

WBS	Risk Type	RI-ID	Title	Summary	Owner	Risk Mitigations	Probability	Cost Impact	Schedule Impact	Technical Impact	Probability Score	Impact Score - Cost	Impact Score - Schedule	Risk Rank	Risk Responses	Risk Status
302.1 - Project Management	Threat	RT-302-1-004	Increase in Overhead Rates	If overhead rates increases are greater than estimated, then there will be a cost increase	Giorgio Apollinari	Add contingency specifically to cover higher overheads. Make sur	0.5	0 -- 964 k\$	0 months	0 (?) - Not yet defined	4 (H)	2 (M)	0 (N)	3 (High)	Overhead rates at the various laboratories have various increases and decreases over the years, often in response to changing methodology. In general, there has been a gradual rise in overhead rates in the last 5 years. Any significant change in a laboratory's overhead rate structure is evaluated for the impact to construction projects. Financial management personnel will closely monitor rate changes and bring to the attention of project management any that are expected to result in a significant cost increase or decrease.	Open
302.1 - Project Management	Threat	RT-302-1-006	Escalation rate greater than predicted	If the future escalation of the project costs is greater than default predictions in the project planning, then the project costs will be greater than the planned budget	Giorgio Apollinari		45.00%	1844 -- 3711 -- 5602 k\$	0 months	0 (N) - negligible technical impact	4 (H)	3 (H)	0 (N)	3 (High)	If inflation rises sharply, the project could avoid higher M&S cost by placing purchase orders as soon as is technically feasible with later delivery dates. Once purchase orders are placed there is generally no provision for changing the per unit price due to inflation, even on long lead time items. Labor inflation cannot be mitigated by early purchase. However, the national laboratories have a history of not allowing labor costs to escalate rapidly. In the case of unavoidable project cost increase, if the dollar amount is sufficiently large then a de-scope option would have to be considered.	Open
302.1 - Project Management	Threat	RT-302-1-007	Interface problems with CERN systems	If interfaces with HL-LHC (technical, shared facilities, scheduling, etc) are inadequately specified due to the early stage of the Project, then as they become better defined there could be cost increases and schedule delays	Giorgio Apollinari		25.00%	0 -- 0 -- 5000 k\$	0 -- 0 -- 6 months	1 (L) - somewhat substandard	3 (M)	3 (H)	1 (L)	3 (High)		Open
302.1 - Project Management	Threat	RT-302-1-008	CERN acceptance of project deliverables takes longer than assumed	If CERN delays the approval of the last US deliverable, then the DOE CD-4 approval may be delayed	Giorgio Apollinari		40.00%	0 k\$	3 -- 6 -- 9 months	0 (N) - negligible technical impact	4 (H)	0 (N)	2 (M)	3 (High)		Open
302.1 - Project Management	Threat	RT-302-1-009	Major ES&H incident	If a contractor or laboratory/university employee is injured or if material is severely damaged in an safety incident, or if an unplanned environmental release occurs during the construction or installation phases, the resulting investigation and implementation of corrective actions could shut down the project and cause schedule delays, depending on the severity of the incident and its impact on critical path work.	Giorgio Apollinari	Maintain a vigorous safety program and adequate level of staffing for project ESH support and oversight. Project construction managers provide daily assistance/oversight, including construction safety, heavy equipment inspection, and independent oversight. External oversight from DOE. Contractors will follow US Labs Worker Safety & Health Program to facilitate development of contractor specific ESH Plan. Frequent methods of communication and feedback deployed to facilitate safety will include; daily tailgate meetings, weekly contractor meetings etc. Job Safety Analysis (JSA's) written for all high risk activities.	1.00%	k\$	6 months	0 (N) - negligible technical impact	1 (VL)	0 (N)	1 (L)	1 (Low)	Ongoing oversight and planning	Open
302.1 - Project Management	Threat	RT-302-1-010	CERN delays approval of documents	If there is a delay in CERN approval key documentation such as functional requirement specifications, acceptance specifications, and interface specifications, then there could be a delay in the DOE CD-2/3b approval process	Giorgio Ambrosio	The project has produced early drafts of key documentation that has already gone through several iterations with the CERN, specially for CD-3b components.	25.00%	20 k\$	1 -- 4 -- 12 months	0 (N) - negligible technical impact	3 (M)	1 (L)	3 (H)	3 (High)		Open
302.1 - Project Management	Threat	RT-302-1-011	Customs delays and cost	If insufficient interagency and international regulatory coordination has occurred, then items moved between countries may be delayed or subject to additional costs.	Giorgio Apollinari	Break shipments into smaller pieces, monitor shipping, talk to government agencies, put assumptions about who pays duties into contracts. possible logistics reviews. talk to other projects to better understand probabilities & impacts and mitigation strategies.	25.00%	k\$	0 -- 6 months	0 (?) - Not yet defined	3 (M)	0 (N)	1 (L)	1 (Low)		Open
302.1 - Project Management	Threat	RT-302-1-002	Changes to the DOE funding profile after CD-2	If DOE needs to change the project funding profile after CD-2 then there could be a delay to the project.	Giorgio Apollinari	have backup plans ready if necessary; understand critical path activities; Be sure priorities are clear among project and collaboration leadership.	10.00%	k\$	1 -- 3 -- 6 months	0 (?) - Not yet defined	2 (L)	0 (N)	1 (L)	1 (Low)	use cost contingency to keep critical path activities on track	Open
302.1 - Project Management	Threat	RT-302-1-001	Changes to the DOE funding profile before CD-2	If DOE needs to change the project funding profile before CD-2 then there could be a delay to the project or if severe enough, even jeopardize the project's ability to move forward	Giorgio Apollinari	Be alert to how to replan work quickly. Have backup plans ready, develop alternate scenarios. Use contingency if necessary and possible to keep critical path items on track. Be sure priorities are clear among project and collaboration leadership.	50.00%	k\$	0 -- 4 -- 12 months	0 (N) - negligible technical impact	4 (H)	0 (N)	3 (H)	3 (High)		Open
302.1 - Project Management	Threat	RT-302-1-005	Need to replace key personnel	If key member of the project (PM, LZ, RM, Deputy, senior engineers, etc.) leave the project, then a replacement must be acquired resulting in schedule delays	Giorgio Apollinari	Current LARP key staff to fill Key positions	25.00%	1000 k\$	6 months	1 (L) - somewhat substandard	3 (M)	2 (M)	1 (L)	2 (Medium)	Work with Fermilab Management to fill key position and allocate full time staff to the project. Increase the Project priority.	Open
302.1 - Project Management	Threat	RT-302-1-015	Exchange rate increase	If the project has contracts placed with European companies and the USD/Euro exchange rate increases, then there may be a cost increase	Giorgio Apollinari		50.00%	0 -- 2353 k\$	months	0 (N) - negligible technical impact	4 (H)	3 (H)	0 (N)	3 (High)	The uncertainty in the exchange rate increases with procurements further in the future. The project can attempt to place foreign procurements as early in the schedule as is technically feasible to limit this effect. As the exchange rate comes into play when the costs are incurred, not at the time of purchase obligation, it may be possible to "front-load" payments without incurring technical risk.	Open
302.1 - Project Management	Threat	RT-302-1-016	Increase in cost due to proposed Tariff on Steel and Aluminum	Expected US tariffs on imported Steel (25%) and Aluminum(10%) will make procurement of Raw Materials for AUP more expensive	Giorgio Apollinari		50.00%	700 -- 1500 k\$	months	0 (N) - negligible technical impact	4 (H)	2 (M)	0 (N)	3 (High)		Open
