NCSX General Requirements Document

Review Comments Tracking Log for PDR Update

Author	Author #	Comment Note: Section Numbers refer to Draft F and may have changed in Draft G & H.	Resolution in Drafts G/H.
Stevenson	1	In the GRD NBI section quoted below, the pulse length of 1.2 seconds is mentioned as an upgrade. First, the existing NBI system will pulse to 0.5 seconds, with more reliable results at 0.3 seconds. No mention of this pulse length is included, but it is a very fixed limit of this system.	Understood. Reworded NB Heating subsections to clarify.
Stevenson	2	Second, the upgrade to 1.2 seconds is a very big leap in time, technology, and cost that includes upgrades to other auxiliary subsystems also, like the water system. The facility should not be initially designed to accommodate the 1.2 second system as stated because the costs will be prohibitive for the initial beam phase and the upgrade to 4 beam phase. Rather, the existing system should be installed so as not to prevent a future upgrade to 1.2 seconds. This 1.2 second upgrade will require extensive changes. Henry and I had this conversation earlier today so I write with his concurrence.	Understood. "Accommodate" as pertains to upgrades in this GRD, implies "do not preclude" as used in this comment.
Blanchard	1	3.2.1.1.2.1 Base Pressure: The initial surface area of the vacuum vessel for first plasma will be approximately 40 M^2 and will be increased significantly in its final configuration. All materials in vacuum should be high vacuum compatible. With a target leak rate in the range of (1-2)x10-5 T-l/sec or less and a pumping speed of 2600 l/sec or better and a well baked and conditioned machine, the device should produce a base pressure in the low 10-8 Torr of impurity gases at 293K. All diagnostics that are not to be left open permanently to the vacuum vessel should have their own pumping system and all appendages, ports and diagnostics should have bakeout capabilities to maintain very high vacuum conditions. All systems and components either in vacuum or with a vacuum interface should be designed to preclude trapped volumes and virtual leaks.	Accepted. Some of this may belong in lower-level specs but include in the GRD for now. See sections on "Vacuum Compatibility," "Base Pressure," and "Pumping Speed."
Blanchard	2	3.2.1.1.2.2 Pumping Speed: delete "which is equal to or greater than that achieved on PBX-M."	Accepted.
Blanchard	3	3.2.1.2.1.1 Bakeout Background: Suggest that it be pointed out that all systems and materials be compatible for the bakeout temperature they will see for strength, compliance for expansion and vacuum compatibility (developing leaks etc.).	Accepted. A clarification of the Bakeout requirement.
Blanchard	4	3.2.1.2.1.2 Glow Discharge Cleaning (GDC) (delete During Bakeout)a) The facility shall provide a glow discharge cleaning (GDC) capability with DC glow for indefinite periods of time with the vacuum vessel and all components internal to the vacuum vessel at room temperature and at their nominal bakeout temperatures. All windows should have shutters to prevent coating during GDC. All large ceramic breaks should be shielded to prevent coating and high resistance shorts between different grounds.	Accepted. A clarification of the GDC requirement.
Blanchard	5	3.2.1.4.4 PFC Configuration d) delete "sealed"	Accepted. The plenum is probably not sealed in the truest sense.
Blanchard	6	3.2.1.4.7.2 Gas Injection. The gas injection system shall be capable of injecting any one of three gases (or combination of gases) with a maximum flow rate of at least 50 T-l/sec per injector. The device and facility shall have a programmable gas injection system with feedback on real-time density measurement.	Accepted, with clarification that feedback control is an upgrade.
Blanchard	7	3.3.1.2 Vacuum Compatibility. a) In-vessel metallic components shall be electropolished when feasible b) All in-vessel components shall be degreased and cleaned as a minimum and baked when practicable prior to installation.c) All in-vessel materials shall be approved by the Project for vacuum compatibility [3].	Electropolish when practicable, otherwise lapped to a 32-microinch finish. **Electropolishing has both benefits and costs which will have to be weighed case-by-case.**
Blanchard	8	3.3.6 Environmental, Safety, and Health (ES&H) Requirements. Somewhere in this section it should state that all vacuum windows of 4" or greater shall have covers over them or otherwise be protected from accidental implosions.	Accepted. Added a "Vacuum Implosion" section.

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Blanchard	9	A few questions/comments:[1] What are the standoff voltages that systems are to be designed to? [2] What is the grounding scheme? [3] What loop resistances can be tolerated? [4] How are they going to be monitored? [5] Some systems should be designed with ease of removing grounds for troubleshooting loop faults (diagnostics, thermocouples etc). [6] It might be helpful for new drafts to have the changes that were made in a different color to expedite subsequent review.	The Electrical Grounding section now specifies a single-point ground and 5kV (TBR) standoff voltage. Loop resistances are TBD.
Blanchard	10	One comment regarding the NCSX vacuum vessel and core systems. These systems should be designed to allow for leak checking and repair of leaks on the vacuum vessel.	Accepted. An amplification of the Base Pressure requirement.
