NCSX Preliminary Design Review Recommendations Tracking Log — 3 November 2003

ID	WBS # Responsible Person	Recommendation / Comment	Proposed Disposition	Cost Impact of Additional Work Scope [1]	Schedule Impact [2]
1	**WBS 14** **Williamson**	**Comment 4 in Section 2**: For Final Design Review significant work remains to be completed on current feed design. Prototyping and testing needs to be performed to assure quality of these elements. If possible, access through the shell at the current feed locations should be available. Care should be exercised to maintain stellarator symmetry in bus systems for conventional coils as well as the modular coil system.	Twisted racetrack coil will prototype leads. Access through shell at current feed locations will be investigated. Additional design and analysis ($20k) will be required. Maintaining stellarator symmetry in TF bus connections will be investigated. This is not possible with PF coils featuring only one bus connection per coil.	$20k	Pre-FDR
2	**WBS 14** **Williamson**	**Comment 2 in Section 2**: Concern exists over the short time between prototype delivery and release of production contracts for minor modifications of winding forms. Close interaction with vendors can help accelerate the feedback into the production design. **Comment 3 in Section 2**: For Final Design and fabrication, verification of the prototype coil should be completed and tested as soon as possible.	In response to this comment, we will revise the schedule to reduce the risk of schedule impacts due to results which arrive late in the prototyping of the winding forms (comment 2) and the windings (Comment 3). The prototype winding forms are scheduled to be delivered on 11 June 04. Release of the final winding form procurement will be delayed one month, from 28 May to 25 June, to allow more time for changes resulting from the prototyping to be incorporated. With this change, the FDR can be delayed one month (from 30 April to 30 May) to accommodate the pre-FDR tasks being added in response to these recommendations without further impact on first plasma. The delay in procurement release will delay delivery of the first production widing form by one month, from 10 November to 10 December. This allows more time to incorporate lessons learned from the prototype coil fabrication and testing (scheduled to be completed 25 October) into the tooling and winding process design before winding the first production coil.	None	Net impact is about a 1-month delay in First Plasma.

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3	**WBS 16, 19** **Williamson, Cole**	**Comment 5 in Section 2**: Coil services, such as liquid nitrogen distribution systems need to be laid out with respect to the overall structure. **Comment 1 in Section 5**: No details were presented on how the LN2 was to be supplied to the coils. What types of tubing and electrical breaks are being used? How do the feed and exhaust lines run to the various coils? How is the LN2 controlled? Is it planned to purge the coils of LN2 before running current through the coils? These issues were not reviewed; however, informal talks with the engineer in charge indicated that these systems are being given serious consideration.	Agree. These details will be developed in Final Design. Teflon tubing is envisioned for the connections to the coils.	<$5K	Pre-FDR
4	**WBS 14** **Williamson**	**Comment 6 in Section 2**: The tolerance budget should be re-examined with regard to assembly to guarantee stellarator symmetry.	Agree. The twisted racetrack coil should provide a better understanding of what we can achieve during the winding process. As our understanding of deflections, positioning, and measurements become clearer during Final Design, the tolerance budget will be re-examined.	<$5K	Pre-FDR
5	**WBS 14** **Williamson**	**Comment 7 in Section 2**: It should be confirmed that the cable is compacted without any lubricant which would degrade the epoxy/copper bonding and lower the shear strength.	We agree that processes that could affect the adhesion of the epoxy to the copper (and thereby effect the mechanical properties of the conductor) need to be identified and controlled. The NCSX project will undertake a test program to determine whether to specify the normal process used in cable fabrication or to introduce a cleaning step to "de-grease" the conductor.	$50K ($25k to complete the test program, and $25K for modifications in the conductor fabrication process)	Pre-FDR
6	**WBS 14** **Williamson**	**Comment 8 in Section 2**: As prototyping and R&D continue, efforts should continue to identify areas where the schedule contingencies could be increased.	Agree.	None	None