302.2.01 - Magnets Design, Integration and Coordination	Opportunity	RO-302-2-01-001	Second prototype magnet accepted for use in HL-LHC	If the second prototype magnet is accepted by CERN for use in HL-LHC, then it can be used as one of the series production magnets resulting in cost and schedule savings.	Giorgio Ambrosio	Accept risk. Monitor the performance of MQXFAP2 during vertical testing at the BNL test facility, and within the prototype cryo-assembly. Discuss with CERN the possibility of using it in a specific tunnel location.	25.00%	2355 k\$	1 months	0 (N) - negligible technical impact	3 (M)	3 (H)	1 (L)	3 (High)	If CERN accepts to use MQXFAP2 in a specific tunnel location, consider using this magnets as part of the production pool. Some work will be needed to remove instrumentation.	Open
302.2.01 - Magnets Design, Integration and Coordination	Opportunity	RO-302-2-01-002	Coil yield higher than in plan	If the coil production yield is higher than estimated, then less make-up coils than planned will be needed resulting in cost and schedule savings.	Giorgio Ambrosio	Accept	20.00%	449 k\$	1 months	0 (N) - negligible technical impact	2 (L)	1 (L)	1 (L)	1 (Low)	Consider reducing the production quantity of make-up coils.	Open

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302.2.01 - Magnets Design, Integration and Coordination	Threat	RT-302-2-01-002	Coils fail to meet specification and are rejected	If some coils fail to meet specification and are rejected, then more coils have to be fabricated, resulting in cost increase and schedule delays to fabricate the additional coils.	Giorgio Ambrosio	A strict QA/QC program based on LARP and CERN experience fabricating coils will be adopted to maximize the production coil yield and attempt to identify bad coils as early as possible during the manufacturing process. A coil yield of 87.5% (7 out of 8) is assumed, and there are provisions in the cost and schedule baseline to fabricate more coils than needed to make up for rejected coils. For a production run of 80 coils, the total number of coils in the plan is 92 coils.	56.00%	551 -- 1653 -- 3306 k\$	0.5 -- 1.5 -- 3 months	0 (N) - negligible technical impact	4 (H)	3 (H)	1 (L)	3 (High)	The coil failure rate will be closely monitored, and if the projected number of total coil failures at 50% coil completion is higher than assumed, then additional strand will be procured with contingency funds to assure strand will be available when needed to fabricate the additional coils (strand is a very long lead item). The additional coils will be fabricated at peak production rate, with no interruption, at the tail end of the coil production run.	Open
302.2.01 - Magnets Design, Integration and Coordination	Threat	RT-302-2-01-003	Magnet assembly does not meet specifications	If a magnet assembly does not meet specifications, then it must be disassembled (partly or fully depending on the source of the non-conformance) and reassembled, causing additional cost and schedule delay	Giorgio Ambrosio	A total of 2 prototypes and 1 pre-series magnets are being planned. The project will not go into production unless at least two of these prototypes are successfully tested. The pre-series magnet will reduce the risk that production magnets are rejected because they do not meet field quality or magnetic length requirements. Therefore, there will be high confidence before production starts that the design and fabrication procedures are ready for production. A rigorous and strong QA/QC program is being instituted to avoid failures or catch them early during magnet fabrication. As a result, the failure rate of magnets at the vertical test stage is expected to be low. Nevertheless, the magnet production plan assumes a magnet production yield of 87%, and there are provisions in the plan cost and schedule to re-work 13% more magnets to offset up to this level of rejected magnets.	32.00%	927 -- 927 -- 1854 k\$	2 -- 2 -- 4 months	0 (N) - negligible technical impact	3 (M)	2 (M)	1 (L)	2 (Medium)	Magnet re-work, typically including disassembly and re-assembly, possibly exchanging one or more coils. If the failure is electrical, investigation into the source of the the electrical breakdown. Lessons-learned would be incorporated into the corresponding procedure and traveler.	Open
302.2.01 - Magnets Design, Integration and Coordination	Opportunity	RO-302-2-01-003	Very low failure rate of magnets allows reducing number of vertical tests	If the failure rate of magnets is very low, then 100% vertical testing of magnets may not be needed resulting in cost and schedule savings	Giorgio Ambrosio		10.00%	100 k\$	1 months	0 (N) - negligible technical impact	2 (L)	1 (L)	1 (L)	1 (Low)	Monitor the success rate of magnet testing. If this rate reaches 100% for 7 magnets in a row, consider sample testing instead of 100% population testing (if concerns in Notes have been addressed).	Open
302.2.01 - Magnets Design, Integration and Coordination	Threat	RT-302-2-01-006	Coil winding and curing line at BNL is ready for production later than planned	If the coil winding and curing line at BNL is ready for production later than planned then only FNAL coils are available for magnet assembly and magnet production rate is lower than planned causing a schedule delay.	Giorgio Ambrosio	Two pre-series coil (202 and 203) will be fabricated at BNL (with the new coil winding and curing line) before starting coil production.	50.00%	20 -- 150 -- 741 k\$	1 -- 3 months	0 (N) - negligible technical impact	4 (H)	2 (M)	1 (L)	3 (High)	Possible action if this risk occurs include the procurement of a second winding mandrel and use of a rotating table at FNAL, for winding & curing more coils than planned at FNAL until the line at BNL is ready. The procurement of the second winding mandrel at FNAL is in progress. The cost for winding and curing one additional coil at FNAL is \$57k (two coils are estimated in the proposed action cost). The set-up cost for the rotating table is \$10k. The total cost of the risk response is \$124k.	Open
302.2.01 - Magnets Design, Integration and Coordination	Threat	RT-302-2-01-008	Integration issue causes component rework and schedule delay	If an issue is found during the integration of components coming from different L3s or labs then rework or adjustments may be needed causing schedule delay and rework costs.	Giorgio Ambrosio	This risk was mitigated by LARP (the US LHC Accelerator Research Program) and AUP during the MQXFA development, because all integration steps up to magnet vertical test have been performed and checked by LARP. AUP has performed skin welding around a short model magnet (MQXFS1d) that was subsequently cold tested and exceeded ultimate current demonstrating no damage after skin welding.	5.00%	271 -- 3429 k\$	0.5 -- 2 months	0 (N) - negligible technical impact	1 (VL)	3 (H)	1 (L)	2 (Medium)		Open
302.2.01 - Magnets Design, Integration and Coordination	Opportunity	RO-302-2-01-004	Magnet yield higher than in plan	If the magnet vertical test yield is higher than estimated, then less magnet re-assembly and re-test than planned will be needed resulting in cost and schedule savings.	Giorgio Ambrosio	Accept	20.00%	797 k\$	2 months	0 (N) - negligible technical impact	2 (L)	2 (M)	1 (L)	2 (Medium)	Consider reducing the production quantity of magnet assemblies.	Open
