

**Breakdown Structure and Categorization of LTX**

**Responsible Engineer:** Dick Majeski  
**Project Director / Cost Center Owner:** Phil Efthimion  
**Head of ES&H:** Jerry Levine  
**Chief Engineer:** Charlie Neumeyer

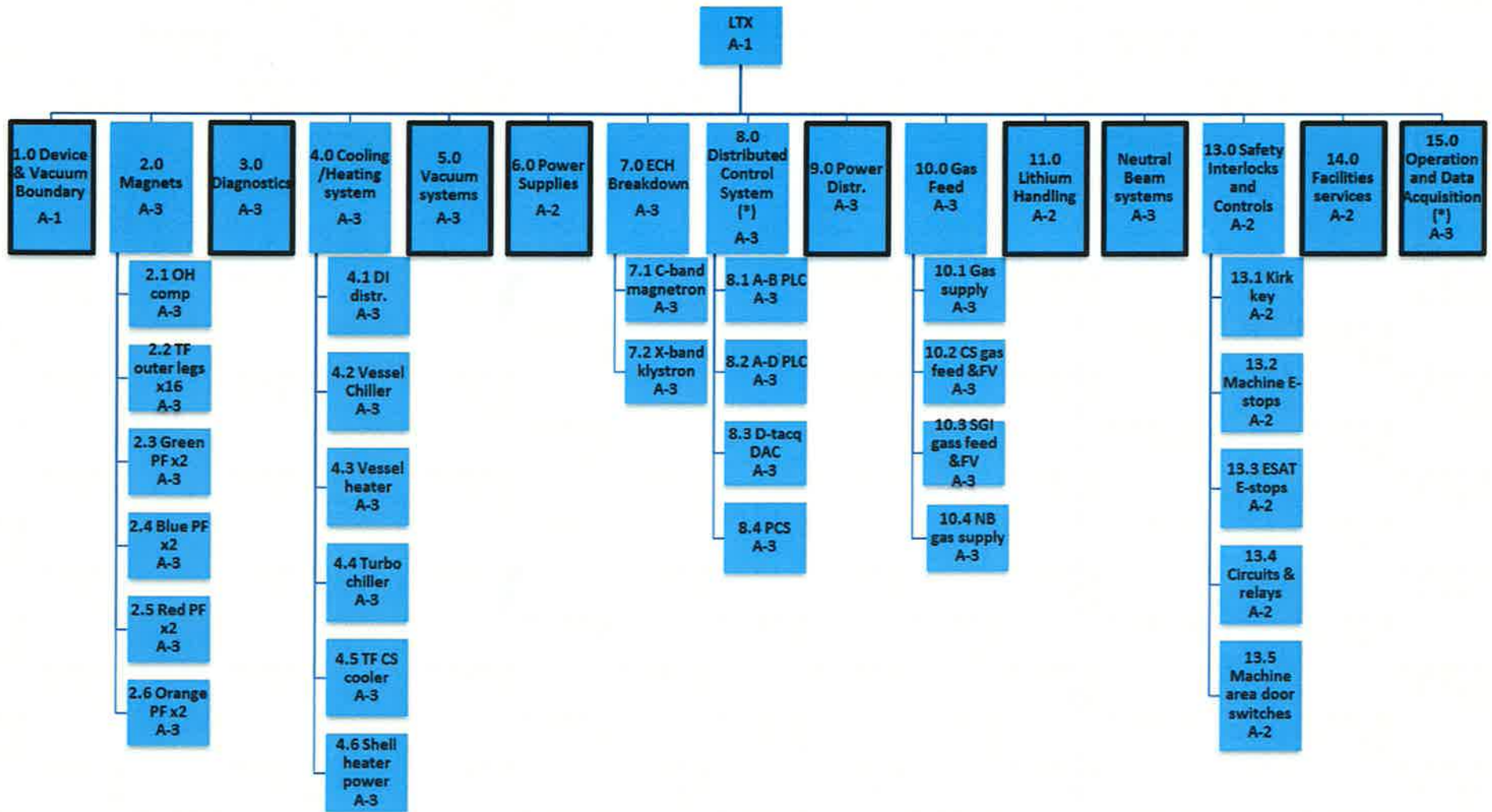
Richard P. Majeski  
Digitally signed by Richard P. Majeski  
DN: cn=Richard P. Majeski, o=PPPL,  
ou=PPPL, email=rmajeski@pppl.gov, c=US  
Date: 2018.10.23 15:45:20 -0400