Goranson	1	3.3.1.2 a) All in-vessel metallic components shall be electro-polished or mechanically lapped to a 32 microinch finish.	Accepted. See Blanchard #7.
Goranson	2	3.3.1.3 a) Plasma facing surfaces (clarify, this is only true for limiters until upgrade)shall be carbon-based, i.e. graphite or carbon fiber composite (CFC) material.	Accepted. Plasma Facing Surface Materials section.
Dudek	1	3.2.1.1.2.2 IF PBX achieved 2600l/s 10-15 years ago what makes us think we can achieve greater with the same pumps. What is really needed?	Accepted. Specify 2,600 l/s and delete reference to PBX-M performace.
Dudek	2	(proposed) 3.2.2.4 Work Platform. Provide a work platform at TBD elevation surrounding the machine to provide convenient access to the core and diagnostics equipment . Platform will be able to carry TBD psf.	Accepted. Reliability, Availability, and Maintainability section. The TBD's belong in lower-level specs.
Dudek	3	(proposed) 3.2.2.5 Utility gas system. Provide a gaseous nitrogen, and compressed air. These systems will provide utility services to the core machine and diagnostics for general use such as venting the vessel to atmosperic pressure and actuating valves and shutters.	Accepted. New subsection under External Interface Requirements.
Ramakrishnan	1	a) The facility shall be designed for a maximum power of ***<u>350MW</u>*** for 0.3s for the Initial Ohmic Phase of operation.	Leave as is. The 350 kW is meant to be the heating power in the plasma due to ohmic heating.
Ramakrishnan	2	3.2.2.3 Experimental Power. All experimental power for NCSX will be provided through the C-site experimental power systems except for the TF, PF, and modular coil power supplies that are connected to the D-site experimental power systems. I think the emphasis has to be D-Site power system. Hence can we reword the same as below? " The bulk of the experimental power is derived form D-Site and is used for all the coil systems except for Trim Coils. The rest of the power is provided from the C-Site systems."	Accepted. The section has been re-named "Electrical Power" and the D-site system is emphasized.
Kugel	1	Table 3-2 refers to vacuum diagnostics checkout, but these vacuum diagnostics do not seem to be listed.Therefore, under 3.2.1.1.2.1 Base Pressure. Insert after the below W.Blanchard sentence, the following sentence: (Blanchard)......., the device should produce a base pressure in the low 10-8 Torr of impurity gases at 293K. The partial pressure components of the base pressure shall be measured with a Residual Gas Analyzer(RGA) mounted at a location on one of the Pumpducts near the Turbomolecular pumps. Each Sector shall have a standard, magnetically shielded, nude Ion Gauge mounted as close to the first wall midplane as possible, and a nearby port shall be provided for at least one Fast Neutral Pressure gauge. These gauges shall be calibrated using 3 Capacitance Manometers (1, 10, and 1000 Torr ranges) mounted near the RGA. All diagnostics...(Blanchard).	A general requirement specifying the types of measurements is added to Base Pressure section. Details left to lower-level specs. **Issue: is all this equipment included in the CDR estimate or is it an upgrade. ACTION: Kugel.**
Kugel	2	I have noted before in response to port requests that each Sector requires at least: one port for a standard Ion Gauge, one port for a Fast Neutral pressure gauge, one port for a GDC anode, one port for GDC Preionization Filaments, and one port for a Gas Injector.	Resolve in lower-level specs.

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Kugel	3	RE: the M.Zarnstorff/H.Kugel Neutral Beam Telcom of 07-AUG-02. Typically it is necessary to close the NBI TIV's during Between-Shot-GDC. This could be avoided by a installing inboard of the TIV, a high conductance shutter, to limit GDC gas flow into the NB Beamline. This appears to be doable but requires analysis of interlock requirements, as-built conductance, engineering costs etc., and hence, is not recommended to be a baseline requirement, although we intend to vigorously investigate this option.	The requirement for isolation of the NBI during GDC is added as an amplification of the GDC requirements. The suggested upgrade should be pursued.
Kugel	4	I discussed with Bill Blanchard the Leak Rate specification for the NCSX First Plasma vacuum goals given in the Project Completion Document. The specification that we recommend is: "A maximum global leak rate of <1x10^-4 torr-l/s will be achieved."	This refers to the First Plasma spec that is documented in the Project Execution Plan. This and all other first plasma specs are now captured in the appropriate sections of the GRD.
Kugel	5	Gas injection requirements: 1 injector per period @ 50T-/s per injector. Upgrades: 1 inboard injector per period, 1 outboard supersonic injector per period. Density feedback an upgrade.	Accepted.