302.2.01 - Magnets Design, Integration and Coordination	Threat	RT-302-2-01-011	2nd Magnet Prototype Development takes longer than estimated	If fabrication and test of the 2nd magnet prototype (MQXFAP2) takes longer than estimated, or the test is not successful, then CD-3b approval is delayed causing a delay of production start for MQXFA cables, coils and magnets.	Giorgio Ambrosio	The mitigation plan includes several elements: - a series of MQXF short models has been assembled and tested by LARP and CERN in order to demonstrate the design features, assess the safe pre-stress range, and develop/test assembly procedures; - LARP has successfully tested a 4m long MQXF coil; and the first prototype (MQXFAP1) reached 96% of ultimate current. - the HL-LHC-AUP project plan has in the baseline a re-assembly and re-test of MQXFAP2.	25.00%	10 k\$	5 months	0 (N) - negligible technical impact	3 (M)	1 (L)	1 (L)	1 (Low)	MQXFAP2 prototype is disassembled, limiting coil is replaced with spare coil and/or prestress is changed, and prototype is re-tested.	Open
302.2.01 - Magnets Design, Integration and Coordination	Threat	RT-302-2-01-012	Coil/Magnet shipping or handling damage	If a coil or magnet is damaged during shipping and handling activities, then there will be schedule delay and cost due to the need to repair or replace the damaged coil/magnet.	Giorgio Ambrosio	The magnet shipping fixtures will be designed and validated during the prototyping phase. The shipping fixture and method are based on and past experience by LARP and projects with similar deliverables as HL-LHC AUP. Instrumentation including accelerometers for recording accelerations (at pre-set frequency and all peaks) will be installed to monitor and record g-forces during shipping. All magnets will be shipped using dedicated truck. In the baseline the project assumes that one fully assembled magnet will be lost due to a shipping or handling incident. This mitigation plan may cover for a single big event (such as a truck incident causing total load loss) or several smaller events (such as a few shipping/handling incidents causing the loss of 4 coils and a magnet structure in separate events).	5.00%	1 -- 551 -- 3131 k\$	0.25 -- 2 months	0 (N) - negligible technical impact	1 (VL)	3 (H)	1 (L)	2 (Medium)	Magnets after shipment and shipment data (shock indicators and accelerometers) will be inspected in order to assess shipper reliability. In case of concerns shipping fixtures and/or shipping method and/or shipper will be changed. If accelerometers show peak accelerations above threshold, analysis of the event and its impact on the item will be performed to decide if the coil/magnet is acceptable or not.	Open
302.2.01 - Magnets Design, Integration and Coordination	Opportunity	RO-302-2-01-005	Fewer coil/magnet handling & shipment damages than in plan	If there are fewer coil or magnet handling & shipment damages, then fewer coils and magnet assemblies will be needed resulting in cost and schedule savings.	Giorgio Ambrosio		50.00%	551 -- 2329 k\$	1 -- 2 months	0 (N) - negligible technical impact	4 (H)	3 (H)	1 (L)	3 (High)		Open

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302.2.02 - Strand Procurement and Testing	Opportunity	RO-302-2-02-001	Accept multiple unit lengths for delivery to reduce strand price	If wire supplier offers a mixture of 500 m and 840 m unit lengths (80%-20%) then the US and CERN can exchange remnants, which results in a 5% reduction of the cost of superconductor	Vito Lombardo	Exploit	50.00%	800 k\$	0 months	0 (N) - negligible technical impact	4 (H)	2 (M)	0 (N)	3 (High)	If CERN procures a conductor that does not allow exchange of unit lengths, then opportunity cannot be taken advantage of.	Open
302.2.02 - Strand Procurement and Testing	Opportunity	RO-302-2-02-002	Convert manufacturer guarantee into project risk to reduce strand price	If strand manufacturer offers strand at a lower price to guarantee delivery with certain exceptions, whereas the actual statistics indicate the rate of occurrence of exceptions will be lower than the guaranteed rate, then the project can obtain strand at a lower cost to project, even when additional length is acquired to cover exceptions.	Vito Lombardo	Accept	50.00%	1400 k\$	4 months	0 (N) - negligible technical impact	4 (H)	2 (M)	1 (L)	3 (High)	Replacing 2.5% of strand requires \$315k (net impact saves \$1.085 M)	Open
302.2.02 - Strand Procurement and Testing	Threat	RT-302-2-02-001	Problems in supply chain cause major disruption of strand delivery	Strand supply relies on a chain from raw ore, to niobium, to strand contractor with few or no alternative options. If unexpected problem occur at any link, then the production of strand can be halted, which jeopardizes meeting the KPP on the scheduled date.	Vito Lombardo	Baseline acquires strand faster than needed rate to build schedule float and mitigate risk of shipment delays. When possible, redundancy has been added to supply chain.	14.00%	0 k\$	3 -- 6 -- 12 months	0 (N) - negligible technical impact	2 (L)	0 (N)	3 (H)	2 (Medium)	There is not much that can be done until the strand delivery resumes, because other qualified vendors of strand do not exist.	Open
302.2.02 - Strand Procurement and Testing	Threat	RT-302-2-02-002	Theft or disaster causes loss of entire strand inventory	If entire inventory of strand is stolen, lost, or damaged, then successor tasks stop until strand inventory can be replaced, which jeopardizes project threshold KPP.	Vito Lombardo	Strand is stored in a locked, clean, dry location. Spools are sealed in plastic wrap. Security procedures are designed to prevent theft. LBNL Buildings and Grounds protects site from extremes.	1.00%	2000 -- 3200 -- 5900 k\$	1 -- 3 -- 6 months	0 (N) - negligible technical impact	1 (VL)	3 (H)	1 (L)	2 (Medium)	Recovery of strand may be possible. Recovery procedures might require cleaning and re-certifying quality. Recovery duration might require 2 to 12 months.	Open
302.2.02 - Strand Procurement and Testing	Threat	RT-302-2-02-003	Strand price is much higher than estimated	If vendor takes advantage of non-competitive position then the escalation of cost exceeds the uncertainty in the baseline (10%) and could impact limits of available funding, affecting all KPPs.	Vito Lombardo	LARP negotiated a procurement for 400 km in Feb 2017, after the merger, which established a price point consistent with the BOE. BOE type became "advanced" for CD-3a based on this procurement. DOE can force cost justifications for same product.	5.00%	850 -- 2500 k\$	0 -- 6 months	0 (N) - negligible technical impact	1 (VL)	3 (H)	1 (L)	2 (Medium)	If risk triggers, then likely action will be for DOE to hold lengthy negotiations to force price back to reasonable level, possibly involving legal actions against supplier.	Open
302.2.02 - Strand Procurement and Testing	Threat	RT-302-2-02-004	Variation in manufacturing rate affects strand delivery schedule	If vendor cannot maintain shipments according to agreed schedule, then strand shipments can show up later than planned, which jeopardizes milestones for cryo-assemblies. This threat could ripple across multiple milestones because single shipments of strand will supply multiple magnets and possibly whole cryo-assemblies, such that objective KPP can change.	Vito Lombardo	Monthly meetings with vendors will alert project to any potential threats; comprehensive benchmarking and inter-laboratory testing reduces likelihood of test discrepancies; ongoing research intends to remove risks of deviations and non-conformities.	64.00%	0 k\$	1.6 -- 2 -- 4 months	0 (N) - negligible technical impact	5 (VH)	0 (N)	1 (L)	2 (Medium)	If risk triggers, then a sudden response will be needed to resolve the delay, such as a testing program to re-certify a failed test. 2 weeks minimum are required to react new test specimens, and additional 1-2 weeks minimum is required to repeat testing. Consultation with a university research group may be required to uncover root cause of discrepancy.	Open