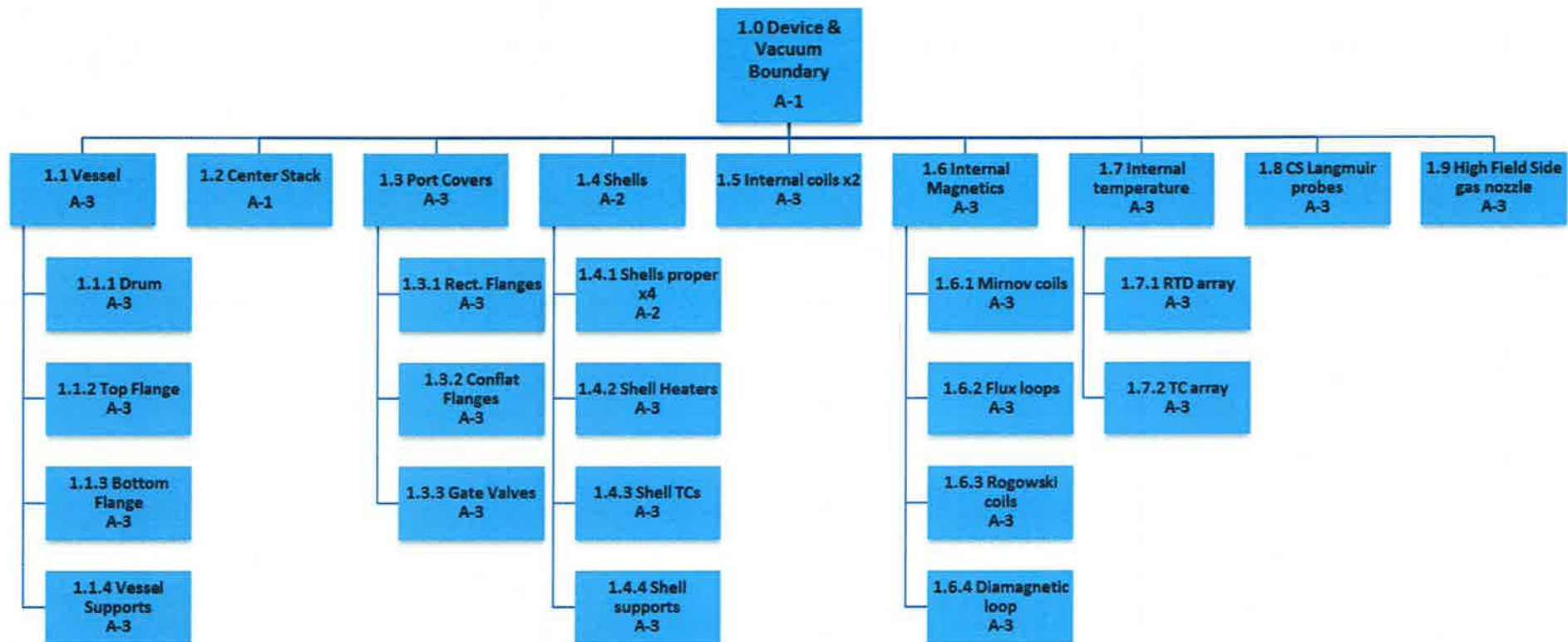
pefthimion-  
lt.ppppl.gov  
Digitally signed by pefthimion-  
lt.ppppl.gov  
Date: 2018.10.23 15:45:20 -0400