Reiersen	1	2.3 Need to get the references right and have a plan to get these documents under configuration control prior to the PDR.	**TBD. Action: Simmons.**
Reiersen	2	Our initial ohmic scenario is much more aggressive than what we are committing to in first plasma. In doing so, we are locking ourselves into a substantially higher cost than we need to to satisfy first plasma requirements. Of course, we want to move expeditiously into operations, but the second phase of operations is field mapping. Should we tak adnvantage of this opportunity to relax our initial ohmic scenario requirements?	**Not at this time, but we should understand the cost breakpoints and program implications for future consideration. Action: Engineering.**
Reiersen	3	Define constraints derived from re-using PBX test cell	**Section 3.2.2.1 and 3.2.3.1 provide general boundary conditions. Is more needed? Floor loading is TBD. Action: Perry.**
Reiersen	4	Restore the concept of "to be revised" (TBR) requirements, to flag requirements that are tentative and subject to change after cost implications are better understood.	Agreed. Explained in "Incomplete and Tentative Requirements"
Nelson	1	3.2.1.1.2.1 Base Pressure. The device and facility shall produce high vacuum conditions with a base pressure of less than or equal to $2x10^{-8}$ torr at 293K of impurity gases with z >2?	Leave as is. The residual gas constitutents after pumpdown and conditioning are understood to be those typical of PBX-M and other fusion experiments.
Nelson	2	3.2.1.4.1 Field Error Requirements. The toroidal flux in island regions due to fabrication errors, magnetic materials, or eddy currents shall not exceed 10% of the total toroidal flux in the plasma during the experimental portion of a shot?.	Leave as is. The words "toroidal flux in the plasma" are understood to mean that it is during the experimental portion of the shot.
Nelson	3	3.2.1.4.3.2 Toroidal Field/Plasma Current Directionality. c) The facility shall have the capability to be reconfigured to operate with both the toroidal and poloidal magnetic fields simultaneously flipped from their standard directions. (two quadrant capability?)	Yes. The toroidal and poloidal field polarities are not independent in a stellarator. The requirement (now called "Magnetic Field Polarity") has been simplified.
Nelson	4	3.2.1.4.5 Disruption Handling. The facility shall be designed to withstand electromagnetic forces due to major disruptions characterized by the disappearance of the plasma instantaneously with a maximum plasma current of 350 kA.	Accepted. "Instantaneous" has been inserted. A note has been added explaining that induced voltages can be ignored.
Nelson	5	3.2.1.4.6.2. ICH b) The facility shall be designed to accommodate three sets of launchers on the inboard side, one at each of the three v=0.5 cross-sections.	Accepted. Added "sets of".

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Nelson	6	3.1.4.10 Pulse repetition rate. The facility shall be designed for pulses to be initiated at intervals not exceeding 15 minutes when constrained by coil or internal component cool-down and 5 minutes otherwise.	Accepted. More specifically, coil or PFC cool-down.
Nelson	7	3.2.1.5.1 Coil warm-up timeline. The cryo-resistive coils (TF, PF, and modular coils) shall be capable of being warmed up from operating temperature (80K) to room temperature (293K) within 48 hours (why not 96 hours?).	**Tentatively accepted by making it 96 hours (TBR). Is there a cost break-point between 48 and 96 hours?**
Nelson	8	3.2.4.1 RAM. c) The stellarator core shall be capable of being disassembled and reassembled within x months? to permit replacement of any part or machine reconfiguration that would require disassembly.	**Accepted. Propose 1 year as a strawman, but cost implications need to be understood.**
Nelson	9	3.3.1.3 PFC Materials. a) Plasma facing surfaces shall be carbon-based, i.e. graphite or carbon fiber composite (CFC) material. Other materials must be approved by the project.	Agree. These requirements are captured in "Vacuum compatibility" and "Plasma Facing Surface Materials."
Nelson	10	3.3.7.2.5 Noise. TBD ATF honked like a diesel locomotive horn – 85 decibels – during each shot. Coupling of vessel to 360 hertz ripple in power supplies (my theory). Do our power supplies have a lot of ripple?	Should not be a problem. ATF used a 6-pulse power supply, NCSX's are 24-pulse.
Hawryluk	1	Update date on cover page	OK
Hawryluk	2	3.1.4 System Functions. Inserted question: Do you mean daily startup or integrated testing prior to ops? 3.2.1.1 Facility startup. I do not understand the purpose the of flow chart. If it is post first plasma, it also does not address scheduled outages.	Added an outer loop to the flow chart and a requirement for a full ISTP before initial operation or startup after a major reconfiguration. The chart maps to the various Subsections of 3.2.1 Performance Characteristics.
Hawryluk	3	3.2.1.1 Facility startup/Background **You also need to address the requirements for a comprehensive ISTP prior to first starting operations. Facility startup is a recurring activity after major outages, which is a subset of the integrated testing needed for initial ops.**	Accepted. See Hawryluk #2.
Hawryluk	4	3.2.1.1.1 Coil Cool-down Background The anticipated operational plans are expected to result in up to less than 150 cool-down and warm-up cycles between room temperature and operating temperature (Add:) over the lifetime of the machine.	Accepted.
Hawryluk	5	3.2.1.1.2.1 Base Pressure I think you should specify a leak rate. The base pressure is a combination of leak rate, wall conditioning and outgassing.	Accepted. "Base Pressure" revised.