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7	**WBS 14** **Williamson**	**Comment 1 in Section 2**: Thermal and electromagnetic load cycles may lead to de-lamination of the copper-epoxy composite due to low shear strength. The conduction cooling of the coil could then be adversely effected. Efforts should be undertaken to examine the expected fatigue properties of the modular coil system. **Recommendation 2-1**: Develop and implement a plan to evaluate shear stress quality of the composite used and fatigue properties of the modular coil system.	Agree. A supplementary test plan has been generated for completion in Final Design. Additional tests include: • Shear strength in the axial direction. • Fatigue properties. • Tests to follow up on open issues from the first round of testing.	$150k to complete material test program	Pre-FDR
8	**WBS 14** **Williamson**	**Recommendation 2-2**: Determine motions from machining in the "tee" section and investigate potential processes to minimize this motion. Significant motion could have a large impact on cost and delivery time. The sample twisted casting could be useful in this regard.	This is part of the MCWF R&D scope.	None	None
9	**WBS 14** **Williamson**	**Recommendation 2-3**: Continue winding and potting coil sections with multiple curvatures to gain experience in conductor placement and clamping and epoxy flow in complex geometries.	Agree.	None	None

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10	**WBS 12** **Goranson**	**Recommendation 3-1**: *Port Extensions*. Transition to stainless steel as soon as possible in the port extensions. If possible this should be done at the short stub weld location. The current design, which extends Inconel to the primary flange location on these ports, introduces added machining and preparation costs on these large vacuum seal surfaces. The selection of vacuum vessel and port material may benefit from a graded approach to technical requirements. Inconel 625 is clearly appropriate for the vacuum vessel due to its high strength, low electrical conductivity and low magnetic permeability, although its cost and difficulty of fabrication are high. As distance from the plasma increases, Inconel's properties are less important. Review of cost and fabrication issues may support the selection of stainless steel for ports and the neutral beam port box. Inconel flanges should be avoided if possible. The panel also recommends that the vessel weld joint be changed on these parts to provide a final internal vacuum integrity pass. The external weld should be a skip weld providing only the area required to react to mechanical loads. After the port openings are cut, an internal weld pass should be made to assure vacuum integrity.	Agreed. The port flanges and everything beyond will be stainless steel. The location of the Inconel to stainless steel transition will be optimized in Final Design. The use of an external skip weld will also be investigated during Final Design. However, the use of full penetration welds in the present design does not require another internal weld to assure vacuum integrity.	<$5K	None

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11	**WBS 12** **Goranson**	**Recommendation 3-2**: *Vessel Welds*. Evaluate feasibility of automating the final vessel assembly welds at the three spool insert locations. The flanges on these welds should provide a convenient means of tracking the weld joint and supporting a fixture for the weld head. This would eliminate the need for manual welding operations in this restricted area during assembly and should produce more reliable root and fill pass weld joints. The project should also evaluate use of Penetration Enhancing Compounds (PEC) to increase root pass penetration depth and reduce the number of fill passes on all vessel welds. This could significantly reduce weld distortion and residual stress. On the ITER project, PEC's were used to increase root pass depth from 2 to 6-mm in an extensive length of 1000 psi water channel close-out welds on a large SS-316 structure without any weld quality, vacuum integrity, or magnetic permeability side effects.	An evaluation of the viability of manual welding will be done during the VV R&D program. If it reveals problems, ORNL will assess the feasibility of automated welding using automated welding tools already developed as part of the ITER project. Following up on this recommendation, we discussed the use of PECs with our suppliers. They advised that it would not be appropriate in this application. We do not believe it is a code-qualified material	<$5K (assuming no problems are identified in the R&D program.)	Pre-FDR
12	**WBS 12** **Goranson**	**Recommendation 3-3**: *Bakeout Temperature*. Assess viability of increasing the vessel bakeout temperature to 350C. This temperature is presently used on the D-III device and it enables conditioning to be accomplished in a few hours. More importantly, it would also eliminate the need for installation of a separate in-vessel PFC heating loop during future upgrades. The PFCs could instead be passively mounted to the wall with simple electrical isolation breaks. This would eliminate costs associated with the 200 psi in-vessel helium system and potential leaks that could develop in this system during operation. **Recommendation 9-1**: If graphite is to be used it would be much preferred to bake the vessel and the PFCs to 350 C and eliminate the complications of invessel helium lines, shields, and complicated support structure. On the other hand, using hi-Z PFCs and no carbon should also be considered.	We agree that it is appropriate to re-visit this issue at this time. In response to this recommendation, the project has identified the issues, including cost, that need to be addressed before this change can be adopted. These will be analyzed early in final design so that a decision can be made in time for CD-2. A 150C bakeout is the requirement for initial operation because there will be little or no carbon inside the vacuum vessel. The GRD requires that alternate material be accommodated as future upgrades, including lithium, tungsten, and molybdenum.	$50k is required to evaluate the 350C option. The cost of implementing a 350C capability in the vacuum vessel design is TBD.	Pre-FDR.