302.2.02 - Strand Procurement and Testing	Threat	RT-302-2-02-005	Additional QC requested by CERN	Increase QC of round wires from 50% to 100% and add Rutherford cable extracted strand Ic test.	Vito Lombardo	NONE	50.00%	2000 k\$	0 -- 0.7 -- 1 months	0 (?) - Not yet defined	4 (H)	2 (M)	1 (L)	3 (High)	Promptly allocate additional resources to timely start additional QC.	Open
302.2.02 - Strand Procurement and Testing	Opportunity	RO-302-2-02-003	Outsource QC of round wires to external qualified test facility	If an external testing laboratory can be contracted, testing costs for round wires will be reduced due to removal of testing constraint at Fermilab, including test rate and cost of labor.	Vito Lombardo		50.00%	700 k\$	0 months	0 (N) - negligible technical impact	4 (H)	2 (M)	0 (N)	3 (High)		Open
302.2.03 - Cable Fabrication	Opportunity	RO-302-2-03-001	Mapping optimization allows leftover from wire spools to be converted to a cable UL	If a spool of wire can be mapped to allow leftover material to be converted to a unit length of wire, and if there are integral multiples of 40 of these pieces, then a cable can be made out of them, saving a cable UL.	Ian Pong	Accept - opportunity will be limited as only integral multiples of 40 UL's of strands can make a cable	57.00%	271 k\$	0.5 months	0 (?) - Not yet defined	4 (H)	1 (L)	1 (L)	2 (Medium)		Open
302.2.03 - Cable Fabrication	Threat	RT-302-2-03-001	Number of cables fails to meet specifications	If a Unit Length of cable fails to meet specifications, then it must be rejected and cannot be used to fabricate a coil, resulting in cost and schedule delays to procure the materials and fabricate a replacement cable.	Ian Pong	A strict QC program based on LARP and CERN experience fabricating Nb3Sn cables will be adopted to maximize production cable yield. A cable yield of 90% is assumed, so there are provisions in the cost and schedule baseline to fabricate 10% more cables than needed to make up for rejected cables. There are also provisions in the project baseline schedule to build an inventory of cables for roughly a 6-month supply during peak coil production to mitigate schedule impact if cable yield is lower than estimated.	44.00%	271 -- 434 -- 1084 k\$	0.5 -- 0.8 -- 2 months	0 (N) - negligible technical impact	4 (H)	2 (M)	1 (L)	3 (High)		Open
302.2.03 - Cable Fabrication	Threat	RT-302-2-03-003	LBNL: significant breakdown of cabling machine	If the LBNL cabling machine suffers a breakdown that requires custom order or specially made parts, then there can be substantial cabling down time to replace or repair, and re-qualifies the facility.	Ian Pong	Ensure sufficient OJT to new technicians/operators to minimize human errors. Plan to use alternate machine at CERN.	72.00%	20 k\$	2 -- 3 -- 6 months	0 (?) - Not yet defined	5 (VH)	1 (L)	1 (L)	2 (Medium)		Open
302.2.03 - Cable Fabrication	Threat	RT-302-2-03-004	Failure of insulation contractor to deliver on time	If insulation line at contractor is not able to deliver insulated cable on time due to contractor's internal issues (including business closure), insulated cables will be delayed for return shipment to coil winding labs, impacting coil winding schedule.	Ian Pong	Accept with plan to use alternate insulation lines, such as using CERN's vendor.	81.00%	1 -- 6 -- 50 k\$	3 months	0 (?) - Not yet defined	5 (VH)	1 (L)	1 (L)	2 (Medium)	Place an order with alternate vendor.	Open
302.2.04 - Coil Parts, Materials, and Tooling Procurement	Threat	RT-302-2-04-001	Vendor Delivery Delay	If the vendor delays the delivery of the coil end parts, then there will be a delay in FNAL coil fabrication	Miao M Yu	At least 10 sets of end parts are available from LARP at the beginning of the production.	7.70%	0 k\$	0.52 -- 3.1 -- 6.2 months	0 (N) - negligible technical impact	1 (VL)	0 (N)	2 (M)	1 (Low)		Open
302.2.04 - Coil Parts, Materials, and Tooling Procurement	Threat	RT-302-2-04-002	Laser Cutting Machine Failure	If the Laser cutting machine fails, then there will be a delay in FNAL and BNL coil fabrication.	Miao M Yu	Start the fabrication of the S2 glass sheet and build up enough inventory.	4.00%	0 -- 5 -- 30 k\$	0 -- 0.5 -- 1 months	0 (N) - negligible technical impact	1 (VL)	1 (L)	1 (L)	1 (Low)	Fabricate more S2 glass sheet to build up the inventory.	Open
302.2.04 - Coil Parts, Materials, and Tooling Procurement	Threat	RT-302-2-04-003	Shipping and Handling Damage	If there is a component damage during shipping and handling activities, then there will be schedule delay and cost due to the need to repair or replace the damaged items.	Miao M Yu	Keep enough coil parts and material in stock to mitigate the schedule risk. Emphasize the shipping and handling damage to the vendor and to the techs at FNAL, and have the components packaged properly.	15.00%	1 -- 5 -- 40 k\$	0.27 -- 1.6 -- 3.2 months	0 (N) - negligible technical impact	2 (L)	1 (L)	1 (L)	1 (Low)		Open
302.2.05 - Coil Fabrication at FNAL	Threat	RT-302-2-05-001	FNAL Winding Machine Failure	If the FNAL winding machine fails, then there will be a delay in FNAL coil fabrication	Alfred R Nobrega	The FNAL Selva winding machine has been recently refurbished to replace obsolete components and increase its reliability. FNAL has a rotating table that can be used to wind a prototype coil or a practice coil (\$30k parts & labor) as part of its qualification. The strong back used to support the coil and mandrel is complete and has been fit checked on the rotating winding table. Spare drivers (\$25k parts and labor) are needed that have been tested. The Selva technical specialist is at retirement age. His knowledge and experience needs to be transferred to his successor before he retires.	81.00%	0 -- 13 -- 25 k\$	0.25 -- 0.75 -- 1 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)	Repair the winding machine. Use backup rotating winding table. Overtime, second shift, or temporary relocation of the winding crew to an alternative site (e.g., BNL or CERN) are other possible options.	Open

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302.2.05 - Coil Fabrication at FNAL	Threat	RT-302-2-05-002	FNAL Curing Press Failure	If FNAL curing press fails, then there will be a delay in FNAL coil fabrication	Alfred R Nobrega	Have six spare cartridge heaters on hand. Before coil curing, the cartridge heaters will be measured and checked. The hydraulic press system will be tested and maintained regularly.	39.00%	0.5 -- 1 -- 50 k\$	0.05 -- 0.1 -- 1 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	Repair the failed components. Overtime winding to catch up the schedule.	Open
302.2.05 - Coil Fabrication at FNAL	Threat	RT-302-2-05-003	FNAL Reaction Oven Failure	If the FNAL reaction oven fails then schedule delay, perhaps coil loss.	Alfred R Nobrega	The probability of reaction oven failures that will require a long time to repair is low. Therefore, the plan is to perform periodic inspections of heaters and thermocouples and have a stock of replacement parts.	81.00%	0.5 -- 2 -- 4 k\$	0.05 -- 0.1 -- 0.25 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)		Open
302.2.05 - Coil Fabrication at FNAL	Threat	RT-302-2-05-004	FNAL Impregnation Station Failure	If the FNAL Impregnation station fails, then there will be delay in FNAL coil fabrication.	Alfred R Nobrega	There is redundancy in the vacuum system which uses 2 pumps. A single pump has the capacity to complete the impregnation process.	39.00%	0 k\$	0.033 -- 0.067 -- 0.25 months	0 (N) - negligible technical impact	4 (H)	0 (N)	1 (L)	2 (Medium)		Open
302.2.05 - Coil Fabrication at FNAL	Threat	RT-302-2-05-005	FNAL Impregnation Station Availability	If the FNAL Impregnation Station is not available when needed, then there will be a delay in the FNAL coil fabrication.	Alfred R Nobrega	Obtain Technical Division management commitment to prioritize the use of the IB2 equipment for this project during production	5.00%	0 k\$	0.05 -- 0.1 -- 0.15 months	0 (N) - negligible technical impact	1 (VL)	0 (N)	1 (L)	1 (Low)		Open