Hawryluk	6	3.2.1.1.2.2 Pumping Speed Delete reference to pumping speed obtained on PBX-M. [I see no value in referencing PBX-M. The question is what leak rate of air does this correspond to with a goal of a base pressure due to air of less than 1e-5?]	Accepted.
Hawryluk	7	3.2.1.2 Pre-operational Initialization and Verification Requirement This is covered under operating procedures. What if any are the ramifications for a general requirements document?	Clarified.
Hawryluk	8	3.2.1.2.1.1.1 Vacuum Vessel Bakeout Temperatures is the temperature to be maintained constant in space or time? Is this a spec on the temp. measurements and heating system?	Maintained in time. Spatial uniformity will be addressed in the vacuum vessel subsystem spec. Affects tube spacing and monitoring.

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Hawryluk	9	3.2.1.2.1.1.2 Carbon-based Plasma Facing Components (PFCs) Bakeout Temperatures Same question?	Same answer.
Hawryluk	10	3.2.1.2.1.1.3 Bakeout Timelines While doing this in 24 hours is desirable is it a requirement?	A typical cycle is 4-5 days, so 24 hours up or down is reasonable, but could live with 48 hours. Make 36 hours (TBR) until cost-benefit tradeoff is understood.
Hawryluk	11	3.2.1.2.1.1.3 Bakeout Timelines Can you cool it down this fast? I would not state pre-shot operating temperatures but give a temperature value. Going all the way to room temperature can take a long time without active cooling. Perhaps you have that.	Return to 40 C (TBR) within 36 hours (TBR). We don't plan active cooling of the PFCs.
Hawryluk	12	3.2.1.2.1.1.3 Bakeout Timelines What temperature are the coils held at during bakeout?	**Added a requirement (TBR) to keep the cryo-resistive coils cold (below ~90K so we can circulate low pressure LN2 in the coils) during bakeout.** **This would ensure that coil cooldown does not drive the time required for bakeout. It would also give us the option of keeping them cold if we wanted to avoid worrying about thermal stresses during warmup and cooldown. It would not preclude letting the coils float up towards RT if we chose to do so, and conserve our LN2 supply. It is TBR until the cost-benefit tradeoff is understood.** **ACTION: Nelson.**
Hawryluk	13	3.2.1.3.2 Pre-Shot Temperature Does this include plasma facing components? If so, they will require active cooling between shots and a lot of it. Sounds too demanding, though your power levels are low. We never came close to this on TFTR, though the bumper limiter was cooled between shots. **I assume this requirement is driving our vacuum vessel cooling system requirements.**	Requirement now sets a minimum pre-pulse temperature on the PFCs but not a maximum. Reproducibility and not overheating during the pulse are the important requirements.
Hawryluk	14	3.2.1.4.1 Field Error Requirements Does everyone agree on how this is defined (i.e., 10% of the total toroidal flux in the plasma)? Does it take into account plasma healing or finite transport? It does not include the fundamental islands generated in the plasma for a perfectly built coil. Of course, this is in addition to the design and the correction from the external correction coils.	The islands excited by each of these factors are evaluated analytically for the standard high-beta equilibrium, or other if more appropriate. The machine will be designed to make the contribution of each individual factor small compared to 10%. The requirement has been modified to require field error compensation coils and to take credit for them in evaluating island widths. We already bought into this for the CDR, the GRD is now catching up.
Hawryluk	15	3.2.1.4.2 Electrical (Eddy Current) Requirements Regarding kink mode stabilization: if the plasma is spinning rapidly, there will be some stabilization from the wall.	Leave as is.

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Hawryluk	16	3.2.1.4.2 Electrical (Eddy Current) Requirements Regarding the time constant of the vacuum vessel and in-vessel structures: Is this toroidal, poloidal and in your case helical modes i.e. for all modes?	Modified to say, "longest-lived eddy current eigenmode." to clarify. a) All modes. Leave as is. b) Add (except coils) or change "structures" to "passive structures". C) Yes. Leave as is. D) Add reference to section with field error requirements. Satisfying a, b, and c does NOT automatically satisfy d. We may have to add multiple toroidal breaks, for instance.
Hawryluk	17	3.2.1.4.2 Electrical (Eddy Current) Requirements Regarding the time constant of all other structures in the stellarator core: is the core well defined? Of course, the pf coils fundamentally are toroidally continuous current paths.	Added "except coils".
Hawryluk	18	3.2.1.4.2 Electrical (Eddy Current) Requirements Regarding the longest time constant in electrically conducting structures outside the vacuum vessel: shall be less than 20 ms: is this the time constant for the modular coil casings?	Yes. See also Zarnstorff #9.
Hawryluk	19	3.2.1.4.2 Electrical (Eddy Current) Requirements Regarding eddy currents in conducting structures surrounding the plasma shall not give rise to unacceptable field errors: How is this defined?	It just means the 10% island requirement. Added reference to that section.
Hawryluk	20	3.2.1.4.2 Electrical (Eddy Current) Requirements Regarding preservation of stellarator symmetry: Why is that a requirement on eddy currents and not on field errors?	Restricting the conductor geometry is the cheapest and simplist way to minimize the risk of symmetry-breaking field errors due to eddy currents.