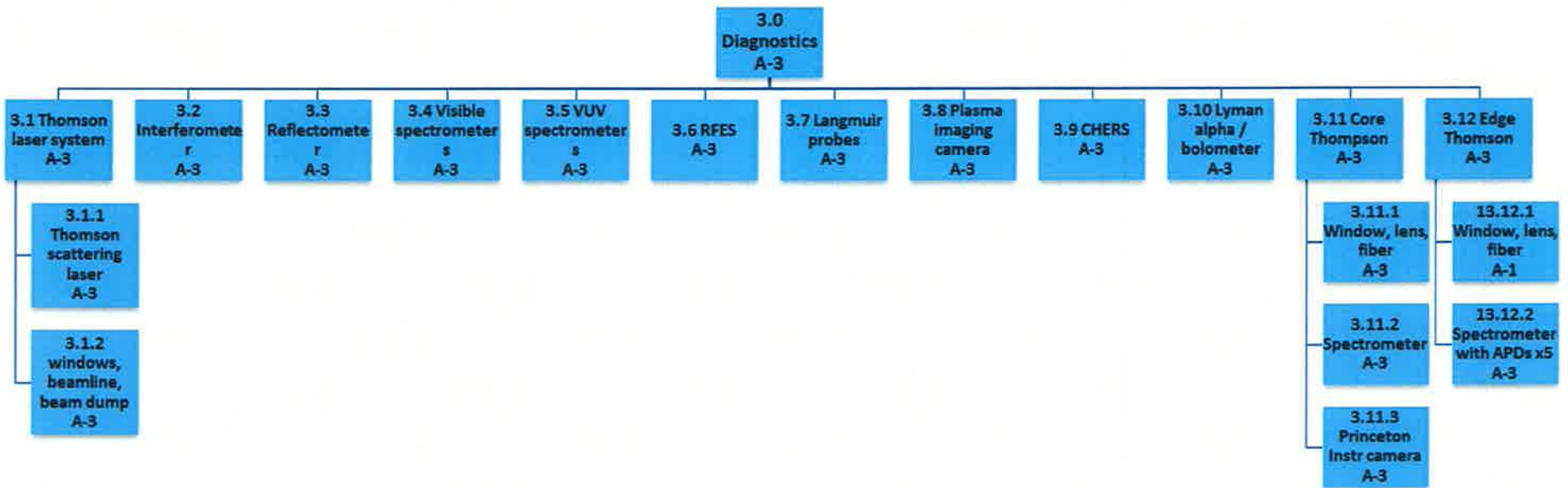
*[Handwritten signature]* 10/23/18

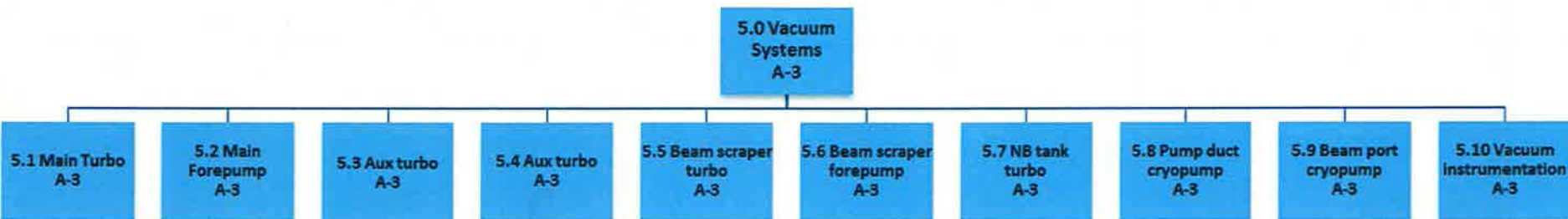
*[Handwritten signature]*

# Breakdown Structure

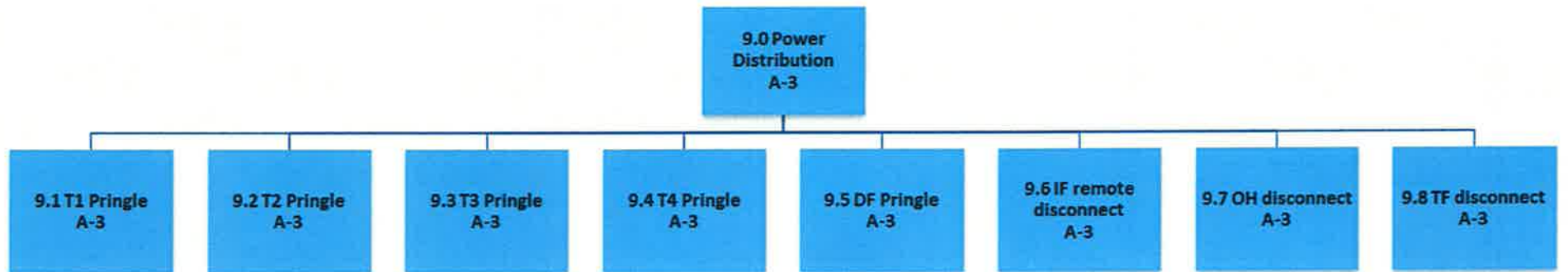


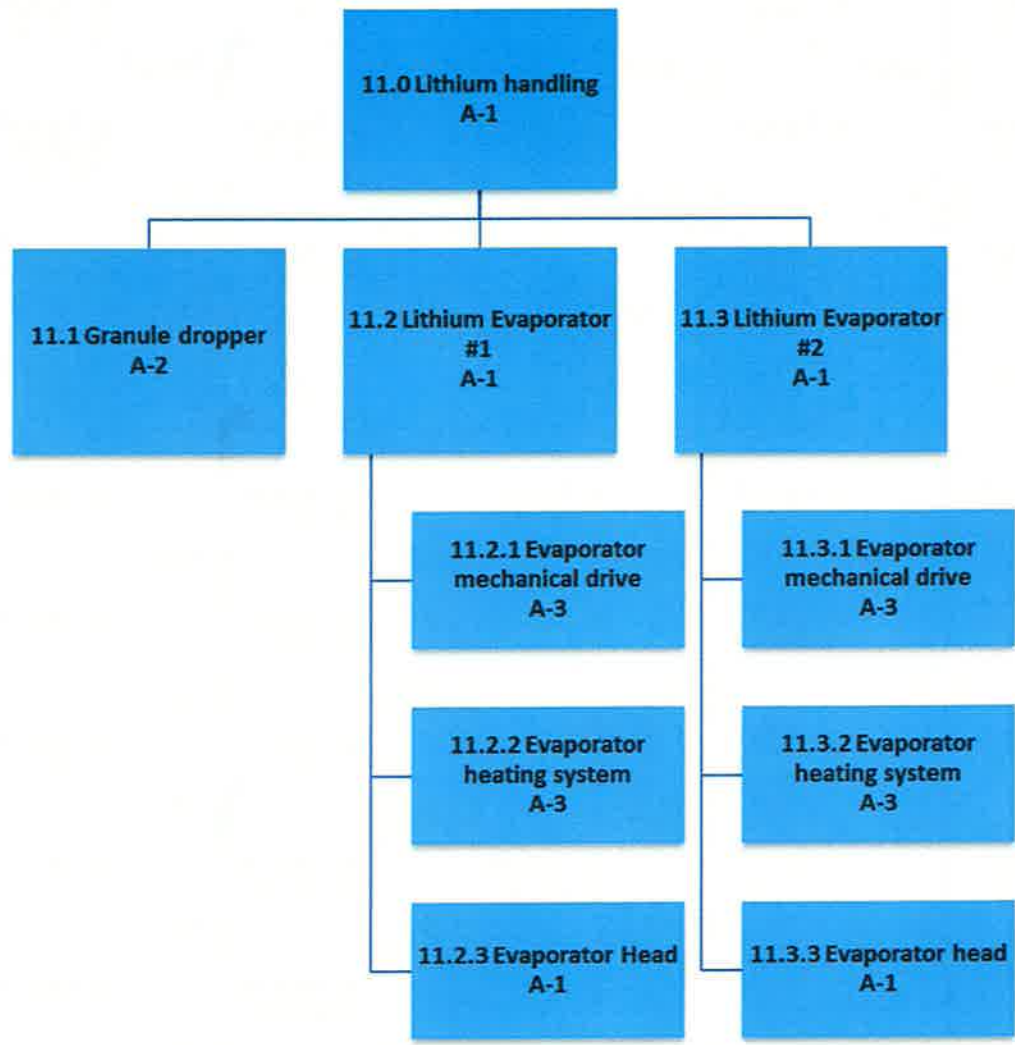


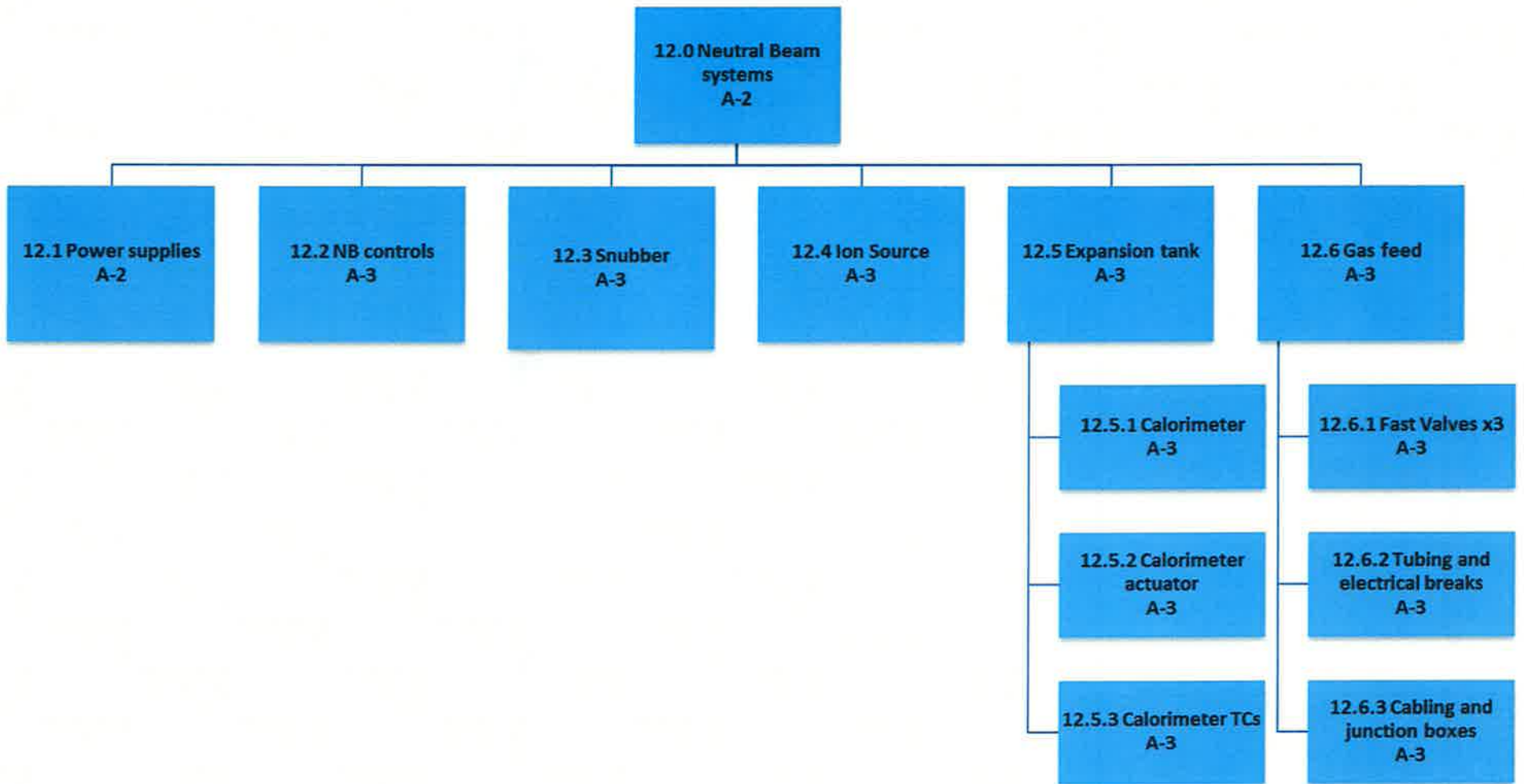


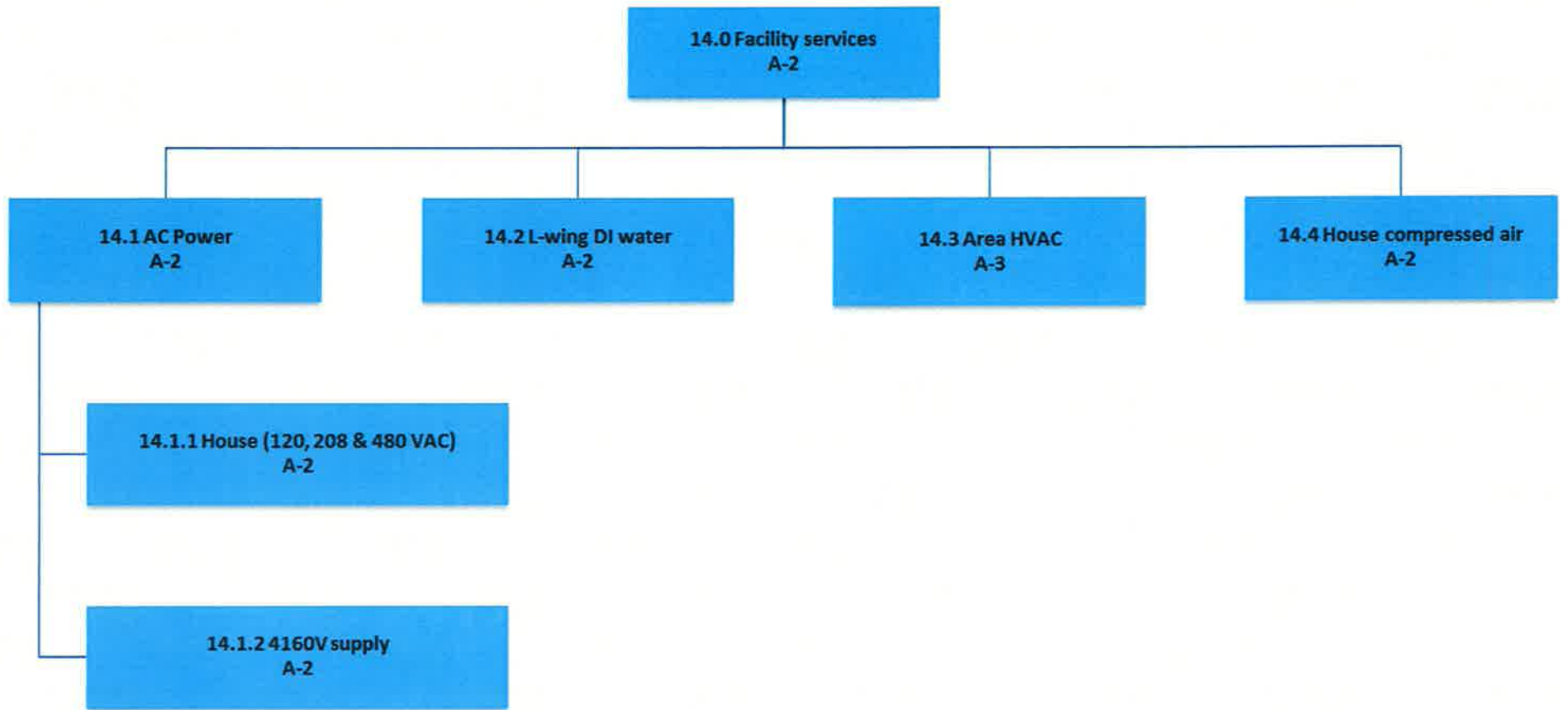












**15.0 Operation  
and data  
acquisition  
A-3**



## Categorization

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
LTX-β	Minor onsite / negligible offsite	> 3 months downtime	> \$500K	Limited industrial or lab experience	None	Change to SAD	Negligible impact	A-1
1.0 LTX Device, vacuum boundary								A-1
1.1 Vessel								A-3
1.1.1 Drum	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Common practice	None	No impact	Negligible impact	A-3
1.1.2 Top flange	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Common practice	None	No impact	Negligible impact	A-3
1.1.3 Bottom flange	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Common practice	None	No impact	Negligible impact	A-3
1.1.4 Vessel support	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Common practice	None	No impact	Negligible impact	A-3
1.2 Center Stack	Minor onsite / negligible offsite	> 3 months downtime	\$100K - \$500K	Limited industrial or lab experience	None	No impact	Negligible impact	A-1
1.3 Port covers								A-3
1.3.1 Rectangular flanges	None	< 1 month downtime	< \$100K	Common practice	None	No impact	Negligible impact	A-3
1.3.2 Conflat flanges	None	< 1 month downtime	< \$100K	Common practice	None	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
1.3.3 Gate valves	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.4 Shells								A-2
1.4.1 Shells proper (x4)	Minor onsite / negligible offsite	1 - 3 months downtime	< \$100K	Limited industrial or lab experience	N/A	No impact	Negligible impact	A-2
