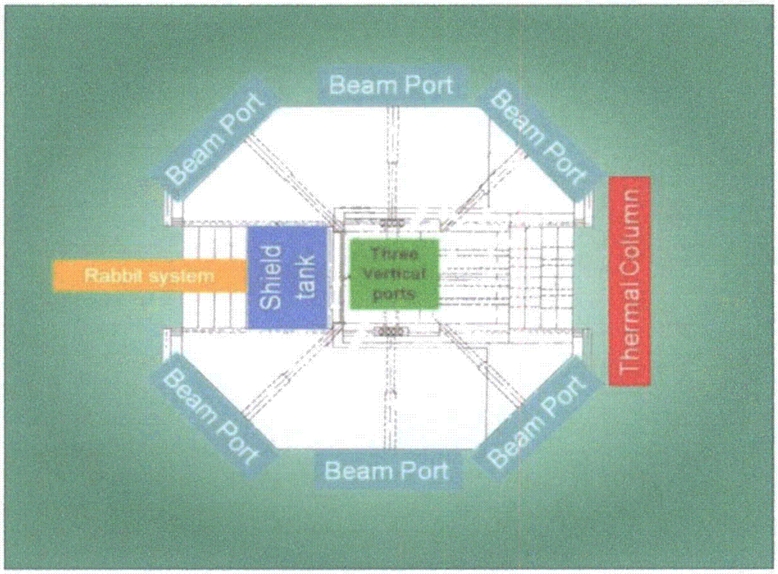


Figure 5 - Schematic of the UFTR

The UFTR primary coolant system is design such that for the allowed operating conditions, there is no possibility of local boiling. Further, because of the thin fuel plate and low power level of the UFTR, the residual heat in a fuel plate is so low that following the reactor shutdown, there is no need for cooling; i.e., there is no need for an active heat removal system. Because of this feature, in addition to the blade-drop, another mechanism for shutting down the reactor is to dump the water out of the reactor core. This not only provides a diverse way of shutting down the reactor, but also eliminates the need for redundant systems, and consequently eliminates the possibility of the common cause failure (CCF).

4.3 Discussion on the proposed digital protection and control system

For this implementation, we are planning to install the AREVA NP's TXS protection system and the Siemens' T-3000 control system.

In order to provide the capability of shutting down the reactor in case of the failure of the TXS system, we have developed a 3-block design including the TXS, the T-3000, and a Manual Reactor Scram System (MRS) as depicted below (Fig. 6):