302.2.06 - Coil Fabrication at BNL	Threat	RT-302-2-06-001	BNL Winding Machine Failure	If the BNL winding machine fails then there will be a delay in BNL coil fabrication until repairs are made.	Jesse Schmalzle	The BNL winding machines is being refurbished to replace obsolete components and increase its reliability. Have some spare parts on hand: drive motors, sensors.	70.00%	10 k\$	0.2 -- 0.5 -- 1 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)	Purchase / fabricate required component and repair the machine. Catch up with production using overtime shifts.	Open
302.2.06 - Coil Fabrication at BNL	Threat	RT-302-2-06-002	BNL Curing Press Failure	If the BNL curing press fails then there will be a delay in BNL coil fabrication until repairs are made.	Jesse Schmalzle	Have some spare parts on hand: hydraulic cylinders, hydraulic pump, electric heaters.	70.00%	10 k\$	0.2 -- 0.5 -- 1 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)	Purchase / fabricate required component and repair machine. Catch up with production using overtime shifts.	Open
302.2.06 - Coil Fabrication at BNL	Threat	RT-302-2-06-003	BNL Reaction Oven Failure	If the BNL reaction oven fails then there will be a delay in BNL coil fabrication until repairs are made.	Jesse Schmalzle	Have some spare parts on hand: fuses, thermocouples.	70.00%	10 k\$	0.2 -- 0.5 -- 1 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)	Purchase / fabricate required components and repair oven. Catch up with production using overtime shifts.	Open
302.2.06 - Coil Fabrication at BNL	Threat	RT-302-2-06-004	BNL Impregnation Station Failure	If the BNL Impregnation station fails then there will be a delay in BNL coil fabrication until repairs are made.	Jesse Schmalzle	Have some spare parts on hand: vacuum pump, electric heaters, peristaltic pump.	70.00%	10 k\$	0.2 -- 0.5 -- 1 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)	Purchase / fabricate required component and repair machine. Catch up with production using overtime shifts.	Open
302.2.07 - Structure Fabrication and Magnet Assembly	Threat	RT-302-2-07-001	LBNL matrixed or shared resources unavailable when needed	LBNL Engineering operates as a matrix Division, with technicians and engineers moving from project to project as needed, or shared between multiple projects simultaneously. If this activity cannot get access to the required resources, then there will be possible schedule slippage, impacting this and all downstream activities.	Daniel W. Cheng	A detailed production schedule will allow us to identify which technical staff should be captured by the project and to schedule equipment use in advance. A well-maintained and reliable upstream schedule and good communication from 302-2-05 and 06 upon coil shipment can help resource negotiation/arrangement internally.	65.00%	0 k\$	0.25 months	0 (?) - Not yet defined	5 (VH)	0 (N)	1 (L)	2 (Medium)		Open
302.2.07 - Structure Fabrication and Magnet Assembly	Threat	RT-302-2-07-002	Bladder pressurizing system failure	If the system providing pressure to the bladders during loading fails, loading work will stop until a replacement system is made available or the unit repaired, causing schedule delays	Daniel W. Cheng	Purchase a backup system. This would furthermore open the possibility of further parallelization of tasks to compress the schedule, or allow for a pressurizing unit to be transported to BNL or FNAL should an unanticipated reloading operation be required.	50.00%	2 k\$	0.25 months	0 (?) - Not yet defined	4 (H)	1 (L)	1 (L)	2 (Medium)		Open
302.2.07 - Structure Fabrication and Magnet Assembly	Threat	RT-302-2-07-004	Structure Procurement delay	If there is a structure procurement delay due to vendor performance issue, then there will be delay in the LBNL magnet fabrication schedule	Daniel W. Cheng	Qualify vendors during prototyping phase. Develop sufficient buffer of components in early phase of project to accommodate incidents. For some elements, multiple vendor contracts may be initiated so flow of parts is not interrupted in case of incident.	50.00%	78 -- 100 -- 300 k\$	1 -- 2 -- 3 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	Have pre-qualified alternate vendors for each deliverable. Issue staged PO's with multiple vendors such that alternate vendor can help production rate.	Open
302.2.07 - Structure Fabrication and Magnet Assembly	Threat	RT-302-2-07-005	Coil dimensional variations require coil matching/sorting	If coil dimensional variations are greater than the criteria defined by the LBNL coil selection procedure SU-1009-1688 "MQXFA Coil Selection Criteria", then there will be a need for coil matching/sorting to meet magnetic field requirements causing delays to the project schedule waiting for an adequate inventory of coils for matching.	Daniel W. Cheng	This is primarily a concern early in the project; once a coil is swapped out, it can be used in the next structure, and the risk reduces.	54.00%	0 k\$	2 months	0 (?) - Not yet defined	4 (H)	0 (N)	1 (L)	2 (Medium)		Open
302.2.07 - Structure Fabrication and Magnet Assembly	Opportunity	RO-302-2-07-001	Second Fuji-paper procedure not required in 9 of 23 structures	If one Fuji-paper check in the coilpacks can be eliminated, then less time will be needed to assemble a magnet resulting in schedule savings of 3 days for each magnet	Daniel W. Cheng		59.00%	7 k\$	1.5 months	0 (?) - Not yet defined	4 (H)	1 (L)	1 (L)	2 (Medium)		Open
302.2.07 - Structure Fabrication and Magnet Assembly	Opportunity	RO-302-2-07-002	Reuse temp compensator strain gauges from earlier magnet assemblies	If early production magnets can retain the temperature compensators and wiring (removed prior to cryostating) then they could be reused in later production magnets.	Daniel W. Cheng	All strain gauges will be purchased in one batch, so all gauges will be matched with one another throughout the entire project.	74.00%	13 k\$	0.25 months	0 (?) - Not yet defined	5 (VH)	1 (L)	1 (L)	2 (Medium)		Open
302.2.07 - Structure Fabrication and Magnet Assembly	Opportunity	RO-302-2-07-003	Wire harnesses to be reused	From earlier magnet assemblies, wire harness can be reused.	Daniel W. Cheng		74.00%	9 k\$	0.13 months	0 (?) - Not yet defined	5 (VH)	1 (L)	1 (L)	2 (Medium)		Open
302.2.07 - Structure Fabrication and Magnet Assembly	Threat	RT-302-2-07-006	Production is stopped because more QC testing/discussions need to be carried out	Production is stopped because more QC testing/discussions need to be carried out	Daniel W. Cheng	Standing army may be likely early in the project. During production where multiple parallel activities are taken place personnel could be redirected while a decision is discussed.	62.00%	k\$	0.2 -- 0.25 -- 0.5 months	0 (N) - negligible technical impact	4 (H)	0 (N)	1 (L)	2 (Medium)		Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-01-001	Raw materials delivery delay	If material from supplier or braze joints do not arrive and clear incoming inspections by the estimated date, then there will be delayed start of cavity manufacture at cavity supplier.	Leonardo Ristori	Initiate procurement of material with enough advance to minimize schedule delays due to late deliveries. Maintain regular contacts with supplier to address promptly any non-conformity and identify/approve corrective actions.	50.00%	0 -- 11 -- 27 k\$	1 -- 6 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	Approve partial shipments if possible. Increase priority of incoming inspections at Fermilab to reduce time to shipment of material to suppliers of cavities. Launch cavity procurement before all raw material is available.	Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-02-001	Bare cavity delivery delays	If supplier offer delivery dates later than anticipated or does not deliver by the promised date, then delayed start of Processing and delays to cold tests	Leonardo Ristori	Define key milestones in the fabrication process. Maintain high level of oversight at supplier's location and hold regular conference calls to discuss progress in respect to the milestones.	50.00%	0 -- 19 -- 38.4 k\$	1 -- 2 -- 6 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)		Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-03-001	Cavity processing or testing infrastructure breakdown	If there is a failure at the ANL/FNAL processing facility or VTS infrastructure failure or interruption of liquid helium supply availability. Some failures are recoverable with a day or two, others may take more than a month.	Leonardo Ristori	Processing and testing facilities at the partner laboratory JLab have been upgraded to accept RFD crab cavities during the LARP program. Cavities can be transported to JLab as needed to reduce the schedule impact of an unforeseen shut-down.	10.00%	1 -- 5 -- 20 k\$	1 -- 2 -- 6 months	0 (N) - negligible technical impact	2 (L)	1 (L)	1 (L)	1 (Low)	Depending on the foreseen down-time at ANL/FNAL and on the amount of notice, a decision can be made between waiting for the facility to resume operations or transferring a portion of the work to JLab.	Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-002	Cavity yield lower than predicted	If actual yield of cavities is lower than predicted (10/12), objective KPP are not met.	Leonardo Ristori	Add additional reprocessing cycles to project plan. Add schedule contingency to re-process and test cavities.	11.00%	445 -- 698 k\$	6 -- 12 -- 18 months	0 (N) - negligible technical impact	2 (L)	2 (M)	3 (H)	2 (Medium)	Launch fabrication of additional cavity	Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Opportunity	RO-302-3-02-002	Yield higher than expected	If the cavity yield is higher than expected, qualification of all 10 deliverables may happen sooner than anticipated and a number of processing-testing cycles can be avoided.	Leonardo Ristori		50.00%	56 -- 56 -- 112 k\$	2 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)		Open

WBS	Risk Type	RI-ID	Title	Summary	Owner	Risk Mitigations	Probability	Cost Impact	Schedule Impact	Technical Impact	Probability Score	Impact Score - Cost	Impact Score - Schedule	Risk Rank	Risk Responses	Risk Status
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-04-001	Helium tank delivery delays	If suppliers order delivery dates later than anticipated or supplier does not deliver by the promised date, or items are returned to vendor, then late clearance of incoming inspections causes a delayed start of dressed cavity processing and testing	Leonardo Ristori	Define key milestones in the fabrication process. Maintain high level of oversight at supplier's location and hold regular conference calls to discuss progress in respect to the milestones.	50.00%	0 -- 20 -- 40 k\$	1 -- 2 -- 4 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	Reduce time to shipment to CERN by increasing priority at Fermilab of incoming inspections, chemical processing and vertical testing.	Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Opportunity	RO-302-3-02-001	Prototype Cavities useable for HL-LHC	If one or both prototypes are fully qualified and no design changes are implemented between prototypes and production units, a lower number of units can be ordered for the production run	Leonardo Ristori		20.00%	698 -- 698 -- 1396 k\$	2 months	0 (N) - negligible technical impact	2 (L)	2 (M)	1 (L)	2 (Medium)		Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-02-002	Cavity Supplier Default on Contract	If the supplier of bare cavities fails to deliver the total number of cavities, a shortage of cavities to be processed and tested jeopardizes the project deliverables.	Leonardo Ristori	The contract for fabricating two RFD crab cavities will be awarded among reputable suppliers of SRF cavities through a technical award process taking into account past experience with such suppliers.	20.00%	581 -- 1509 -- 3018 k\$	8 -- 12 -- 24 months	0 (N) - negligible technical impact	2 (L)	3 (H)	3 (H)	2 (Medium)	Depending on the amount and nature of work necessary to complete the fabrication of all cavities, several options are available: 1. Issue POs with other suppliers in the original bid process, to produce the balance number of cavities from scratch. If not enough raw materials are available, POs will need to be issued. 2. Take possession of parts from supplier and complete the fabrication at JLab. This laboratory has already completed fabrication of SRF cavities and in particular during the LARP program, four crab cavities were completed there successfully.	Open
302.3 - RFD Dressed Cavities Design, Fabrication, and Testing	Threat	RT-302-3-02-001	Damage of cavity due to mishandling	If a cavity is damaged beyond possible repair at any moment during incoming inspections, chemical processing, vertical testing, helium vessel welding and shipping, then the threshold number of cavities can't be delivered to CERN.	Leonardo Ristori	Operational procedures are available at all laboratories where crab cavities are handled. Such procedures cover all methods and tools that must be followed to avoid any sort of damage to any SRF cavity, including crab cavities. Also, an electronic traveler system is used to keep track of cavity movements and hand-offs between laboratories and groups within the same laboratory.	5.00%	445 -- 698 k\$	8 -- 18 months	0 (N) - negligible technical impact	1 (VL)	2 (M)	3 (H)	2 (Medium)	Once a cavity is deemed damaged beyond any possible repair (either technically impossible or financially/timely non-favorable), a change of order needs to be issued promptly with the cavity supplier to produce the extra cavity.	Open
302.4.01 - Magnets Vertical Test	Threat	RT-302-4-01-002	BNL Vertical Test Facility Breakdown	If there is a failure of the BNL Vertical Test Facility (VTF) during a test, then magnet testing will be delayed until repairs are completed and the cold mass assembly schedule may be impacted while waiting for accepted magnets to be available. Such a failure as proposed here could involve either the cryogenics facility and liquid He plant or the power supply. Performing 100% training and testing of production magnets is an important element of the project QA/QC plan. Given the high BNL vertical test facility occupancy during peak production times, there is little tolerance for unscheduled facility downtime. An extended downtime of several weeks will cause significant project schedule delays.	Joseph F. Muratore	BNL has purchased critical spare components and established redundant systems with BNL Internal Development Funding. These include a backup 1000 Watt CVE/Air Liquide refrigerator, and a Sullair 500 HP compressor. See US-HILumi-doc-19 for details. BNL will add spares of critical power supply components such as IGBT modules. In addition, all IGBT "slave" units will be replaced by "master" units to increase device reliability. Driver cards will be supplied by a new vendor which has a more robust design. BNL has recently added adequate critical spare components and redundancy to operate the test facility with high availability, therefore the probability of this risk is "Low" (~10%). The availability of critical spares is expected to keep the mean time to repair to a few days or weeks, therefore the Schedule impact is considered "Low". The resulting risk rank is "Low", therefore this risk will be accepted with no mitigation actions added to the project baseline.	75.00%	26 -- 65 -- 130 k\$	0.48 -- 0.63 -- 1.8 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)		Open
