Resource Loaded Schedule, costs and risks for the completion of the MICE project

1 Actions and recommendations

A full response to each action and recommendation made by the RLSR Panel or the MPB at the November 2014 review of the project is given in the "Response to Feedback" submitted in February 2015 [1]. The responses given in [1] stand. The project team would like to make the following additional comments in the light of the progress that has been made since the 2^{nd} February 2015 when the Response to Feedback was submitted.

- **RLSR recommendation 1;** the importance of expediting the extraction of results from Step IV data taking.

  Recognising the importance of the efficient and timely commissioning of the experiment, the operations team turned the lessons learnt in the mock-data run executed on the 21^{st} January 2015 [2] into an action list [3]. The action list is being tracked by the operations team. The activation run planned for the 8^{th} March 2015 was cancelled by ISIS due to problems encountered in the recommissioning of the accelerator.

  The MICE commissioning and operations plan for the present ISIS User Run (2014/03) is being carried out by running the experiment at weekends so as not to interfere with the construction work taking place on weekdays. The experiment was operated for the first time on the weekend of the 21^{st} and 22^{nd} March 2015. As summarised in section 2 and described in more detail in the report to the MICE Project Board [**?**], the commissioning and operations activity is on track. The importance of maintaining the momentum of this activity is recognised to be a priority.

  The project team notes that the summer 2016 ISIS User Run is expected to end in late June or early July 2016. Given the pressure on Step IV running time, the project team is seeking ways in which this User Run can be exploited to the full without delaying the start of operations in the cooling-demonstration configuration.

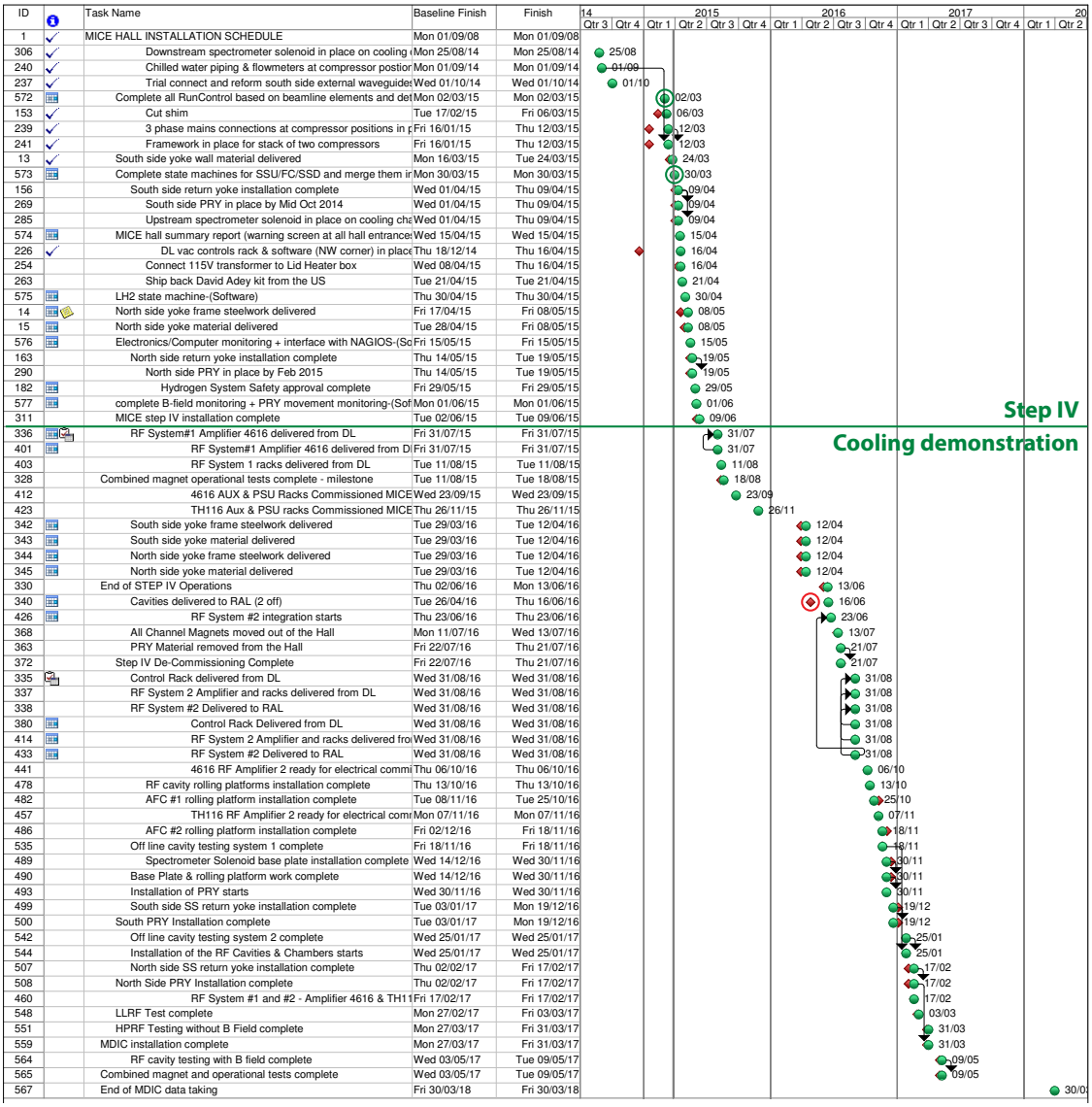
- **RLSR action 1;** the importance of ensuring the availability of the necessary RF-engineering resources; and

  MPB superconducting magnets recommendation 1; the importance of mitigating the risks associated with coupler (and cavity) commissioning.

  The plans to test the first set of production couplers summarised in the Response to Feedback are being carried out. The requirement to deliver first results from the cooling-demonstration configuration in US fiscal year 2016 places a premium on the early commissioning of the RF system (low-level RF, high-power amplifiers and single-cavity modules) in the MICE Hall. Therefore the project team is investigating scenarios that would allow RF commissioning to begin at the end of Step IV operations. To be successful, such a plan would require installation of the necessary equipment in parallel with Step IV operation and the availability of the necessary electrical- and RF-engineering expertise in UK financial years 2015 and 2016. The necessary discussions with ASTeC management have been initiated and the cost and schedule implications of the parallel installation activities are being investigated.

Finally, the RLSR panel requested bi-monthly updates of the project Dashboard. The updated project dashboard may be found at `http://micewww.pp.rl.ac.uk/dashboard/`. This, combined with the present report, constitutes the second bi-monthly update on the progress of the project.