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13	**WBS 84** **Zarnstorff**	**Recommendation 9-2**: Bakeout on C-Mod requires 5 to 10 days at 130C. This long bake period is primarily the result of water evolution from cabling and conduits. DIII-D at 350 C bakes for 10 hours or so. So this tradeoff should also be considered.	In the present design, the vacuum vessel bakeout temperature is 150°C. The transport of water out of carbon PFCs drops dramatically below about 300°C, so it is not clear that there is an acceptable tradeoff of time for temperature if carbon is contemplated.	None	None
14	**WBS 12** **Goranson**	**Recommendation 3-4**. *Insulation*. Alternatives should be assessed to the proposed use of Microtherm blankets for the vessel insulation. While efficient, this insulator will be difficult to conform to the compound curvatures associated with the NCSX vessel. On Wendelstein 7, this insulator needed to be made in 10x10-cm tiles that were stitched together to form a blanket. Newer high-performance, flexible insulating blankets are available using silica aerogel technology that should be applicable to the NCSX environments. Aerogel materials are ultra low conductivity, low density insulations that offer market-leading thermal insulation, acoustic protection, and infrared suppression performance.	Agree. We will investigate alternatives to the Microtherm blanket, including a flexible Aerogel blanket.	Nonc. Assuming the adequacy of microtherm and no need for a more expensive solution, currently unforeseen, arises.	None

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15	**WBS 12** **Goranson**	**Recommendation 3-5**. *Prototype Sector*. Due to the significant amount of welding used in vessel fabrication, the panel is concerned about possible effects of residual weld stress on the vessel dimensional stability. We therefore recommend that a 400 C thermal stress anneal cycle be performed on one of the prototype vessel sectors to evaluate possible benefits of this added fabrication step on the dimensional stability of the vessel after fabrication. This anneal cycle should be performed before the port extensions are removed so that the extended port structure is in-place to help maintain the wall stub geometry until weld stresses are relieved. In addition, the panel recommends that fabrication of a complete, 120-deg sector of the vessel be initiated as soon as possible once supplier down-select is completed. The contract should allow for staged delivery of the full-scale prototype sectors so that the first one is available early to assess tolerance build-up and dimensional stability of a full sector of the vessel to determine if any Final Design or manufacturing process adjustments are needed prior to exercising the option for the remaining sectors. This will provide incentive for the supplier to achieve first-time quality and full confidence to proceed with the remaining vessel sector fabrication.	Stability under thermal cyclic is a fundamental requirement for the production vacuum vessel. Thermally cycling of the vessel to temperatures higher than the nominal highest operating temperature in order to verify that this requirement is met is planned. The project agrees with the recommendation that this should be verified on the prototype vacuum vessel segment as well. Production of the first 120-degree sector is already on a fast track. In response to this recommendation, we have decided to expedite delivery by not requiring factory fit-up of all three sectors. Proper fit-up will be assured through the use of precision fixtures. A complete inspection is planned for the first article to find out if there are any deficiencies that should be corrected in subsequent fabrications. We do not believe that a true prototype - a fourth 120-degree sector – is warranted, nor do we understand that to be the intent in the Panel's recommendation.	None.	The first article will arrive after it is produced and inspected at the supplier's facility, instead of being held until fit-up of all three sectors is completed.
16	**WBS 12** **Goranson**	**Recommendation 3-6**: *Port Bakeout*. The panel recommends that additional measures be taken to assure that the large wall surface areas associated with the neutral beam boxes and other port extensions be raised to above 100 C to assure good wall conditioning prior to operation. This could be done using external heating blankets and insulation blankets where appropriate, but a plan for heating these volumes should be presented at the FDR.	Port extensions are already required to be baked to 150C. Neutral beam boxes do not require baking because of the large pumping capacity of the cryopumps inside the beam boxes. The transition ducts between the VV and the neutral beams are treated as port extensions.	None	None