302.4.01 - Magnets Vertical Test	Threat	RT-302-4-01-001	Critical BNL Personnel Unavailable for Magnet Testing	If BNL personnel are unavailable for magnet testing, then testing could be delayed and that will impact the cold mass assembly schedule.	Joseph F. Muratore	Test supervisor/physicist J. Muratore can be substituted by a combination of P. Joshi and P. Wanderer during testing; electrical engineer P. Joshi can be substituted by George Ganetis (former magnet Division electrical engineer) if needed; electrical technician S. Dimlata can be substituted by one of the former Magnet Division electrical technicians now working at RHIC or NSLSII; cryogenics technician/operator W. McKeon can be substituted by a to-be-trained cryogenics technician or a cryogenics technician from RHIC. The second cryogenics technician/operator is expected to be in place in time for the production magnet testing. A substitute from RHIC would result in a few days to a week delay due to availability (whether RHIC is running or not) and how much specific familiarity would be needed to be learned before operating the facility.	27.00%	0 -- 0 -- 0 k\$	0.044 -- 0.22 -- 0.44 months	0 (N) - negligible technical impact	3 (M)	0 (N)	1 (L)	1 (Low)		Open
302.4.01 - Magnets Vertical Test	Threat	RT-302-4-01-003	Loss of He Gas	There is the risk of a loss of He gas during testing caused by the failure of a Cryogenics Facility component or a power outage which will shut down the compressors. If a loss of He gas should occur, then the impact would be cost to replace the gas and several days to a week delay in testing, depending how soon gas can be delivered.	Joseph F. Muratore	Valves and other components are being replaced with new parts and many parts of the facility have been refurbished. Diagnostic and control programs have been used in real tests now and improvements have been made to make communications problems less likely. Power outages, due mainly to storms, are not predictable, but such shutdowns are not frequent. The search for leaks is ongoing.	27.00%	2.3 -- 5 -- 6.9 k\$	0.044 -- 0.13 -- 0.22 months	0 (N) - negligible technical impact	3 (M)	1 (L)	1 (L)	1 (Low)		Open
302.4.02 - Cold Mass Assemblies Fabrication	Threat	RT-302-4-02-001	More effort than anticipated to meet CERN's safety rules	If it takes more effort than estimated to meet CERN's safety requirements, then schedule delays and cost increase will be incurred to satisfy these requirements	Sandor Feher	Actively working with CERN's HL-LHC Safety Officer and CERN's HSE Organization communicating standard US Labs safety practices and requesting the formalization of US/CERN safety agreements for HL-LHC. The plan is to have a clear agreement before baselining the project at CD-2.	25.00%	95 k\$	0.5 months	0 (N) - negligible technical impact	3 (M)	1 (L)	1 (L)	1 (Low)		Open
302.4.02 - Cold Mass Assemblies Fabrication	Threat	RT-302-4-02-002	CERN fails to supply CERN-provided components for production on schedule	If the CERN-provided parts for the production Cold Mass Assembly are late, then there will be a delay in the Cold Mass Assembly fabrication waiting for the parts to arrive	Sandor Feher	At the time of project baseline and before CD-2, there will be a signed letter from a CERN representative stating the agreement of CERN-supplied components and their delivery schedule. Frequent communication will be maintained during project execution related to shipment preparation of these items.	30.00%	20 -- 60 k\$	2 -- 6 months	0 (?) - Not yet defined	3 (M)	1 (L)	1 (L)	1 (Low)	Try to transfer personnel to other tasks while waiting for the parts to arrive.	Open
302.4.02 - Cold Mass Assemblies Fabrication	Threat	RT-302-4-02-003	CERN fails to supply CERN-provided components for Prototype fabrication on schedule	If the CERN-provided parts for the Prototype Cold Mass Assembly are late, then there will be a delay in the Prototype Cold Mass Assembly fabrication waiting for the parts to arrive. The Cold-mass assembly fabrication can be also late if the Cold Mass assembling station is not ready by the planned start time.	Sandor Feher	At the time of project baseline and before CD-2, there will be a signed letter from a CERN representative stating the agreement of CERN-supplied components and their delivery schedule. Frequent communication will be maintained during project execution related to shipment preparation of these items We will also follow closely the tooling design development and tooling procurement process to make sure that there is no delay producing the tooling on time.	30.00%	20 -- 60 k\$	2 -- 6 months	0 (N) - negligible technical impact	3 (M)	1 (L)	1 (L)	1 (Low)	Try to transfer personnel to other tasks while waiting for the parts to arrive.	Open

WBS	Risk Type	RI-ID	Title	Summary	Owner	Risk Mitigations	Probability	Cost Impact	Schedule Impact	Technical Impact	Probability Score	Impact Score - Cost	Impact Score - Schedule	Risk Rank	Risk Responses	Risk Status
302.4.02 - Cold Mass Assemblies Fabrication	Threat	RT-302-4-02-005	Magnet issues due to skin welding	If skin welding causes an issue then the successful test of the cryo-assembly prototype is delayed causing a delay of CD-3 and of all Q1/Q3 deliverables	Sandor Feher	The main risk mitigation element is the cold test of a short MQXF model (MQXFS1d) after welding a stainless steel skin around it. This welding will be performed simulating procedures that will be used for welding the cold mass skin around the MQXFA magnets. If issues are found, this process will be repeated until a safe procedure is found. Strain gauges will be used during skin welding on the short model and on the LMQXFA cold masses in order to assure that no damage is caused to the magnets. The work on the short model is supported by LARP (LHC Accelerator Research Program). Installation and monitoring of the strain gauges on LMQXFA cold mass is supported by the AUP project.	25.00%	189 -- 3223 k\$	1 -- 7 months	0 (?) - Not yet defined	3 (M)	3 (H)	2 (M)	3 (High)		Open
302.4.02 - Cold Mass Assemblies Fabrication	Threat	RT-302-4-02-004	ICBA addition completion is late for 1 year	If ICBA addition completion is late for a year the Cold mass production will be delayed half a year. CERN provided parts exchange is under negotiation. Several parts might be paid by AUP that is not in the budget.	Sandor Feher	Close communication with TD headquarters.	5.00%	0 k\$	6 months	0 (?) - Not yet defined	1 (VL)	0 (N)	1 (L)	1 (Low)	Try to transfer personnel to other tasks while waiting for ICBA to be completed.	Open
302.4.02 - Cold Mass Assemblies Fabrication	Threat	RT-302-4-02-007	CERN provided parts cost more than budgeted		Sandor Feher	Actively consulting CERN on this issue and try to agree on the parts exchange list ASAP.	50.00%	1400 -- 1700 k\$	1 -- 2 months	0 (?) - Not yet defined	4 (H)	2 (M)	1 (L)	3 (High)		Open
302.4.03 - Cryo-assemblies Fabrication and Shipment	Threat	RT-302-4-03-001	More effort than anticipated to meet FNAL's cryostat safety requirements	If it takes more effort than estimated to meet FNAL's cryostat safety requirements, then schedule delays and cost increase will be incurred to satisfy these requirements so the cryo-assembly can be tested at FNAL	Sandor Feher	Close communication between the US and CERN regarding the safety rules under which the CERN cryostat kit will be design and fabricated. There is a news FESHM Chapter 2110 "Ensuring Equivalent Safety Performance when Using International Codes and Standards" that define the process to obtain approval to operate equipment provided by international partners at Fermilab. Cryostat parts that require approval include Vacuum vessel and cryogenic piping.	20.00%	24 k\$	1 months	0 (?) - Not yet defined	2 (L)	1 (L)	1 (L)	1 (Low)		Open