1.4.2 Shell heaters	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.4.3 Shell Thermocouples	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.4.4 Shell supports	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.5 Internal coils (x2)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.6 Internal magnetics								A-3
1.6.1 Mirnov coils	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.6.2 Flux loops	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.6.3 Rogowski coil	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.6.4 Diamagnetic loop	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.7 Internal temperature								A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
1.7.1 RTD array	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.7.2 Thermocouple array	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.8 C-S Langmuir probes	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
1.9 High field side gas nozzle	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.0 LTX magnetic field coils								A-3
2.1 OH compensations coils	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.2 TF coil outer legs (x16)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.3 Green PF coils (x2)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.4 Blue PF coils (x2)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.5 Red PF coils (x2)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.6 Orange PF coils (x2)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
2.6 Yellow PF coils (x2)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
3.0 Diagnostics								A-3
3.1 Thomson laser system								A-3
3.1.1 Thomson scattering laser	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
<b>3.1.2 Windows, beamline, beam dump</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.2 Interferometer</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.3 Reflectometer</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.4 Visible spectrometers</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.5 VUV spectrometer</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.6 RFEA</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.7 Langmuir probes</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.8 Plasma imaging camera</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.9 CHERs</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.10 Lyman alpha/bolometer array</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.11 Core Thomson viewing system</b>								A-3
<b>3.11.1 Viewing window, lens, fiber</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
<b>3.11.2 Spectrometer</b>	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
3.11.3 Princeton Instruments camera	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
3.12 Edge Thomson viewing system								A-3
3.12.1 Viewing window, lens, fiber	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
3.12.2 Spectrometers with APDs (x5)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
4.0 Cooling/heating systems								A-3
4.1 LTX DI water distribution system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
4.2 Vessel chiller	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
4.3 Vessel heater	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
4.4 Turbo chiller	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
4.5 TF centerstack cooler	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
4.6 Shell heater power	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.0 Vacuum systems								A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