2 Introduction



ID	Task Name	Baseline Finish	Finish
1	MICE HALL INSTALLATION SCHEDULE	Mon 01/09/08	Mon 01/09/08
306	Downstream spectrometer solenoid in place on cooling	Mon 25/08/14	Mon 25/08/14
240	Chilled water piping & flowmeters at compressor postior	Mon 01/09/14	Mon 01/09/14
237	Trial connect and reform south side external waveguides	Wed 01/10/14	Wed 01/10/14
572	Complete all RunControl based on beamline elements and det	Mon 02/03/15	Mon 02/03/15
153	Cut shim	Tue 17/02/15	Fri 06/03/15
239	3 phase mains connections at compressor positions in p	Fri 16/01/15	Thu 12/03/15
241	Framework in place for stack of two compressors	Fri 16/01/15	Thu 12/03/15
13	South side yoke wall material delivered	Mon 16/03/15	Tue 24/03/15
573	Complete state machines for SSU/FC/SSD and merge them ir	Mon 30/03/15	Mon 30/03/15
156	South side return yoke installation complete	Wed 01/04/15	Thu 09/04/15
269	South side PRY in place by Mid Oct 2014	Wed 01/04/15	Thu 09/04/15
285	Upstream spectrometer solenoid in place on cooling cha	Wed 01/04/15	Thu 09/04/15
574	MICE hall summary report (warning screen at all hall entrances	Wed 15/04/15	Wed 15/04/15
226	DL vac controls rack & software (NW corner) in place	Thu 18/12/14	Thu 16/04/15
254	Connect 115V transformer to Lid Heater box	Wed 08/04/15	Thu 16/04/15
263	Ship back David Adey kit from the US	Tue 21/04/15	Tue 21/04/15
575	LH2 state machine-(Software)	Thu 30/04/15	Thu 30/04/15
14	North side yoke frame steelwork delivered	Fri 17/04/15	Fri 08/05/15
15	North side yoke material delivered	Tue 28/04/15	Fri 08/05/15
576	Electronics/Computer monitoring + interface with NAGIOS-(So	Fri 15/05/15	Fri 15/05/15
163	North side return yoke installation complete	Thu 14/05/15	Tue 19/05/15
290	North side PRY in place by Feb 2015	Thu 14/05/15	Tue 19/05/15
182	Hydrogen System Safety approval complete	Fri 29/05/15	Fri 29/05/15
577	complete B-field monitoring + PRY movement monitoring-(Sof	Mon 01/06/15	Mon 01/06/15
311	MICE step IV installation complete	Tue 02/06/15	Tue 09/06/15
336	RF System#1 Amplifier 4616 delivered from DL	Fri 31/07/15	Fri 31/07/15
401	RF System#1 Amplifier 4616 delivered from DL	Fri 31/07/15	Fri 31/07/15
403	RF System 1 racks delivered from DL	Tue 11/08/15	Tue 11/08/15
328	Combined magnet operational tests complete - milestone	Tue 11/08/15	Tue 18/08/15
412	4616 AUX & PSU Racks Commissioned MICE	Wed 23/09/15	Wed 23/09/15
423	TH116 Aux & PSU racks Commissioned MICE	Thu 26/11/15	Thu 26/11/15
342	South side yoke frame steelwork delivered	Tue 29/03/16	Tue 12/04/16
343	South side yoke material delivered	Tue 29/03/16	Tue 12/04/16
344	North side yoke frame steelwork delivered	Tue 29/03/16	Tue 12/04/16
345	North side yoke material delivered	Tue 29/03/16	Tue 12/04/16
330	End of STEP IV Operations	Thu 02/06/16	Mon 13/06/16
340	Cavities delivered to RAL (2 off)	Tue 26/04/16	Thu 16/06/16
426	RF System #2 integration starts	Thu 23/06/16	Thu 23/06/16
368	All Channel Magnets moved out of the Hall	Mon 11/07/16	Wed 13/07/16
363	PRY Material removed from the Hall	Fri 22/07/16	Thu 21/07/16
372	Step IV De-Commissioning Complete	Fri 22/07/16	Thu 21/07/16
335	Control Rack delivered from DL	Wed 31/08/16	Wed 31/08/16
337	RF System 2 Amplifier and racks delivered from DL	Wed 31/08/16	Wed 31/08/16
338	RF System #2 Delivered to RAL	Wed 31/08/16	Wed 31/08/16
380	Control Rack Delivered from DL	Wed 31/08/16	Wed 31/08/16
414	RF System 2 Amplifier and racks delivered fro	Wed 31/08/16	Wed 31/08/16
433	RF System #2 Delivered to RAL	Wed 31/08/16	Wed 31/08/16
441	4616 RF Amplifier 2 ready for electrical commi	Thu 06/10/16	Thu 06/10/16
478	RF cavity rolling platforms installation complete	Thu 13/10/16	Thu 13/10/16
482	AFC #1 rolling platform installation complete	Tue 08/11/16	Tue 25/10/16
457	TH116 RF Amplifier 2 ready for electrical comi	Mon 07/11/16	Mon 07/11/16
486	AFC #2 rolling platform installation complete	Fri 02/12/16	Fri 18/11/16
535	Off line cavity testing system 1 complete	Fri 18/11/16	Fri 18/11/16
489	Spectrometer Solenoid base plate installation complete	Wed 14/12/16	Wed 30/11/16
490	Base Plate & rolling platform work complete	Wed 14/12/16	Wed 30/11/16
493	Installation of PRY starts	Wed 30/11/16	Wed 30/11/16
499	South side SS return yoke installation complete	Tue 03/01/17	Mon 19/12/16
500	South PRY Installation complete	Tue 03/01/17	Mon 19/12/16
542	Off line cavity testing system 2 complete	Wed 25/01/17	Wed 25/01/17
544	Installation of the RF Cavities & Chambers starts	Wed 25/01/17	Wed 25/01/17
507	North side SS return yoke installation complete	Thu 02/02/17	Fri 17/02/17
508	North Side PRY Installation complete	Thu 02/02/17	Fri 17/02/17
460	RF System #1 and #2 - Amplifier 4616 & TH11	Fri 17/02/17	Fri 17/02/17
548	LLRF Test complete	Mon 27/02/17	Fri 03/03/17
551	HPRF Testing without B Field complete	Mon 27/03/17	Fri 31/03/17
559	MDIC installation complete	Mon 27/03/17	Fri 31/03/17
564	RF cavity testing with B field complete	Wed 03/05/17	Tue 09/05/17
565	Combined magnet and operational tests complete	Wed 03/05/17	Tue 09/05/17
567	End of MDIC data taking	Fri 30/03/18	Fri 30/03/18

Figure 1: Milestone waterfall plot for the completion of the MICE project including the integration of Step IV, Step IV data taking and the implementation of the configuration necessary to demonstrate ionization cooling. The solid red diamonds indicate the milestone dates in the baseline schedule defined in November 2014. The solid green circles indicate the projected milestone-completion date at April 2015. A "tick" in the box close to the left margin indicates a task that is complete. The milestones that have been circled in green or red are discussed in the text.