302.4.03 - Cryo-assemblies Fabrication and Shipment	Threat	RT-302-4-03-004	Cryo-assembly fails to meet specifications	If a cryo-assembly fails to meet the approved functional requirement specifications, then it must be rejected and cannot be delivered to CERN, resulting in schedule delays and cost to re-work the assembly	Sandor Feher	A prototype cold mass will be assembled and tested as part of the baseline plan, so there will be high confidence that the cold mass design and fabrication procedures are ready for production. A strong and rigorous QA/QC program, including testing of each magnet in the BNL vertical test stand, will be instituted so failures can be avoided or caught early in the manufacturing process. To mitigate the remaining risk, the project baseline includes the re-work of one cold mass assembly.	50.00%	459 -- 753 k\$	4 -- 8 months	0 (N) - negligible technical impact	4 (H)	2 (M)	2 (M)	3 (High)		Open
302.4.03 - Cryo-assemblies Fabrication and Shipment	Threat	RT-302-4-03-003	Cryo-assembly prototype fails and need rework	If the cryo-assembly prototype fails to meet requirements, than it need rework and CD-3 (construction start for cryo-assemblies) will be delayed causing a delay of cold masses and cryo-assemblies production start	Giorgio Ambrosio	The two magnets in the prototype cryo-assembly have been previously trained and tested in the BNL Vertical Test Facility, substantially increasing the likelihood that the cryo-assembly will be successful. Still, there are several possible failure modes of the cold mass assembly that may render the cold mass unacceptable. For example, splices, heat exchanger, helium vessel, and so on.	25.00%	20 -- 909 k\$	1 -- 6 -- 12 months	0 (N) - negligible technical impact	3 (M)	2 (M)	3 (H)	3 (High)	The cryo-assembly and cold mass will be disassembled in order to fix the problem. In case a coil/magnet should be replaced, MQXFA3 will be available.	Open
302.4.03 - Cryo-assemblies Fabrication and Shipment	Threat	RT-302-4-03-002	CERN fails to supply a complete CERN cryostat kit for the production on schedule	If the CERN-provided cryostat kit for the production is late, then there will be a delay in the cryo-assembly fabrication waiting for the cryostat parts to arrive	Sandor Feher	At the time of project baseline and before CD-2, there will be a signed letter from a CERN representative stating the agreement of CERN-supplied components and their delivery schedule. Frequent communication will be maintained during project execution related to shipment preparation of these items.	30.00%	25 -- 75 k\$	2 -- 6 months	0 (N) - negligible technical impact	3 (M)	1 (L)	1 (L)	1 (Low)	Try to transfer personnel to other tasks while waiting for the parts to arrive.	Open
302.4.03 - Cryo-assemblies Fabrication and Shipment	Threat	RT-302-4-03-005	CERN fails to supply a complete CERN cryostat kit for the prototype on schedule	If the CERN-provided cryostat kit for the prototype is late, then there will be a delay in the cryo-assembly fabrication waiting for the cryostat parts to arrive	Sandor Feher	At the time of project baseline and before CD-2, there will be a signed letter from a CERN representative stating the agreement of CERN-supplied components and their delivery schedule. Frequent communication will be maintained during project execution related to shipment preparation of these items.	30.00%	25 -- 75 k\$	2 -- 6 months	0 (N) - negligible technical impact	3 (M)	1 (L)	1 (L)	1 (Low)	Try to transfer personnel to other tasks while waiting for the parts to arrive.	Open
302.4.04 - Cryo-assemblies Horizontal Test Facility	Threat	RT-302-4-04-001	FNAL Horizontal Test Facility non-cryogenic failure	Non-cryogenic failures at the FNAL Horizontal Test Facility during a cryo-assembly test may impact the test schedule and the cryo-assembly delivery to CERN.	Michael A. Tartaglia	Regular maintenance of the test stand infrastructure, DAQ and monitoring equipment by TD/Test and Instrumentation department. Stock critical spares.	71.30%	2 -- 6 k\$	0.15 -- 0.24 months	0 (N) - negligible technical impact	5 (VH)	1 (L)	1 (L)	2 (Medium)	Repair or replace failed components of the power system, energy extraction system, DAQ or monitoring systems. Cool down the cryo-assembly again if necessary	Open
302.4.04 - Cryo-assemblies Horizontal Test Facility	Threat	RT-302-4-04-002	IB1 Cryogenic System Failure	If there is a failure of the IB1 cryogenic system during a cryo-assembly test, then the testing schedule will be delayed impacting the cryo-assembly shipment to CERN	Guram Chlachidze	The FNAL test facility has spares for the helium compressor, cold box turbines, DC power system supplies, and Kinney Vacuum pumps. Therefore, failure of one of these critical components is not expected to cause a substantial unscheduled downtime. Less likely failures of components without spares or redundancy (e.g., cold box, feed box) may result in extended downtime. The facility has an annual preventive maintenance program that mitigate the risk of unscheduled shutdowns. Cold box contamination has been a frequent cause of relatively short unscheduled shutdowns, and this risk is being mitigated by the installation of a purification system for sub-atmospheric operations. Nevertheless, the FNAL test facility has at the present time a single-source of Liquid helium supply so the risk of extended downtime of this single-source of LHe has to be considered.	63.20%	0.5 -- 9.6 k\$	0.05 -- 0.4 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	The FNAL test facility has spares for the helium compressor, cold box turbines, DC power system supplies, and Kinney Vacuum pumps. Failed components will be replaced.	Open
302.4.04 - Cryo-assemblies Horizontal Test Facility	Threat	RT-302-4-04-003	Unavailability of IB1 Liquid Helium	If there is not enough Liquid Helium available in IB1 to support the cryo-assembly test, then testing will be delayed impacting the cryo-assembly shipment to CERN	Guram Chlachidze		50.00%	0.5 -- 1.5 k\$	0.05 -- 0.14 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	Reduce or limit testing until the liquid helium inventory is available again.	Open
302.4.04 - Cryo-assemblies Horizontal Test Facility	Threat	RT-302-4-04-004	Magnetic Measurement System Failure	If there is a failure of the magnetic measurement system during a cryo-assembly test, then testing will be delayed impacting the cryo-assembly shipment to CERN	Guram Chlachidze	Spare units will be available for the critical components of the measurement system	63.00%	2 -- 5 k\$	0.1 -- 0.24 months	0 (N) - negligible technical impact	4 (H)	1 (L)	1 (L)	2 (Medium)	Malfunctioning components of the measurement system will be replaced or repaired.	Open
302.4.04 - Cryo-assemblies Horizontal Test Facility	Threat	RT-302-4-04-006	Upgrade of horizontal test stand is not completed by the planned start time	If horizontal test stand is not ready then the testing schedule will be delayed impacting the cryo-assembly shipment to CERN	Sandor Feher	New technicians will be hired and trained before the test stand upgrade starts.	10.00%	0 k\$	1 -- 3 months	0 (N) - negligible technical impact	2 (L)	0 (N)	1 (L)	1 (Low)	Hire more contractors when necessary	Open

WBS	Risk Type	RI-ID	Title	Summary	Owner	Risk Mitigations	Probability	Cost Impact	Schedule Impact	Technical Impact	Probability Score	Impact Score - Cost	Impact Score - Schedule	Risk Rank	Risk Responses	Risk Status
302.4.04 - Cryo-assemblies Horiz	Threat	RT-302-4-04-007	Excessive Heat Load to 1.9K Cooldown	With the existing pumping capacity at Horizontal Test Stand we can successfully cooldown Q1/Q3 cryo-assembly if heat load to 1.9K is less than the estimated limit. In new configuration the cryoassemblies are equipped with additional power leads used for the CUQ and trim currents, which are increasing the heat load. Also, cryostat design is not finalized, therefore we do not know the total expected heat load.	Roger J Rabehl		40.00%	10 -- 180 k\$	0 months	0 (N) - negligible technical impact	4 (H)	1 (L)	0 (N)	2 (Medium)	Increase pumping capacity by using the existing Kinney pumps or purchase new Kinney pumps.	Open