Hawryluk	21	3.2.1.4.3.2 Toroidal Field/Plasma Current Directionality Regarding the standard toroidal field direction: By this do you mean the field direction from the TF or module field coils or total? b) The facility shall be configured for the standard poloidal field direction to be positive, corresponding to a positive toroidal (plasma) current. **Is this an overspecification? The modular coil geometry specification has a particular helicity direction built into it. Once you specify the standard toroidal field direction, it fixes the poloidal field. Perhaps there needs to be a requirement that defines what the positif p.f. direction is.** Does this mean a positive vertical field along with a counter –clockwise plasma current? While I assume all of this is correct, I am having trouble following it. Perhaps, it associated with the rotational transform from the module coils.	Requirement has been cleaned up. See Nelson #3.
Hawryluk	22	3.2.1.4.3.2 Toroidal Field/Plasma Current Directionality Regarding the standard poloidal field direction: Does this mean a positive vertical field along with a counter –clockwise plasma current? Perhaps, it associated with the rotational transform from the module coils. Clarify.	Requirement has been cleaned up. See Nelson #3.
Hawryluk	23	3.2.1.4.3.3.1 Reference Scenario Definition???? IS THIS ADDRESSED BELOW?	Clarified under "Background".
Hawryluk	24	Changes common to all reference scenario definitions: ramping the plasma current to its maximum value of 154kA at a rate (add: up to) 1.6MA/s, and Maintaining the plasma current constant for…	No - not up to. The other change is accepted.
Hawryluk	25	3.2.1.4.7.2 Gas Injection programmable gas injection system (add: with the capability for) feedback on real-time density measurement.	See Blanchard #6.

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Hawryluk	26	3.2.1.4.8.2 Diagnostics Implementation I suspect that you will not be able to measure total stored energy with magnetic diagnostics in the the initial operation, if you mean plasma stored energy.	Clarified that it means "plasma stored energy" The diagnsotics listed should be able to measure it with the accuracy needed.
Hawryluk	27	3.2.1.4.10 Pulse Repetition Rate What is driven by the 5 min. requirement?	Won't know until we get deeper into the ancillary systems design, but 5 minutes is typical of this class of experiments.
Hawryluk	28	3.2.1.4.11.2 Abnormal Termination If you need to shutdown the equipment to avoid equipment damage or avoid personnel injury you will not have a controlled shutdown of the plasma in general. I think this is too constraining.	Clarified. When an abnormal condition is detected, the system must respond to remove the hazard, is all it means.
Hawryluk	29	3.2.2.1 Shelter Regarding fire suppression: Is this a project or facility responsibility for these four items? Since I think it is facilities, be more explicit.	It says that NCSX assumes the facility will be received with certain equipment, i.e. it is not NCSX's responsibility.
Hawryluk	30	3.2.2.2 Water Systems Regarding NCSX will utilize the existing water system: not quite. we are likely to tie into to the D-site water cooling tower.	Clarified.
Hawryluk	31	3.2.4.1 Reliability, Availability, and Maintainability Background the number of plasma discharges achieved in a run period is a large percentage (greater than 75%) of the number planned (add: after the initial shakedown and commissioning phases of the facility.)	Accepted.
Hawryluk	32	3.2.4.1 Reliability, Availability, and Maintainability Background I am in favor of FMECA's as part of the safety evaluation. I do not think they are that helpful for RAM.	NCSX will use FMECAs as a means of illuminating problematic failure modes and focusing on ways to avoid or mitigate them. RAM plan is forthcoming.
Hawryluk	33	3.2.4.2 Design Life 13,000 per year: Ok but this is unrealistically large, if you mean at full design parameters.	There are several operating scenarios, not all at full parameters. The distribution has not been defined.
Hawryluk	34	3.3.1.2 Vacuum Compatibility Electropolishingis a new requirement relative to other PPPL devices. No comment as to whether or not it is a good idea.	See Blanchard #7.
Hawryluk	35	3.3.1.2 Vacuum Compatibility Regarding, baked and outgassed prior to installation: What about the vessel itself? It is an in-vessel component.	Clarified.
Hawryluk	36	3.3.3.1 Labels Is this level of detail necessary here? I suspect not. I do not believe we did this for NSTX. For example I am not aware of labels on the PF coils.	The point here is that key components and equipment need tobe well labeled.
Hawryluk	37	3.3.6.2.4 Oxygen Depletion Oxygen levels in the vicinity of the cryostat shall be monitored (add: and alarmed) to detect excessive leakage of nitrogen from the cryostat.	Accepted.
Hawryluk	38	3.3.7.2.4 Emergency Lighting Why is there an additional requirement for control room lighting beyond NFPA?	Agreed. NFPA 101 should be sufficient, per Ray Jeanes.