Since the November 2015 Resource Loaded Schedule Review (RLSR) the project team has worked to:

- Ensure that the integration of Step IV is completed on schedule;
- Expedite the commissioning and operation of the experiment;
- Finalise the details of the cooling-demonstration configuration; and
- Ensure that engineering resources are directed effectively to allow the timely release for manufacture of the long-lead-time components of the cooling demonstration.

To date, the project is being executed essentially on the baseline schedule defined at the November 2014 RLSR.

This is indicated in figure 1 which shows a waterfall plot of the milestones to the completion of Step IV and the implementation of the ionization-cooling demonstration. In line with the rebaselined schedule, the plot shows Step IV completion in June 2015 and the completion of the ionization-cooling-demonstration configuration by summer 2017.

The two milestones circled in green in figure 1 relate to the completion of the "Run Control based on the beam line and the detectors" and the completion of the state machines for the spectrometer solenoids and the focus-coil module. Run control for the MICE Muon Beam is complete and the preparation of the detector state machine is well advanced. The state machines for the spectrometer-solenoid and focus-coil magnets were developed to allow the acceptance-test programmes to be carried out. As a result the state machines for these devices are mature. The modifications to the "stand-alone" systems that are required to allow the magnets to be operated as part of the MICE channel will be completed in time for the initial commissioning of the devices on the beamline.

The milestone circled in red relates to the delivery to RAL of the two single-cell cavity modules. As described in section 3.3, the detailed design of these modules has now been completed. The work required to complete these modules is larger than was anticipated at the November 2014 review and causes a delay in the delivery of the modules to the laboratory.

Good progress has been made in commissioning the experiment. The full read-out chain, which takes data from the front-end boards to the batch reconstruction processors on the GRID, was exercised in a "mock-data" run without beam on the 21^{st} January 2015. A rolling programme of improvement has been established such that the MICE Muon Beam (MMB) and the instrumentation as far as TOF1 was commissioned and used to take data during the weekends of the 21^{st} and 28^{th} March 2015. These data have been used to make a first calibration of TOF0 and TOF1 and to rehearse the analysis that will be required to optimise the MMB for Step IV. Good progress has also been made in commissioning the tracker readout. The opportunity to operate the experiment during the weekends in April 2015 will be exploited to commission TOF2, KL and EMR with beam and to take the data required to optimise the MMB for Step IV.

This document presents an overview of the schedule, the cost to complete and the risks that have been identified within the project. The information has been prepared for the Resource Loaded Schedule Review that will take place at the Rutherford Appleton Laboratory (RAL) on the 16^{th} of April 2015. Detailed information can be found via the link on the page the collaboration has prepared at:
`http://micewww.pp.rl.ac.uk/projects/mipo-doc/wiki`

2.1 Evolution of tracking milestones

The evolution of the tracking-milestone dates is presented in table 1 and on the project dashboard `http://micewww.pp.rl.ac.uk/dashboard/`. Milestones with Ids 1 to 4 are complete. As reported at the November 2014 RLSR, substantial delays had been incurred in the delivery of the PRY plate material to the manufacturer. Release of contingency held by the US project allowed the machining of the plates to be carried out in parallel by four sub-contractors. This, together with the decision to ship the first set of PRY-support legs early and to airship the plates that make up the south side of the PRY, reduced the delay to milestone Id 5 (North side yoke material delivered) to just over one week. By adjusting the order in which installation tasks have been carried out and revising the north-side installation plan in line with experience gained in the installation of the south side, it has been possible to maintain the dates of the "Step IV installation complete" and "Combined magnet operational tests complete" milestones within approximately one week of the baseline date.

By advancing the procurement of material for the extension to the PRY required for the cooling demonstration and placing a contract with the manufacturer, it has been possible to bring forward the timetable for the delivery to RAL of the PRY extension required for the cooling demonstration (milestone Id 10). Since the November

2014 review, the detailed design of the single-cavity module has been carried out. This has led to a much greater understanding of the work content. As a result, the estimate of the time it will take to complete the module has increased; this is reflected in the delay to the completion of milestone Id 11. The projected completion of the decommissioning of Step IV (milestone Id 12) has been brought forward by revising the plan for the transition from Step IV to the cooling-demonstration configuration such that the upstream spectrometer solenoid will be left in position and kept cold. This reduces the work content and allows milestone Id 12 to be brought forward.

3 Schedule

3.1 Overview

An overview of the schedule for the completion of MICE is shown in Figure 2. The baseline schedule has been derived by including a time contingency of 35% on each task for which the UK project is responsible. Within the US, "in-project" contingency funds are retained to address contingencies without incurring additional delays. The tasks that make up the schedule (i.e. in both the UK and the US projects) have been analysed and classified into five classes from "High Level" risks (RISK1), which are assigned a period of 16 weeks for remedial work to be carried out should the risk be realised, to "Low Level" risks (RISK4) which are assigned a period of 2 weeks. Milestones, or risk-free routine tasks (RISK5), are not considered to carry a risk-mitigation period beyond the 35% time contingency. The critical-path analysis is performed on task-end dates that include time contingency ("baseline critical path") and risk ("including risk critical path"). The critical path does not necessarily pass through the same tasks in the baseline and including-risk critical paths. The additional delay to the end date of the task in the "Including risk" schedule is derived by adding the product of the raw risk-mitigation period (e.g. 16 weeks for tasks classified as RISK1) and the estimate of the probability that the risk will occur.

In the baseline schedule, the completion dates for Step IV and the cooling demonstration are June 2015 and April 2017 respectively; i.e. the completion dates have changed very little since the November 2014 review. The Step IV construction-complete date that is derived from the risk analysis is 26^{th} June 2015, while including the risk analysis, the construction-complete date for the final MICE Step is August 2017; these dates are also essentially unchanged since the November 2014 review. A key assumption for the deployment of the cooling demonstration is the need to terminate Step IV running in early June 2016. At present, an ISIS run is anticipated in the June to July 2016 time-frame which would serve as critical contingency for Step IV operations. Alternatives to the present staging plan are being explored which could enable the use of the anticipated run while not significantly impacting the start of the cooling demonstration.