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17	**WBS 12, 16** **Goranson, Williamson**	**Recommendation 3-7**: *Auxiliary Utility Lines*. The panel is concerned that costs associated with electrical breaks, single point grounding, and other installation details associated with the auxiliary LN2 and high pressure helium lines that must penetrate the cryostat are not properly accounted for in the PDR cost assessment. Due to the large number of these lines, more typical installation detail is needed prior to the FDR to assure that these costs are properly budgeted for in the estimate.	Agree. The budgets for this scope in the Vacuum Vessel (WBS 12) and Coil Services (WBS 16) will be revisited. We do not intend to use any ceramic cryogenic insulators, but will use Teflon tubes as are used by C-Mod. Helium lines will probably require a minimum of 6 ceramic breaks, i.e. a supply and return insulator for each field period.	$100K to cover the possibility of significant overlooked costs.	Pre-FDR
18	**WBS 18** **Chrzanowski**	**Comment 1 in Section 4**: Although the metrology tools have been identified for measuring locations of critical points, the software for resolving these points into the NCSX coordinate system has not been developed/procured. This is a critical element of the assembly process and should be obtained as early as possible. **Recommendation 4-1**: Obtain metrology software to allow testing and debugging before critical needs arise.	Agree. Our plan is to gain experience with the metrology systems on prototypes and mockups as soon as possible.	None	None
19	**WBS 18** **Chrzanowski**	**Comment 2 in Section 4**: The surfaces of the modular coil castings will be contour machined only where the coil winding pack will be placed and there is high reliance on CAD models to assure the castings will provide adequate clearance during assembly – although a worst case condition of clearances approaching _ inch is envisioned. Time should be allowed in the schedule to pre-assemble castings for each type of joint: A-A, A-B, B-C, C-C, to assure the planned clearance exists. **Recommendation 4-2**: Plan time in the schedule to pre-assemble each type of modular casting assembly joint to assure adequate clearance exists between mating parts.	We will add time in the schedule for pre-assembly, but will try to minimize impact on the winding schedule. This means we may be fitting a winding form with a coil wound on it with a winding form just received from the supplier. Nonetheless, some schedule impact is expected. We will continue to rely on QA and metrology as our primary and "early warning," means for detecting interference problems with our-of-spec parts. We will rely on mockups (based on our CAD models) to assure that there are no interferences embedded in our CAD models.	$20k for performing additional pre-fitting	Post-FDR

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20	**WBS 18** **Chrzanowski**	**Comment 4 in Section 4**: The integration of the modular coil pair subassemblies around the vacuum vessel segment is a critical operation. At the earliest possible time, a full-scale mockup should be developed that allows this operation to be practiced. This same mockup, if so constructed, could be used to demonstrate adequate clearance for making all the in board connections between subassemblies at final assembly. Experience could also be gained with the metrology tools and software using the mockup. **Recommendation 4-3**: Develop a full-size mockup to be used to demonstrate the assembly of the modular coil pairs around the vacuum vessel segment.	Agree. The budget for procuring the mockup coils and vacuum vessel are already in our plans for developing metrology techniques. The additional activities recommended here will be added.	<$5K	Post-FDR
21	**WBS 18** **Chrzanowski**	**Comment 3 in Section 4**: The alignment of coils utilizing custom shims can become complex. Guidelines should be established to utilize standard shims unless some acceptable threshold misalignment is exceeded. **Recommendation 4-4**: Develop misalignment threshold for installation of customized shims.	Standard shims or shim packs will be used. The NCSX project will assess whether the nominal clearance for shims is adequate.	None	None
22	**WBS 12** **Goranson**	**Comment 5 in Section 4:** Welding of port extensions may prove to be more challenging than presently envisioned. There is a need to document flange locations and tolerances so a short development effort can be conducted to demonstrate that these requirements can be met during the assembly process.	This is covered in the prototype vacuum vessel segment R&D program.	None	None