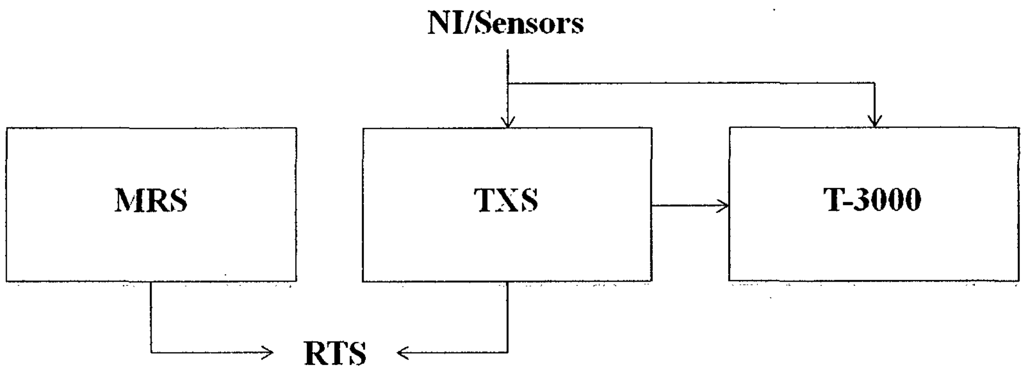
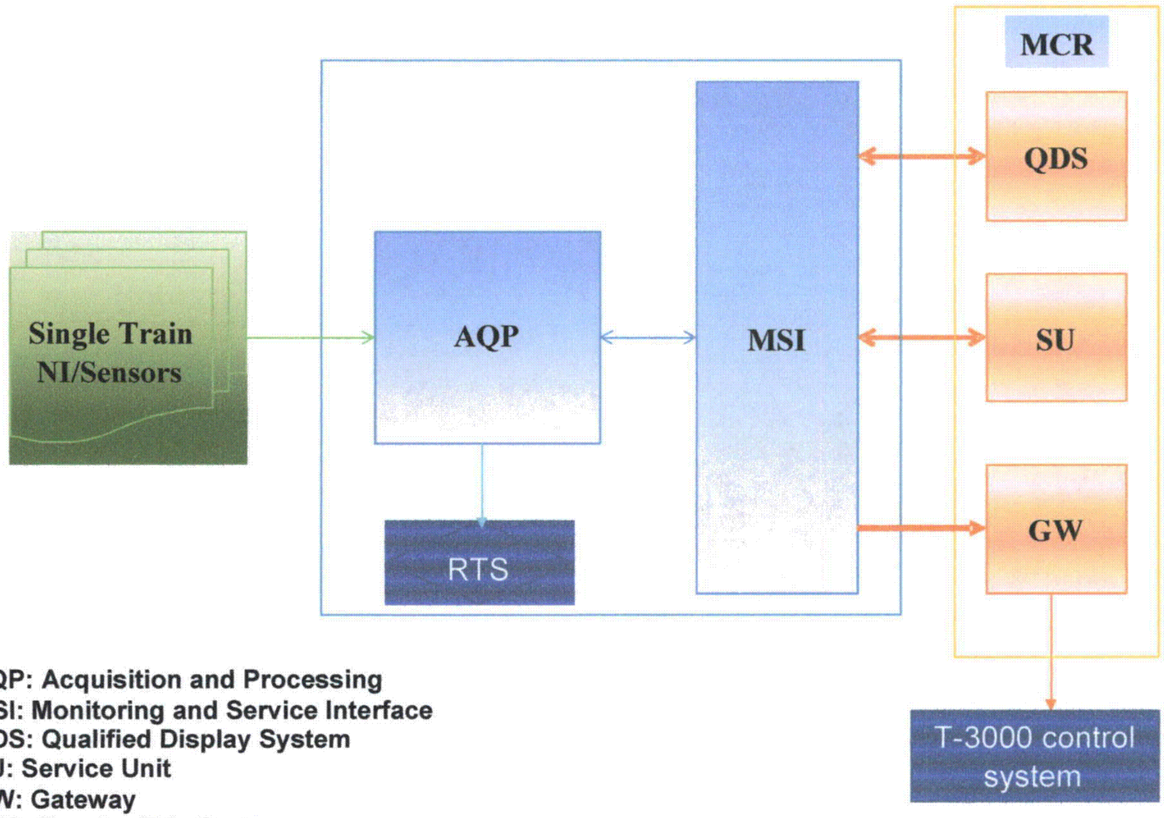


Figure 6 - The proposed Protection System for the UFTR

The above design is developed in order to make sure that the reactor is protected in case the TXS freezes. In this design, the T-3000 is used as an indicator, which informs the operator of the failure of the TXS, and therefore the operator will be able to shutdown the reactor through a diverse manual system, i.e., the MRS.

For further detail, the reader should consult the documents on Diversity and Defense in-Depth (D3), /1/, and Safety System Design Basis, /2/.

The proposed TXS protection system includes one safety train of several signals, which are processed by an Acquisition and Processing (AQP) processor, and the processed data are sent to the Main Control Room (MCR) and the Gateway (GW), which provides one-way communication with the T-3000 control system. Fig. 7 shows the proposed TXS system.



AQP: Acquisition and Processing
MSI: Monitoring and Service Interface
QDS: Qualified Display System
SU: Service Unit
GW: Gateway
RTS: Reactor Trip System

Appendix A provides the network diagram (Fig. A.1) corresponding to the above proposed system, and the schematics (Figs. A.2 and A.3) of the two cabinets containing different components of the proposed system.

The monitored parameters (signals), monitoring devices, and monitored region of the UFTR included within the single train are listed in Table II.