Hawryluk	39	3.3.7.4 Protective Equipment Why is this in general requirements? This is in the Health and Safety Manual.	Agreed. Requirement now makes a general statement and refers to PPPL ES&H directives
Hawryluk	40	4.2 Responsibility For Inspection By contractors, do you mean PPPL or contractors to us? What is our role for oversight of the inspections?	Deleted the "Responsibility" requirements from the GRD. Responsibilities are defined in other documents, e.g. SOW's and Plans. See also Malsbury #1.

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Neilson (Draft D)	1	2.3 NCSX Documents [1] NCSX Mission, Experimental Plan, and Preparations (part of Conceptual Design Report).	Delete. This is not a controlled document.
Neilson (Draft D)	2	3.1.1 General Description New official sentence: The mission of the NCSX is to acquire the physics knowledge needed to evaluate compact stellarators as a fusion concept, and to advance the physics understanding of three-dimensional plasmas for fusion and basic science. The NCSX device is a medium-scale (R=1.4 m), low aspect ratio (A~4) stellarator-tokamak hybrid. It features modular coils, toroidal field (TF) coils, and poloidal field (PF) coils for plasma shaping and control. It also has a vacuum-tight vessel internal to the coils.	Revised language to be consistent with approved PEP and AEP.
Neilson (Draft D)	3	3.1.2 Fabrication Project Scope The NCSX Fabrication Project scope includes all equipment required at the start of operations (first plasma), including the support subsystems (central I&C and utility systems) required to support that equipment. In addition, the NCSX Fabrication Project scope includes the re-commissioning, installation, and subsystem testing of two of the beamlines formerly installed on the PBX-M tokamak. The NCSX will be designed so that anticipated equipment upgrades can be accommodated when needed. This specification provides requirements for the Fabrication Project, including requirements to be able to accommodate certain upgrades. For equipment not included in the Fabrication Project but required as a future upgrade, sufficient analysis must be done to assure that the equipment can be plausibly accommodated as a future upgrade.	Re-worked to be consistent with approved PEP and AEP.
Neilson (Draft D)	4	Table 3 1 Level II Work Breakdown Structure Needs to be updated to latest	Accepted.
Neilson (Draft D)	5	3.2.1.4.3.3 Reference Scenarios Background NCSX is designed to be a flexible, experimental test bed. To ensure adequate dynamic flexibility, a series of reference scenarios has been established. TF, PF, and modular coil systems and the vacuum vessel will be designed to meet the requirements of all the reference scenarios. Electrical power systems shall be designed and initially configured to meet the requirements of the Initial Ohmic Scenario and shall be capable of being upgraded to meet the requirements of all other reference scenarios. The NCSX Project will document coil geometries and current waveforms required for each reference scenario in technical data files. I understand we plan to control these as part of the technical baseline. What about the first wall envelope, which is also a key physics-engineering handshake?	**It now says that coil current centers, coil currents, and first-wall surface geometry will be provided in technical data files.** **Action: Reiersen**
Neilson (Draft D)	6	3.2.1.4.6.1.2 Ultimate NB Heating Complement a) The facility shall be designed to accommodate neutral beam heating using the four (4) beamlines previously used on PBX-M (as a future upgrade) in two possible configurations: [1] 2 co- and 2 counter-directed beamlines and [2] 3 co- and 1 counter-directed beamlines. b) The facility shall be designed to accommodate an extended heating pulse duration of 1.2s. Isn't this redundant with 3.2.1.4.4.2(b)?	Clarified.
Neilson (Draft D)	7	3.3.2.Electrical Grounding Should there be a requirement for voltage isolation between the VV and attachments?	Yes, in order to help maintain the integrity of the single-point ground system. 5 kV (TBR), recommended by Ramakrishnan.

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Neilson	1	Under "Major Item of Equipment Project Scope," insert: "The system shall demonstrate a level of system performance sufficient for the start of research operations, as specified in the Project Execution Plan." and spell out where those specs appear in the GRD.	Accepted.
Simmons	1	(1) Cover page - I would recommend that there is only one preparer (in this case you for GRD), Mike (and others as appropriate) will be a concurrence signature (a review signature doesn't tell me anything), and only one approver (in this case Hutch). We should follow this scheme for all of our plans and documents.	Accepted.
Simmons	2	(2) Does the GRD address any requirements during the fabrication project or just the finished product? I think it is the latter, but perhaps I am missing something here.	It is the system spec for the finished product of the MIE project.
Simmons	3	(3) Record of Revisions - might be nice to show what the major changes is Rev E and F were.	The Record of Revisions will identify the changes between formal revisions. Changed features in the drafts will be identified by using the change tracking feature.
Simmons	4	(4) Section 2.3 - minor grammatical correction => put comma before "where wbs #..."	Agreed.
Simmons	5	(5) Section 2.3 - do we want to add CMP or address how these changes to these requirements will be handled? No need to go into much detail, but merely mention that changes handled via CMP.	Leave as is. The CMP does not belong in 2.3 because it is not referenced in the GRD. The GRD does not define how changes to the GRD are made.