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23	**WBS 17, 62** **Gettelfinger**	**Recommendation 5-1**: More consideration should be given to providing an external vaporizer to provide initial room temperature GN2 pressurization of the cryostat. Initial removal of moisture from the cryostat and machine surfaces should be done without introducing LN2 into the system since control of the low temperature vapor from such a system would be difficult. On the scale of NCSX, this is a minor cost with large benefits for the facility. **Recommendation 5-2**: The addition of humidity sensors inside the cryostat is strongly encouraged. Otherwise it will not be known for certain how well sealed the system is or when introduction of cool gas and liquid into the system should be made.	An external vaporizer and humidity sensors will be provided prior to operation at cryogenic temperature. However, they are not needed prior to First Plasma.	None	None
24	**WBS 12** **Goranson**	**Comment 2 in Section 6**: Vacuum vessel and port welds, particularly field welds that may be made with limited access, may develop leaks anytime throughout the life of the machine. This process of leak locating should be identified during the design of the machine. This may require the permanent installation of helium injection tubes to the area of the weld on the outside of the vessel.	Strongly agree. Isolation and repair of vacuum leaks is a fundamental requirement that will be addressed in Final Design. Full penetration welds should minimize the likelihood of leakage, but does not obviate the need for fault isolation and repair.	<$5K	Pre-FDR

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25	**WBS 16, 19** **Williamson, Cole**	**Comment 3 in Section 6**: Space allocation inside the cryostat is limited. Before the Final Design review, space allocations should be well defined. The following is a short list of equipment to be packaged within this volume: 1. Electric power feeds to all coil systems 2. Turn to turn electrical connection for the TF coils 3. Insulated bake out helium supply and return manifolds, lines and electrical breaks 4. Instrumentation lines 5. Nitrogen supply lines 6. Grounding cables Sufficient design work should be done to assure a reasonable arrangement could be developed within the space allocated.	Agree. Space allocations inside the cryostat will be determined in FY04.	<$5K	Pre-FDR
26	**WBS 14** **Williamson**	**Comment 1 in Section 6**: The issue of the lack of access for bolt installation and tightening of fasteners between field period assemblies in the inboard area needs to be addressed. These equivalent bolts are accessible during build up of the Field Period Assemblies since the TF coils are installed last into these assemblies. The presence of the wedged TF coils during the machine assembly task forms a barrier to the access required for these bolts. **Recommendation 6-1**: Resolution of the bolting between field period assemblies is required. The preload requirement for this joint is uncertain. Can the bolt requirement be met by additional accessible bolts at the top and bottom or by spacers compressed between the field period assemblies? A cure-in-place shim the full height of the joint might be feasible. This could be made from an inflatable shim bag filled with pressurized epoxy. Would this be beneficial?	We agree that access to the bolts is a primary consideration. Bolting of the modular coil flanges will be addressed in modular coil Final Design.	<$5K	Pre-FDR