5.1 Main turbo	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.2 Main Forepump	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.3 Aux turbo	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.4 Aux forepump	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.5 Beam scraper turbo	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.6 Beam scraper forepump	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.7 NB tank turbo	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.8 Pump duct cryopump	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.9 Beam port cryopump	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
5.10 Vacuum instrumentation	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.0 Power supplies								A-2
6.1 OH power supply								A-2
6.1.1 A charging supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.2 A cap bank	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.3 A IGBT switches (x28)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
6.1.4 A charging circuits	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.5 A trigger circuits	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.6 B charging supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.7 B cap bank	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.8 B IGBT switches (x28)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.9 B charging circuits	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.10 B trigger circuits	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.11 Current instrumentation	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.12 OH control and data acquisition (NI PXI 8110)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.1.13 OH safety interlocks	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
6.2 IF power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.3 DF power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.4 T1 power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.5 T2 power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.6 T3 power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
6.7 T4 power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.8 PEI power supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.9 Green cap bank	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
6.10 Yellow cap bank	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
7.0 ECH Breakdown systems								A-3
7.1 C-band magnetron system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
7.2 X-band klystron system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
8.0 Distributed control systems								A-3
8.1 A-B PLC	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
8.2 A-D PLC	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
8.3 D-tacq DAC	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
8.4 PCS	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.0 Power distribution								A-3
9.1 T1 Pringle	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.2 T2 Pringle	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
9.3 T3 Pringle	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.4 T4 Pringle	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.5 DF Pringle	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.6 IF remote disconnect	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.7 OH disconnect	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
9.8 TF disconnect	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
10.0 Gas feed system								A-3
10.1 Gas supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
10.2 C-S gas feed and fast valve	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
10.3 SGI gas feed and fast valve	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
10.4 NB gas supply	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
11.0 Lithium handing								A-2
11.1 Granule dropper	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Limited industrial or lab experience	N/A	No impact	Negligible impact	A-2