Table 2 shows the interface points identified in the schedule analysis. The date at which a major item is required for installation is listed together with the date on which the schedule shows the item to be delivered to RAL. The "Required" date for each major component has been identified by a careful analysis of the installation schedule. Two status columns are shown to illustrate areas of change or completion since the last RLSR.

The hydrogen-system delivery date now accommodates the additional work required by the Hydrogen System Review that took place earlier this year. Impedance calculations were repeated and showed that the relief line would create too much back pressure within the absorber body. A larger diameter relief line will be fitted to alleviate this problem. The Review panel also asked for a destructive test of the absorber safety windows. This test will will require the support of specialist operators from ISIS. Discussions with ISIS are underway and the test is being scheduled into the test section of the hydrogen-plant plan. The completed relief line will be finished by the delivery date quoted in the table. At this point the system will be fully operational and cool-down and vacuum tests can be carried out.

The Step IV completion date has slipped slightly due to the timetable for ISIS operation and MICE construc-

Table 1: Evolution of the tracking milestone dates.

Id	Milestone	Baseline November 2014	April 2015	Comment
Step IV				
1	Compressors ready for cooling channel tests	29th January 2015	Complete	
2	Rack Room Complete	2nd February 2015	Complete	
3	South side yoke material delivered	16th March 2015	Complete	
4	South side return yoke installation complete	1st April 2015	9th April 2015	See section 3.2.
5	North side yoke material delivered	28th April 2015	8th May 2015	Surface shipment.
6	North side return yoke installation complete	14th May 2015	19th May 2015	South-side experience used to optimise installation.
7	MICE Step IV installation complete	2nd June 2015	9th June 2015	Revised installation plan to recover some lost time.
8	Combined magnet operational tests complete	11th August 2015	18th August 2015	Consequence of delayed start.
9	End of Step IV Data taking	1st June 2016		
Cooling demonstration				
10	Partial Return Yoke materials arrive at RAL	10th May 2016	12th April 2016	Material procurement underway. Contract placed with manufacturer.
11	RF Cavities arrive at RAL	18th May 2016	16th June 2016	Detailed design has yielded better understanding of work content.
12	Step IV De-Commissioning complete	22nd July 2016	8th July 2016	Plan to keep u/s solenoid cold and in position has reduces required work.
13	RF Amplifier delivered	31st August 2016		
14	RF Amplifier 1 ready for electrical commissioning	6th October 2016		
15	RF Amplifier 2 ready for electrical commissioning	7th November 2016		
16	Installation of PRY South starts	14th December 2016	30th November 2016	Revised reconfiguration programme.
17	Installation of the RF Cavities and Chambers starts	19th January 2017	25th January 2017	Delay due to introduction of offline testing of cavities in MICE Hall.
18	Installation of North PRY complete	1st February 2017	17th February 2017	Consequence of delay to Id 17.
19	Cooling Demonstration construction complete	24th March 2017	31st March 2017	Consequence of delay to Id 18.
20	Cooling Demonstration commissioning complete	2nd May 2017	9th May 2017	Consequence of delay to Id 19.
21	End of data taking in the cooling-demonstration configuration	31st March 2018		

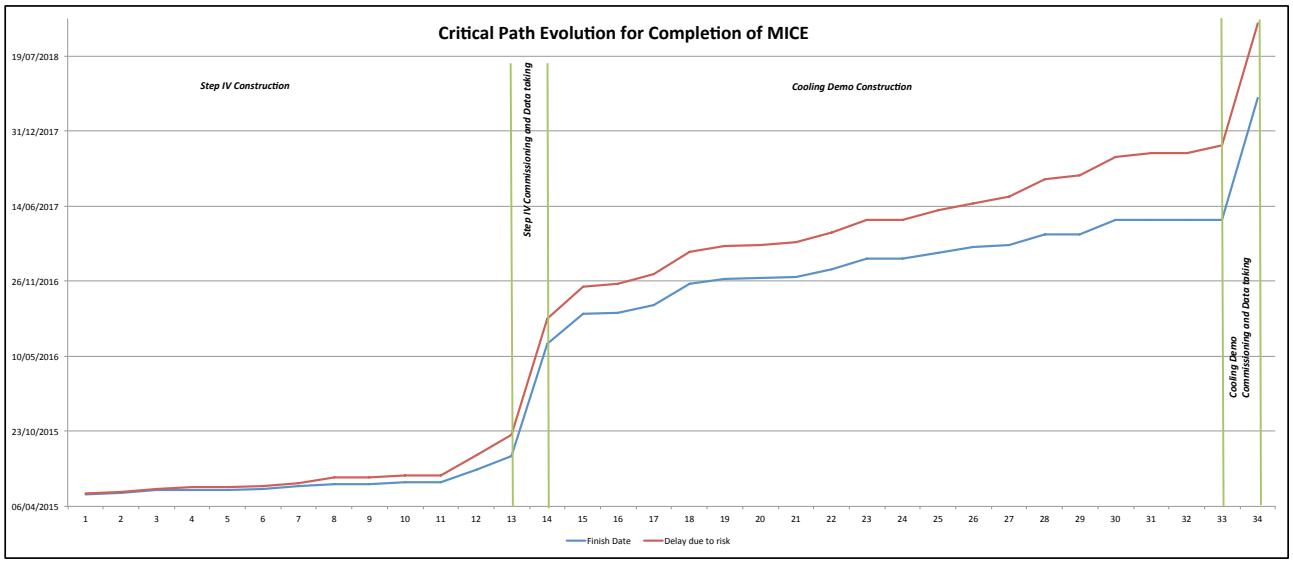


Figure 2: Critical path for the construction of the MICE experiment. The critical path that arises from the analysis of the schedule including the risk analysis described in the text is shown as the red line. The baseline critical path is shown as the blue line. The various critical paths do not necessarily pass through the same tasks as re-scheduling has been performed to mitigate and manage the delays that are incurred should risks be realised. The data taking periods for both the Step IV and cooling demonstration are shown.

Table 2: Interface points identified in the MICE baseline-schedule analysis. The dates associated with the interface points at November 2014 are also shown.

	Nov-14 Rebaselined		Apr-15	
Description	**Delivered**	**Required**	**Delivered**	**Required**
Step IV				
Liquid Hydrogen A	09-Feb-15	04-Mar-15	15-May-15	19-May-15
Step IV integration complete	02-Jun-15	17-Mar-15	09-Jun-15	02-Jun-15
Cooling Demonstration				
RF Cavities and associated chambers	18-May-16	01-Nov-16	16-Jun-16	23-Sep-16
South PRY Plates	10-May-16	19-Dec-16	12-Apr-16	14-Dec-16
North PRY Plates	10-May-16	10-Jan-17	12-Apr-16	10-Jan-17
Cooling Demonstration integration complete	24-Mar-17		31-Mar-16	

Table 3: Tasks that lie on the critical path for the completion of MICE. The Finish Date is the date the task is scheduled to complete in the re-baselined schedule (see text). The Risk Level, Risk Impact, Risk Level Duration and Probability are also given. The column "Delay due to risk" reports the date on which the task is projected to end taking into account the risk level and the probability of occurrence.