Simmons	6	(6) Section 3.1.1 - is this mission consistent to what we said in the PEP? (7) Sectiojn 3.1.2 - PEP Annex I specifies specific definition of the Fabrication Project -- perhaps you may want to reference that. YOu really don't specify the fab project scope here.	The PEP is a higher level document. The GRD has been made consistent with the PEP in the mission and scope descriptions.
Schmidt	1	1) We should be very careful to make the GRD consistent with the First Plasma prescription. Where a requirement does not need to be met at First Plasma we should so state (e.g. base pressure, availability).	Accepted. The GRD has been modifed in a number of places to be consistent with the First Plasma specs that were approved in the PEP.
Schmidt	2	2) Do we need a seismic requirement?	Yes. Added a requirement that we will design according to DOE standards recommended by Kalish.
Schmidt	3	3) Not having a disruption time constant implies an instantaneous current decay. I think this is what you want; however, it does result in infinite voltages across some internal hardware. Maybe we should note that this apparent problem is to be neglected.	Clarified.
Johnson	1	I see nothing in the general requirements for the vacuum vessel or PFC's regarding penetrations permitting sightlines and feedthru's, etc, for diagnostics.	Requirements for feedthroughs and sightlines belong in lower-level specs. They have to be derived from the GRD requirements which identify the required diagnostics.
Johnson	2	There is nothing about the requirement for manned entry during outages for installation and maintenance tasks.	Accepted. Revised "Reliability, Availability, and Maintainability" to make this a requirement.

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Johnson	3	Some high-level requirements are not readily usable by Diagnostics designers, for example field error requirements expressed in terms of an island width. Derived requirements in engineering units, e.g. dimensional tolerances for construction and installation, are needed. Should these be in the GRD? If not, where does a designer go to find them?	These belong in lower-level specs.
Johnson	4	A project metrology strategy is needed soon. Need to locate reference landmarks on the machine and adopt measurement technologies that will enable us to make measurements referenced to the magnetic field for purposes of locating and installing hardware over the life of the machine. The existing Faro arm is not suitable for use in the NCSX VV (too large) and the laser trackers is limited by the line-of-sight requirement.	**A strategy and plan is needed. GRD impacts, if any, will have to be folded in as changes later.**
Zarnstorff	1	1.3.1 Clarify that lower-level requirements will be documented elsewhere, i.e. in subsystem specs.	Accepted.
Zarnstorff	2	3.2.1.1 Facility startup. It is critical to carefully check the polarities of all coils and connections as part of the ISTP.	Agreed that this is part of the ISTP. For GRD purposes, it is included as an example of what will be in the ISTP.
Zarnstorff	3	3.2.1.2.1.1 Bakeout. In general, bakeout is not done overnight, but rather at the start of a run. Bakeout should be moved up to Section 3.2.1.1, Facility Startup.	Accepted. The section has been re-named "Electrical Power" and the D-site system is emphasized.
Zarnstorff	4	3.2.1.2.1.1.3 Bakeout timelines. Temperature rise and fall time should be no longer than 48 hours, preferably 24 hours if not too costly or risky. Compromise: 36 hours (TBR).	Accepted. See also Hawryluk #10 and #11
Zarnstorff	5	3.2.1.2.1.2 Glow Discharge Cleaning (GDC). Add methane to the list of gases.	Accepted.
Zarnstorff	6	3.2.1.3.2 Pre-shot temperature. Cooling the VV all the way to 25C before the next shot could be expensive and is not necessary. Shot-to-shot reproducibility is more important. Make it "a prescribed pre-shot temperature in the range of 40C (TBR)"	Accepted.
Zarnstorff	7	3.2.1.3.2 Pre-shot temperature. Cooling the PFCs down to the same temp. as the VV before the next shot could be expensive and is not necessary. Shot-to-shot reproducibility and not over-heating during the pulse are more important. For the PFCs, make it "a minimum pre-shot temperature of 40C (TBR) of 40C (TBR)"	Accepted.
Zarnstorff	8	3.2.1.3.2 Pre-shot temperature. Add a requirement to be able to maintain the VV in the presence of a hot liner (210 C TBR). For compatibility with a possible liquid lithium liner upgrade.	Accepted.
Zarnstorff	9	3.2.1.4.2 Electrical (eddy current) requirements. Requirement (d), that eddy currents shall not give rise to unacceptable field errors, may govern the longest acceptable time constant. Concerned that 20ms in the ex-vessel structures may not be short enough; calculated island widths are marginal and error fields are large for the current structure design.	Noted. Project will make best efforts to reduce the structure time constant.
Zarnstorff	10	3.2.1.4.3.3.1 Reference Scenario Definition. Need to add a 1.2 T, 1.1s flattop, high-beta scenario to ensure the capability for 1.2s pulses.	Accepted.
Zarnstorff	11	3.2.1.4.3.4.2 External iota flexibility. Requirement should be -0.2 to +0.2.	Accepted.
Zarnstorff	12	3.2.1.4.3.4 Add a requirements for radial and vertical position flexibility. Radial: ±16 cm; Vertical ±2 cm. Both TBR.	Accepted.