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
11.2 Lithium evaporator #1								A-2
11.2.1 Evaporator mechanical drive	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
11.2.2 Evaporator heating system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
11.2.3 Evaporator head	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Limited industrial or lab experience	N/A	Change to SAD	Negligible impact	A-2
11.3 Lithium evaporator #2								A-2
11.3.1 Evaporator mechanical drive	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
11.3.2 Evaporator heating system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
11.3.3 Evaporator head	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Limited industrial or lab experience	N/A	Change to SAD	Negligible impact	A-2
12.0 Neutral beam systems								A-2
12.1 Power supplies	Minor onsite / negligible offsite	< 1 month downtime	\$100K - \$500K	Common practice	N/A	No impact	Negligible impact	A-2

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
12.2 NB controls	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.3 Snubber	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.4 Ion source	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.5 Expansion tank	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.5.1 Calorimeter	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.5.2 Calorimeter actuator	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.5.3 Calorimeter thermocouple system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.6 Gas feed								A-3
12.6.1 Fast valves (x3)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.6.2 Tubing and electrical breaks	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
12.6.3 Cabling and junction boxes	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
13.0 Safety interlocks and controls								A-2

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety impact of item / activity failure	Potential reputation impact	Category
13.1 Kirk key systems	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	Change to SAD	Negligible impact	A-2
13.2 Machine area E-stops	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	Change to SAD	Negligible impact	A-2
13.3 ESAT area E-stops	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
13.4 Circuits and relays	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
13.5 Machine area door switches	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
14.0 Facilities requirements								A-2
14.1 AC power								A-2
14.1.1 House (120, 208, & 480 VAC)	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
14.1.2 4160V supply	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
14.2 L-wing deionized water supply	Minor onsite / negligible offsite	1 - 3 months downtime	\$100K - \$500K	Common practice	N/A	No impact	Negligible impact	A-2
14.3 Area HVAC	Minor onsite / negligible offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
14.4 House compressed air	Considerable onsite and/or minor offsite	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-2
15.0 LTX operation and data acquisition								A-3
15.1 D-Tacqs (x3)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3

	Potential hazard of item/activity to people/environment	Potential mission impact of item / activity failure	Potential cost impact of item / activity failure	Technical risk of item / activity	Potential radiological impact of item / activity failure	Potential safety Impact of item / activity failure	Potential reputation impact	Category
15.2 PCs (x16)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
15.3 Position Control System (PCS)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
15.4 CAMAC (x1)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
15.5 Edge Thomson VME crate + digitizers	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
15.6 NI PXI 1042 system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
15.7 NI PXI 1071 system	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3
15.8 Video surveillance (webcams and monitors)	None	< 1 month downtime	< \$100K	Common practice	N/A	No impact	Negligible impact	A-3