WBS	Name	Finish Date	Risks_Level	Risk_Impact	Risk Level Duration	Probability	Delay due to risk	Sequencial Delay	
3.1.3	North side yoke frame steelwork delivered	08/05/2015	(RISK)-(R4)	Contractor late delivery	10	0.25	10/05/2015	2.5	
4.2.1.4.4	Install frame legs (inc drilling plates)	11/05/2015					13/05/2015	2.5	
4.2.1.5	Fit North side yoke plates	19/05/2015					21/05/2015	2.5	
4.2.1.6	North side return yoke installation complete	19/05/2015	(RISK)-(R4)	Installation time extension	10	0.5	26/05/2015	7.5	
4.2.5.9.1	North side PRY in place by Feb 2015	19/05/2015					26/05/2015	7.5	
4.2.5.9.2	Cryostat stands - North side in place	22/05/2015					29/05/2015	7.5	
4.2.5.9.3	Move North side cryostats to hall and place in position	29/05/2015					05/06/2015	7.5	
4.2.5.10.3	Reform and connect external waveguides to fit from PP to Cryostat - After North PRY installation	04/06/2015	(RISK)-(R3)		20	0.5	21/06/2015	17.5	
4.2.5.10.4	Errect trellis to support external waveguides - After North PRY installation	05/06/2015					22/06/2015	17.5	
4.2.6	Re-install TOF2, KL, EMR	09/06/2015					26/06/2015	17.5	
4.2.7	MICE step IV installation complete	09/06/2015					26/06/2015	17.5	Step IV
5.2	Spectrometer Solenoid preparation for lattice operation	14/07/2015	(RISK)-(R2)	Items found to be non operational in field ramping	40	0.5	20/08/2015	37.5	
5.3	Combined magnet operation	18/08/2015	(RISK)-(R2)	Extended period for training all magnets together - delay stepIV	40	0.5	14/10/2015	57.5	
5.6	End of STEP IV Operations	13/06/2016	(RISK)-(R3)	Additional data runs required to complete matrix	20	0.5	19/08/2016	67.5	
6.3.1.1.1.2.2.1	RF System 2 Amplifier and racks delivered from DL	31/08/2016	(RISK)-(R4)	Late delivery	10	0.5	11/11/2016	72.5	
6.9.2.3	Make up all services connections	02/09/2016	(RISK)-(R4)	Additional tooling required	10	0.5	18/11/2016	77.5	
6.9.2.4	Pump down cavity	23/09/2016	(RISK)-(R4)	Additional pumping required	10	0.5	14/12/2016	82.5	
6.9.2.5	cavity testing sytem 1	18/11/2016	(RISK)-(R3)	Additional testing period required	20	0.25	13/02/2017	87.5	
6.9.3.1	Install cavity 2 in MICE hall adjacent to wall	01/12/2016					26/02/2017	87.5	
6.9.3.2	Install coax to cavity	05/12/2016					02/03/2017	87.5	
6.9.3.3	Make up all services connections	07/12/2016	(RISK)-(R4)	Additional tooling required	10	0.5	09/03/2017	92.5	
6.9.3.4	Pump down cavity	28/12/2016	(RISK)-(R4)	Additional pumping required	10	0.5	04/04/2017	97.5	
6.9.3.5	cavity testing sytem 2	25/01/2017	(RISK)-(R3)	Additional testing period required	20	0.25	07/05/2017	102.5	
6.9.4.1	Installation of the RF Cavities & Chambers starts	25/01/2017					07/05/2017	102.5	
6.9.4.2	Place online and couple to magnets	10/02/2017	(RISK)-(R2)	Extended off line testing of RF cavities	40	0.25	02/06/2017	112.5	
6.9.4.3	Vac Pump cooling channel	24/02/2017	(RISK)-(R4)	Pump and bake needs additional time	10	0.5	21/06/2017	117.5	
6.9.4.4	LLRF Tests	03/03/2017	(RISK)-(R3)	Additional testing time required	20	0.5	08/07/2017	127.5	
6.15	MDIC installation complete	31/03/2017	(RISK)-(R2)	Delay due to currently non-dritical items reaching critical path	40	0.5	25/08/2017	147.5	Reconfiguration
6.10.1	HPRF tests	31/03/2017	(RISK)-(R3)	Additional testing time required	20	0.5	04/09/2017	157.5	
6.16.1	Cooling Channel magnet Commissioning	09/05/2017	(RISK)-(R2)	3 of the 4 magnets have been commisioning together in Step IV	40	0.25	23/10/2017	167.5	
6.16.2.1	Test and condition cavities, with B field, 1MW	09/05/2017	(RISK)-(R2)	Additional testing time required - offline testing	40	0.25	02/11/2017	177.5	
6.16.2.2	RF cavity testing with B field complete	09/05/2017					02/11/2017	177.5	
6.17	Combined magnet and operational tests complete	09/05/2017	(RISK)-(R2)	Delay due to currently non-critical items reaching critical path	40	0.5	22/11/2017	197.5	
6.18	Cooling Demonstration Data taking Period	30/03/2018					13/10/2018	197.5	Cooling demo

tion contingencies. The "Required" date has been changed to bring it in line with the start of the next ISIS User Run. The completion of the Step IV channel will allow the commissioning of the magnetic channel to begin in parallel with the commissioning and operation of the all of the instrumentation.

As noted above, both the single-cavity module fabrication plan and the RF-system test and commissioning plans have been revised. This has led to changes in the date at which the RF infrastructure is required and the date when the RF-module "hook-up" will take place.

Finally, the required and delivered dates for the cooling-demonstration PRY have been revised in the light of changes to the integration plans described in section 3.3.

3.2 Step IV

The remaining tasks on the critical path to the completion of Step IV are shown in table 3 (section marked "Step IV"). The installation of the north side of the PRY and the cryogenic and electrical services to the experiment make up the critical path. The north-side PRY was assembled at the manufacturer (Keller Engineering, New York) prior to shipment. Experience gained in the installation of the south-side PRY is directly applicable to the installation of the north-side. The project team is therefore optimistic that the north-side installation will go smoothly. The completion of the services places pressure on the Hall engineering (fitting) and electrical teams. The Project Manager, Project Engineer and Hall Manager are actively engaged in discussions within the Laboratory with a view to ensuring that appropriate staffing arrangements are in place to deliver Step IV on schedule.