Table II: List of devices sending signals to the TXS within the single train

Monitored Parameter	Monitoring Device	Monitored Region
Whole power range	Fission chamber (FC), Ion Chamber (IC)	Core
Whole power range, Reactor period	Boron Tri-fluoride detector (BF3), IC	Core
Temperature	Resistive Temperature Detector (RTD)	Core, primary & secondary loops
Flow rate	Flow Rate Monitor (FRM)	Primary & secondary loops
Water level	Water Level Monitor (WLM)	Core, Storage tank, shield tank
Area radiation level	Area Radiation Monitor (ARM)	East, north, south & west
Fan air flow	Fan Monitor (FM)	Core ventilation, stack dilution

It is important to note that the new system has two diverse sets of instrumentation for measuring the whole range of power. Further, within the system, for increased reliability, RTD's are used in lieu of thermocouples for temperature measurement.

Finally, the T-3000 system is used as the reactor control system. This system not only will provide all control functions, but also provides an environment for displaying various reactor parameters and surveillance data during the reactor operations. The final installed system includes utility software for extraction of various reactor physics parameters, which are used for both confirmatory operational data and provide educational value.

Appendix A – TXS System Diagrams

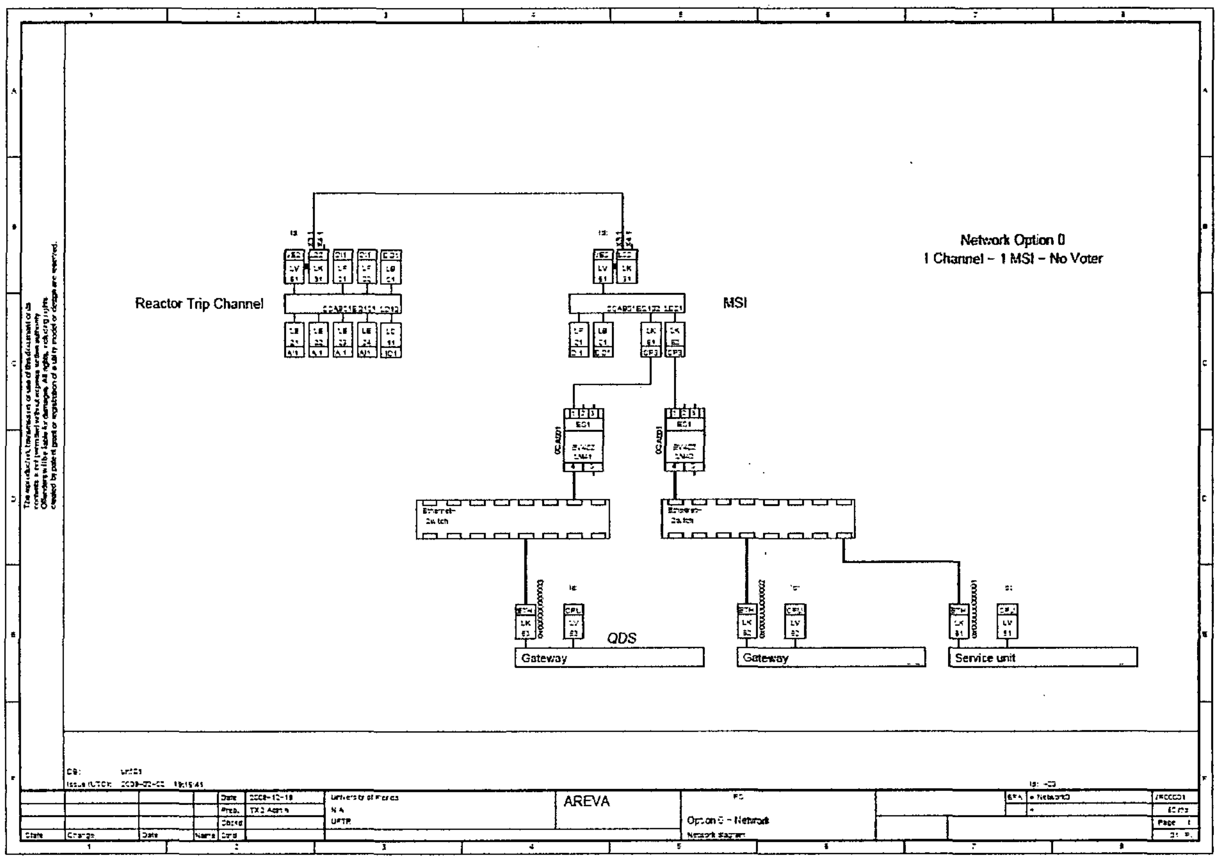


Figure A.1 TXS System Network Diagram

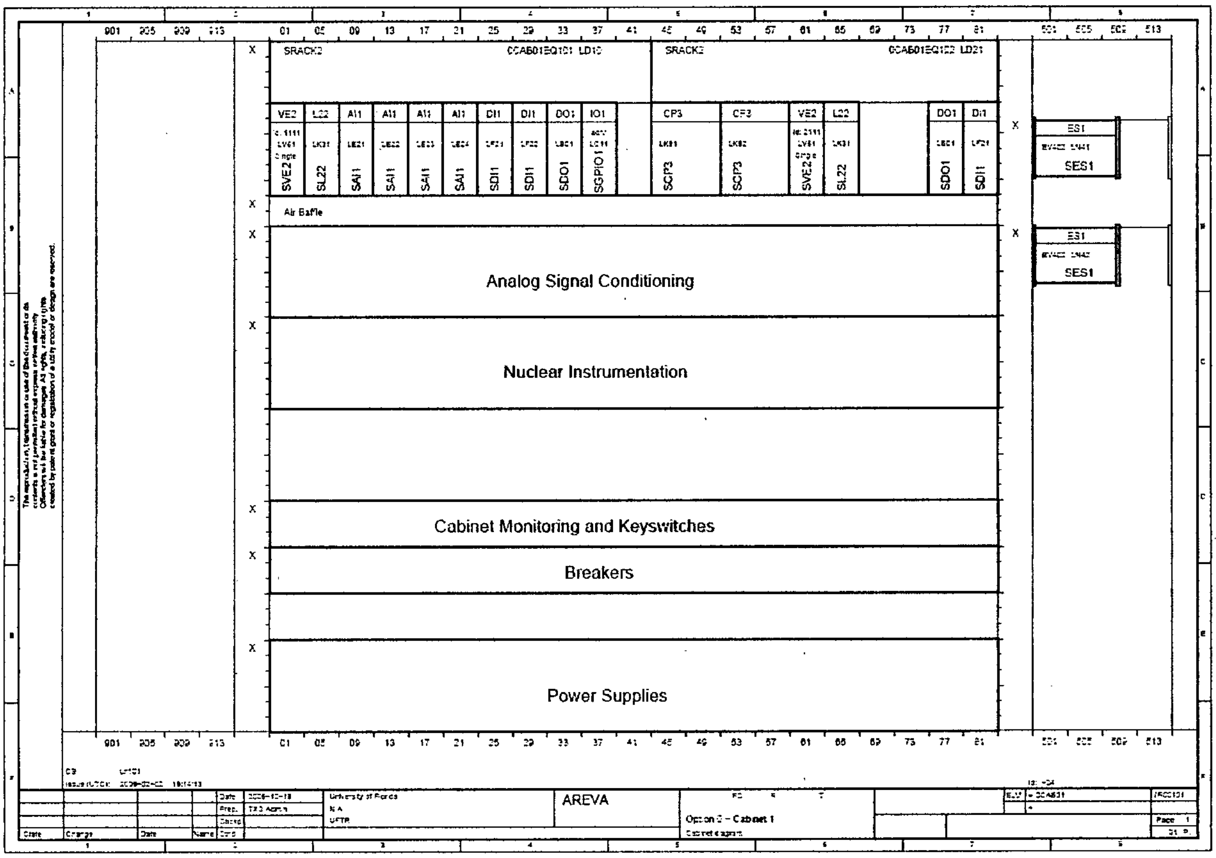


Figure A.2 UFTR TXS Cabinet 1 (Including AQP, NI signal processing)