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27	**WBS 4** **Ramakrishnan**	**Comment 1 in Section 7**: It appears that the deployment of a ground fault monitor to sense the status of the many insulating breaks in the machine structure has not been included in the Project scope. Although the system is not needed during construction, it would save time and reduce risk beginning with the first energization of the magnets. **Recommendation 7-1**: It is recommended that the wiring of these elements to a single point ground, along with a ground fault monitor, be included in the project scope.	Wiring of components to a single point ground is already included in the project scope. Our experience on previous devices is that a ground fault monitor is not very useful during the construction phase, so our plans are to incorporate it after First Plasma.	None	None
28	**WBS 84** **Zarnstorff**	**Recommendation 11-1**: Develop more specific goals for the field mapping experiments following MIE that take into account that NCSX has a highly variable magnetic configuration.	Agree.	None	None
29	**WBS 84** **Zarnstorff**	**Comment 2 in Section 11**: Diagnostic issues are minor at this stage relative to construction needs. Looking to the future, there is some uncertainty in the plan for field mapping experiments to be carried out following project completion. While field mapping equipment is provided for in the project budget (but will not be used), there is no provision in the budget to check out and hook up the existing power supplies for the trim coils that should be included in the field mapping experiments. Furthermore, the Initial Operation period calls for wall conditioning, but installation of glow discharge cleaning has been postponed until after this period. **Recommendation 11-2**: One can defer purchase of e-beam equipment until completion of project; consider implementing funds for GDC earlier.	Though the e-beam mapping apparatus is not needed for First Plasma, it is in scope because it provides capability needed to begin the research program. The GDC is not needed for First Plasma, provided that we can bake the vacuum vessel at 150C. However, it will be added early in experimental operations. Trim coils are planned to be used to heal islands during experimental operations but are not needed at the start of the research program. The focus of the Initial Field Line Mapping campaign (at room temperature) will be to identify the islands that exist due to coil misalignments (and other potential sources of field errors) and to correct them as much as possible, by re-aligning the coils.	None	None

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30	**WBS 3** **Johnson**	**Comment 3 in Section 11**: Present diagnostic integration studies i.e., how to implement profile diagnostics in 3-D plasma geometry through long port extensions have begun, and have been responsible for improving the port design. Nonetheless, many of the studies appear to be mainly conceptual at this stage, and not yet inclusive of all appropriate diagnostics. **Recommendation 11-3**: Review diagnostic integration studies, and strengthen emphasis on critical diagnostics. After April 2004 (scheduled FDR for the vacuum vessel), it will be too late for further accommodations.	Development of VV interfaces (including diagnostic interfaces) is an ongoing task and will be completed well in advance of the vacuum vessel FDR.	None	None
31	**WBS 8** **Neilson**	**Comment 4 in Section 12**: The Project should document the items removed from the scope baseline between the CDR and the PDR. The rationale for these changes should be included in this documentation. This will provide a documented history for removal of these components and justification for their consideration as upgrades during operations.	The NCSX project will document items removed from the scope baseline and their rationale.	None	None
32	**WBS 8** **Neilson**	**Comment 3 in Section 12**: Project management acknowledged the value of continuing a value engineering activity but was not clear on what form this should take. The Subcommittee strongly urges the Project Management to make and document this decision and implement a continuing value engineering activity for NCSX. **Recommendation 12-1**: The project should clearly identify and document how value engineering will be applied and used during the life of the project.	Value engineering is a standard part of our work planning process. At the start of each design phase, each system is surveyed to assess where value engineering studies might identify cost-effective improvements in the requirements and/or design. These are then incorporated into our work plans and reviewed as part of the design review at the end of that design phase. Examples of value engineering studies already ongoing or planned: • Use of the C-site power supplies to initially power the coils. • Indirect heating of the PFCs by raising the vacuum vessel temperature to 350°C. • Simplified glow discharge cleaning system. • Wireless networking.	None	None

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33	**WBS 8** **Neilson**	**Comment 1 in Section 12**: The annual "bottom-up" cost estimate provides a valuable management tool to Project leaders/managers and the Subcommittee strongly recommends that NCSX management commit to this activity. This activity will be a major impact on Project activities and progress each year, therefore, this activity needs to be included in the Project's master schedule, with milestones associated with this continuing activity. **Recommendation 12-2**: The project needs to document the plan to do an annual "bottom-up" estimation of cost to complete. This activity should be included in the project schedule.	Agree.	None	None
34	**WBS 8** **Neilson**	**Comment 2 in Section 12:** The Project management stated their intention of keeping the Risk Management Plan current throughout the life of the Project. This is essential and Project Management must commit to this idea. Many of the identified risks will be managed and handled successfully, but as the Project proceeds new risks will be identified and earlier identified risks will indeed become reality and must be dealt with.	Agree.	None	None

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