At the time of the November 2014 review, a significant contingency issue was in progress where the delivery of the US-provided PRY materials was delayed due to a production delay in Japan, severe weather conditions in both Japan and the US, and a work slow-down at the Port of Los Angeles. The US project team released contingency funds to expedite the fabrication in the US as well as delivery to the UK. Furthermore, a re-optimisation of the installation plan to enable simpler deployment in the UK was executed. These actions have mitigated the impact of the delays to the scale of a week.

3.3 Cooling demonstration

Table 3 lists the tasks on the critical path to the completion of the cooling demonstration configuration (sections marked "Reconfiguration" and "Cooling demonstration"). The critical path is shown in figure 2.

Analysis of the schedule shows that the main driver of the critical path remains the installation and commissioning of the two RF systems. In consequence, the requirement to deliver first results from the cooling demonstration before the end of US fiscal year 2016 places a premium on the timely commissioning of the full RF system. Therefore, the project team is developing plans to bring forward the commissioning of the amplifiers into the cavities, including the low-level RF (LLRF) and feedback systems, in the MICE Hall. To reap the maximum benefit from this activity some installation work must be carried out in parallel to Step IV operations. This work will put pressure on the installation team and will require careful planning. In addition, it will be essential that the commissioning of the second RF amplifier at the DL as well as the development of the LLRF and controls systems proceeds as planned in the baseline schedule and that deployment and commissioning of the full system in the MICE Hall is expedited. This will require the presence at DL, and then at RAL, of the requisite, expert, RF-engineering resource. The project team is aware of the pressures on the ASTeC RF engineering team and is in discussion with ASTeC management with a view to ensuring that the necessary effort is available when required. The project team recognises that it may be necessary also to seek support from other laboratories and institutions.

To allow the start of procurement of long lead-time items such as the extension to the PRY and the single-cavity vacuum vessels, the project team has taken care to define responsibilities, envelopes and interfaces. These specifications will allow the US engineering personnel to complete the detailed designs of critical components while the engineering resources in the UK are directed to completing the integration of Step IV.

4 Cost

The construction project is broken down into work-packages for which the UK is responsible and work packages for which the US is responsible. The financial reports presented below reflect these lines of responsibility. The UK and US budget summary is presented figure 3. For both the UK and the US, the budgets include support for the experimental collaboration. The cost of ISIS Operations Group staff effort supporting MICE operations is also included in the UK budget projections. The figures do not take account of "income" that arises from the Common Fund and a number of European Commission awards.

5 Risk

The top level risks identified within the tasks that make up the UK contributions to the project risk register are presented in table 4. The top level risks identified within the tasks that make up the US contributions are presented in table 5.

Insufficient staff for efficient completion of the project is a persistent risk but mitigation plans have been discussed and are being put into place. Since the project last reported to the RLSR panel, the US project team has retired "Risk 3–Step IV Partial Return Yoke Magnetic Shielding Fit-up". The remaining total weighted risk within the US project is 130 working days and approximately $537k.

The UK is moving toward the preparation of a proposal to raise the resources required to complete, and then to operate, the cooling demonstration. The MICE-UK project has many University partners that employ staff on fixed term contracts who are supported through grants awarded by the STFC. UK employment legislation requires employers to give employees six months warning of termination of employment. Such warnings will

	FY 14/15	FY 15/16	FY 16/17	FY 17/18
UK (£k)	**3100**	**3277**	**3249**	**2730**
Cumulative UK (£k)	**3100**	**6377**	**9626**	**12356**
UK ($k)	*4604*	*4866*	*4825*	*4054*
Cumulative UK ($k)	*4604*	*9470*	*14295*	*18349*
US ($k)	***8484***	***6835***	***3731***	***1135***
Cumulative US ($k)	**8484**	**15319**	**19050**	**20185**
US (£k)	*5713*	*4603*	*2512*	*764*
Cumulative US (£k)	*5713*	*10316*	*12828*	*13593*

Exchange rates	
UK - US	1.485
US- UK	0.673

UK values include University staff and Risk mitigation
US values include Risk mitigation

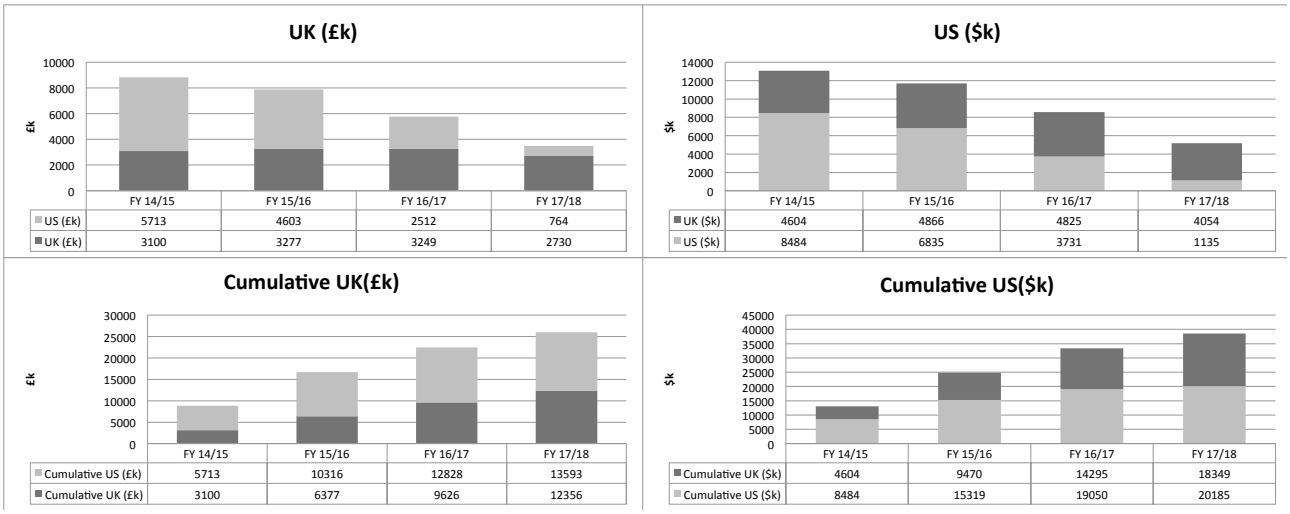


Figure 3: Top panel: Roll-up of the annual cost of the UK and the US of the MICE project to Step VI. The offset in the cells of the table are intended to indicate the staggered start to the financial year in the UK relative to the US. To aid in comparison, the cost to the UK recorded in £ k is converted to $k using the exchange rates presented in the box to the right of the main table. Equivalently, the cost to the US recorded in $k is converted to £ k. In the case of the UK project, the costs include the cost of the operations and analysis work packages. Middle panel: UK and US spending profile for the completion of the MICE project. The dark shaded bars represent the cost to the UK while the cost to the US are shown as the light shaded bars. The left panel shows the spend in £ k while the spend is presented in $k in the right panel. In the case of the UK project, the costs include the cost of the operations and analysis work package. Bottom panel: UK and US cumulative spending profile for the completion of the MICE project. The dark shaded bars represent the cumulative cost to the UK while the cumulative cost to the US are shown as the light shaded bars. The left panel shows the cumulative spend in £ k while the cumulative spend is presented in $k in the right panel.