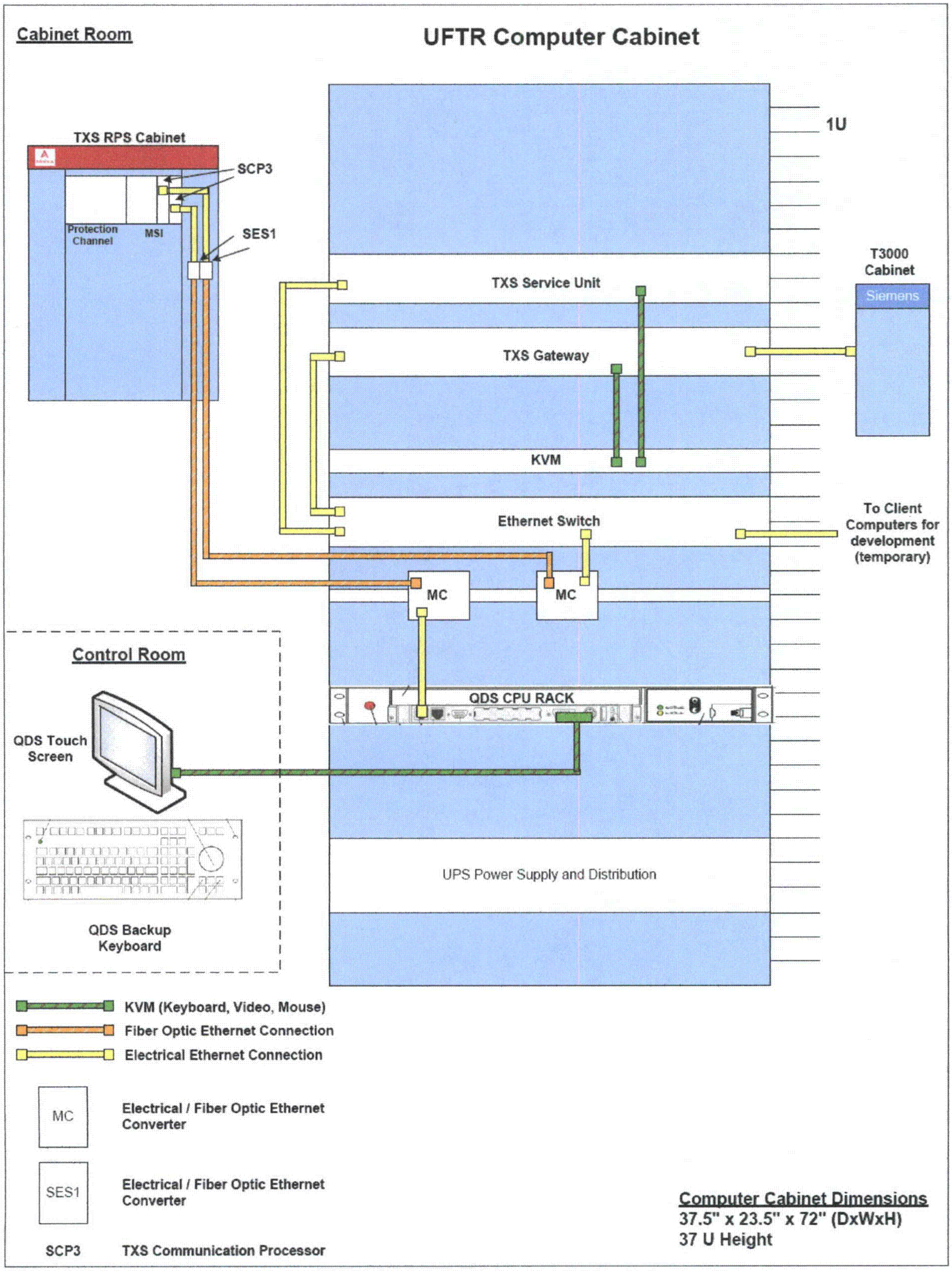


Figure A.3 UFTR TXS Cabinet 2 (Including SU, GW, MSI, &QDS)