Zarnstorff	13	3.2.1.5.6 Add a requirement to be able to accommodate an ECH upgrade: 3 MW, 1.2s, 70-140 GHz.	Accepted.
Zarnstorff	14	3.2.1.4.7.1 Fuel species. Add helium.	Accepted.
Zarnstorff	15	3.2.1.4.7.3 Pellet injection. Inside launch guide tubes should be in the baseline.	Accepted.
Zarnstorff	16	3.2.4.1 RAM. There should be a requirement to accommodate personnel entry into the VV for installation and maintenance activities.	Accepted.
Zarnstorff	17	3.3.1.3 a) Carbon requirement only pertains to the baseline PFCs.	Accepted.
Zarnstorff	18	3.3.1.3 Add a requirement that in-vessel materials shall be compatible with lithium.	Accepted.
Zarnstorff	19	3.3.2.1 Electrical grounding. Specify that a single-point ground is required.	Accepted.

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Zarnstorff	20	3.3.2.1 Electrical grounding. Add a requirement for a ground-loop detection system to facilitate maining the integrity of the ground system.	Accepted.
Zarnstorff	21	Need a requirement defining the VV location relative to the coils.	Agree, but should it be in the GRD or lower-level specs? ACTION: Engineering to analyze.
Zarnstorff	22	Need a metrology strategy.	See Johnson #4
Fredrickson	1	Why is bakeout under pre-ops (3.2.1.1) rather than facility start-up (3.2.1.2)? There does not appear to be an overnight bakeout capability.	Accepted.
Fredrickson	2	Should there be power and coil system check-outs at facility startup (3.2.1.1) and Pre-operatinal initialization and verification (3.2.1.2)?	This needs to be addressed in the ISTP and pre-operational procedures, not the GRD.
Fredrickson	3	3.2.1.4.3.1.1 Does there need to be a requirement for minimum field ramp-down rates to provide for safe termination of the plasma.	Safe discharge termination is the requirement. Engineering can determine the ramp-down rates to accomplish that.
Fredrickson	4	Diagnostics: some sort of locked mode detection system (possibly the flux loops, if properly designed) is needed. Magneticx sensors, toroidal array of soft x-ray cameras, or reflectometers?	**TBD.** **Action: Physics / Diagnostics**
Fredrickson	5	The test cell grounding system should be designed with diagnsotics in mind. Grounding issues have been a major headache on NSTX, important regarding RF shielding also.	**There is a GRD requirement for a single-point grounding system. The specifications need to be developed. NSTX lessons learned need to be folded in.** **Action Engineering / Ramakrishnan.**
Malsbury/Malinowski	1	The GRD should identify requirements, not responsibilities.	Agreed. Deleted "Responsibility for Inspection" and "Responsibility for Conformance"
Malsbury/Malinowski	2	Section 4 in the GRD should be retitled to something like "Verification and Validation Requirements." The topics discussed in this section are solely concerned with V&V, not the full scope of Quality Assurance. In addition, the project has an approved QA Plan, so further requirements are not needed in the GRD.	The terms Quality Assurance and Quality Conformance as used in this GRD follow standard usage in military and industry specs.
Malsbury/Malinowski	3	Include details in the planned to be developed Test and Evaluation Plan.	Agreed.
Malsbury/Malinowski	4	Quality Conformance, seems like a wrong title. It should be "Required Tests."	See Item #2. Clarified this section to explain its purpose a little better.
Stratton (Draft G)	1	3.2.1.5.7.1 Gas Injection: the gas injection system should also be capable of handing impurity gases, e. g, He, Ne, Ar, and methane, and mixtures of these gases with the working gas. This would be useful for certain experiments and for diagnostics in specific cases.	The baseline has H, D, and He; the others can probably be added later without making it a GRD requirement.
Stratton (Draft G)	2	3.2.1.5.9 Instrumentation, Control, and Data Acquisition: specify a facility clock capable of sending triggers to other systems (diagnostics, gas injectors, auxiliary heating systems, etc.) at pre-determined times up to and including discharge initiation for setup and triggering of these systems. Standard timing modules would then be used to introduce additional delay times for triggering systems at specific times during the discharge.	GRD will require that it be a "flexible" system. Detailed specs will be in the lower-level spec for the Central I&C and Data Aq. system.
Stratton (Draft G)	3	3.2.1.5.9 Instrumentation, Control, and Data Acquisition: specify that data from all systems shall be retrieved and archived within a specified time (5 minutes?) after the shot so that there will be sufficient time to view the data and do further analysis in preparation for the next shot.	The Pulse Repetition Rate requirement accomplishes this. That requirement will flow down to the Central I&C/Data Aq. system spec.
Stratton (Draft G)	4	3.2.1.5.9 Instrumentation, Control, and Data Acquisition: specify that that data archival shall be done so that the data can be retrieved with widely available cross-platform software, e g., MDS Plus.	Accepted.

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Stratton (Draft G)	5	3.2.1.5.9 Instrumentation, Control, and Data Acquisition: experimental data for each shot should be archived in multiple copies, including one that is kept off-site.	Accepted.