Table 4: Top level risks for the sub-projects for which the UK is responsible. Recently retired risks are shaded in grey.

ID	Risk Description	Potential impact on project	Risk score			Ownership	Proposed Action	Post-action risk score			Comment / Conclusion	Cost of mitigation		Likely retirement of requirement
			L	I	LxI			L	I	LxI		Staff years	Non-staff (£k)	
MICE 3	Magnetic field effecting operation of electrical equipment relating to the continued operation of the cooling channel magnet systems and detectors.	Inability to operate the cooling channel	5	5	25	MICE - UK / MAP	Installation of a partial return yoke has mitigated the major risk. Movement of the control and power supply equipment to a dedicated room outside of the magnetic field.	1	4	4	Much work has been completed and provision of additional rack room has enabled the majority of the sensitive equipment to be moved away from the hall. The PRY has not yet been installed and so has not been tested, the residual risk still applies. Significant investment from UK and US to mitigate risk has been expended. Non staff risk persists in the event of additional material being required.	0.2	100	End of project
MICE 4	Extended period of re-training for the lattice of magnets for Step IV - SS1/AFC/SS2.	Timescales for the training period, cost of the amount of LHe required to carry out the training the availability of the Lhe. Expert personnel required to be available for magnet operations over a protracted period of time.	4	5	20	MICE-UK / MAP	Discussions with BOC (or supplier) to agree delivery timescales and availability during heavy use periods. Magnet integration task force to define commissioning method to keep schedule and cost to a minimum.	4	4	16	Each re-cool and fill of the Spectrometer Solenoid can take upto 500l LHe, AFC remebers it's training. Each full lattice quench could cost in the region of £7K. Initial investigations with BOC show that the predicted amount of LHe will be available during the commissioning period.	1	100	End step IV
MICE 7	VAT payable on the delivery of all equipment imported from the non-UK collaborators	Budgetary constraints resulting in reduced work force and installation activities being carried out.	4	5	20	MICE UK	Escalation of the issue to the legal department of the STFC	2	4	8	At the moment it is unknown if the cost can be mitigated. STFC to bear the cost burden, 20% of the value of each item imported. With the shipping of the RFCC removed very large amounts are no longer possible.	0.1	100	Impacts final step
MICE 8	Resourcing issues from the STFC and national labs	inability to complete significant sections of work on agreed time or cost scales.	4	5	20	MICE - UK / MAP	Escalation of the issue to the STFC and DOE.	2	4	8	Project scope has changed leading to a different labour profile required to complete the project.	2		Impacts Step IV and all other steps.
MICE 9	Senior management of the MAP collaboration / MICE-US changes.	Leadership and direction of the construction team unfocused.	4	5	20	MAP	Discussion with senior MAP and MICE management	1	4	4	The critical actions for design and precurement are underway. Oversight to completion required.			End of Cooling Demo
MICE 10	Late delivery of the PRY and / or Cavities for Cooling Demo after advanced scheduling.	Standing army cost for period after hall preparations are complete and receipt of the PRY materials / Cavities	3	5	15	MICE-UK / MAP	Interaction with the MICE-US construction team.	1	5	5	Cost will need to be borne as releasing and then re-forming the team will be difficult with an unknown timescale. From the MAP schedule analysis the PRY and RF Modules will arrive well in advance of the requirement	£90k / Month		End of Cooling Demo
MICE 11	US budget cuts changing magnet manufacture, commissioning and delivery	Halting project installation and subsequent data taking. Loss of key personnel from the project. Inability to continue with full cooling program.	4	5	20	MAP	Discussion with senior STFC management.	2	4	8	DOE has assigned a budget profile of 9 / 6 / 3 for the next 3 US finacial years.			Impacts Step IV and Cooling Demo
MICE 12	RF Power systems are not available for cavity testing	The critical path items following the RF system installation will extend in time. Testing of the cavities with and without B field. Commissioning of the channel and gaining data for the final step	4	5	20	MICE UK	Discussions with UK senior management to gain sufficient staff to carry out the work required on the RF systems and controls. Additional technical staff from collaborating institutes for installation work.	2	5	10	Successful completion of the RF power system installation will result in delays leading to the US collaborators being unable to contribute to the data taking period for Cooling Demo. Further interaction with STFC senior management to gain sufficient staffing for RF completion.	2	75	End of Cooling Demo
MICE 14	Loss of key project and operational staff	Continuation of the funding to allow re-newal of University contracts	3	5	15	MICE UK	Discussions with The STFC senoir staff. Preparation of funding profiles, plans and staffing to completion of the Cooling Demo	1	5	5	Much of the key aspects of the operation of the Step IV stage of the project are carried out by University staff. Gaining replaceable resource from the national labs would be difficult	10	50 (LTA / Travel)	Novemeber 2015
MICE 15	Restricted entry to the UK for key project and operational staff	Visa and invitation burocratic difficulites procluding non-EU engineers and scientific staff from entering the UK to carry out work at the STFC RAL.	3	5	15	MCIE UK	Arragements with the imigration department of the SBS and highlight / escelating difficulties to the STFC senoir staff	2	5	10	Much of the key aspects of the operation of the Step IV stage of the project are carried out by University staff. Gaining replaceable resource from the national labs would be difficult	10	50 (LTA / Travel)	End of the Cooling Demo
MICE 16	Failure of a Focus Coil Magnet	Internal cold mass or associated equipment deep within the assembly. LTS leads.	2	5	10	MICE UK	Follow all specific operational aspects as defined by the experts for the superconducting magnet	2	5	10	Transportation, dis-assembly, investigation, fix and reassembly would be extreamly costly and extensive with regard to schedule. A spare magnet would be out of the reach of the project. A repair intervention would be 12 months including testing and commissioning and manufacture of new magnet system, test and commission around 2 years.	3	500	End of the Cooling Demo
MICE 17	Failure of a Spectrometer Solenoid Magnet	Internal cold mass or associated equipment deep within the assembly. LTS leads.	2	5	10	MAP	Follow all specific operational aspects as defined by the experts for the superconducting magnet	2	5	10	Any repair work required would be outside the budgetry constraint. Timescale would be extensive and expert personnel and workshop area will not be available in a short time frame.	3	500	End of the Cooling Demo
MICE 18	Inability to procure Lithium Hydride for secondary absorbers	Reduction in scientific output and resulting cooling effect.	3	5	15	MICE-UK / MAP	Design and analysis for the use of plastic in the bore of the Spectrometer Solenoid will give a similar, but slightly lower value for the cooling effect. Investigations of a hybrid design utilising plastic and LiH.	1	5	5	The design for the placement of the secondary absorber at the radiation shutter placement is underway. The changes to the design of the Helium window 'Top hat' will be small. Any hybrid design will require design investigations.	0.2	30	End of the Cooling Demo

Table 5: Top level risks for the sub-projects for which the US is responsible. Since the prior RLSR-report in November 2014, Risk 3–Step IV Partial Return Yoke Magnetic Shielding Fit-up–has been retired. The remaining total weighted risk is 130 working days and approximately $537k.

ID	MAP WBS	Risk Description	Potential Impact on Project	Risk Score L	I	LxI	Ownership	Proposed Action	Post-Action L	I	LxI	Comment/Conclusion	Estimated Cost of Mitigation SWF (K$)	M&S (K$)	OH (K$)	Total (K$)	Estimated Mitigation Duration (Working Days)	Estimated Mitigation Probability (%)	Weighted Costs (K$)	Weighted Durations (Working Days)	Targeted Retirement Date	Status (Active or Retired)
1	3.2.9.11	Additional magnetic issues found with design and surface treatment of MICE 201 MHz Couplers. Note, original prototype cavity showed no adverse B-field impact, so this risk is restricted to the coupler design.	Delay of readiness of MICE Final Step production couplders and full RF module.	2	4	8	MAP	Analyze adverse behavior, evaluate and implement coupler design and surface treatment changes required.	1	3	3	Given that the original prototype tested to ~10MV/m in Lab G magnet field, the likelihood of having an effect that adversely impacts the minimal operating configuration is considered very modest since significant design improvements to the coupler/window design have been implemented and fully simulated.	50	25	55.75	130.8	80	30%	39.23	24	4/16/2015	Active
2	5.2.1.6.1.9	RF Module #1 & #2 Assembly	Likely impact is a months-scale delay due to module fit-up issues	2	2	4	MAP	Execute design and/or fabrication corrections at LBNL.	1	1	1	Design now directly derives from the SCTS prototype so all assembly issues fully tested.	25	50	36.5	111.5	40	30%	33.45	12	3/29/2017	Active
3	5.4.1.1.1.27	Step IV Partial Yoke Fit-Up Completion	Likely impact is a 1-2 month delay in PRY delivery	3	2	6	MAP	Expedite design and/or fabrication corrections at vendor effort and and/or expedite delivery methods (e.g., air-ship parts)	1	1	1	Procurement delays and external circumstances (e.g., Japanese typhoon resulting in delayed shipment) have exercised all planned schedule contingency. Remaining potential exists for assembly issues to be identified at vendor.	10	100	33	143	30	50%	71.50	15	2/16/2015	Retired
4	5.4.1.2.2.6	MICE Final Step Magnetic Shielding 2 Week Review Window	Delay in constuction and delivery of MICE Final Step shielding.	3	1	3	MAP	Update design to satisfy requirements of MICE Step 3pi/2 operating configuration and then launch fabrication. Impact would be of order 1 month of re-engineering.	1	2	2	Minimal impact anticipated in Step 3pi/2 construction schedule due to significant slack in shielding construction schedule.	50	0	50	100	20	50%	50.00	10	4/14/2015	Active
5	5.4.1.2.3.8	Final Step Partial Yoke Fit-Up Completion	Likely impact is a multi-month delay due to need to re-machine large parts.	1	2	2	MAP	Execute design and/or fabrication corrections at vendor.	1	2	2		25	50	36.5	111.5	40	10%	11.15	4	3/29/2017	Active
6	5.6.2.1.3	RF Module #1 & #2 Integration Issues at RAL.	May require design changes or corrections. Potentially results in months-scale field engineering delays.	2	4	8	MAP	Correct all identified issues (eg, vacuum performance) in the field.	1	2	2	SCTS test in the MTA helps to define the necessary operation specifications and allow them to be dealt with in advance.	150	75	167.3	392.3	80	30%	117.68	24	3/29/2017	Active
7	5.6.2.2.3	Spectrometer Solenoid integration and commissioning issues at RAL.	Delay of MICE Step IV commissioning and experimental operations.	3	4	12	MAP	Assess failure and repair magnet (s). Likely delay of > 3 months in commissioning schedule.	1	3	3	Magnets have been fully tested in a range of configurations in the US. The principal concern is that damage might have occurred during shipping. However, shock sensors and monitoring did not indicate any shipping issues.	200	100	223	523	80	50%	261.50	40	8/3/2015	Active
8	5.6.2.3.3	MICE Step IV Partial Yoke Shielding Integration Issues at RAL.	Likely impact is a multi-month delay due to need to re-machine large parts.	1	4	4	MAP	Re-do integration engineering for partial yoke solution in MICE Hall.	1	3	3	Decision to do full fit-up of components prior to shipping to UK largely mitigates this risk.	25	50	36.5	111.5	80	10%	11.15	8	8/3/2015	Active
9	5.6.2.4.3	MICE Final Step Partial Yoke Shielding Integration Issues at RAL.	Likely impact is a multi-month delay due to need to re-machine large parts.	1	4	4	MAP	Re-do integration engineering for partial yoke solution in MICE Hall.	1	3	3	Decision to do full fit-up of components prior to shipping to UK largely mitigates this risk.	25	50	36.5	111.5	80	10%	11.15	8	3/29/2017	Active
												Totals for All Items (Active Risks Only)	550	400	642	1592			535.3	130		

therefore be issued in October 2015 unless the Universities receive additional resource to extend the period of employment. The risk to the project, should the excellent post-doctoral researchers on whom the project relies receive such letters, is that our young research staff will seek alternative employment outside MICE. The loss of expert staff at such a critical time would cause substantial damage to the ability of the collaboration to deliver the science programme that will, by that time, be underway. Further, recruitment of staff to replace the lost expertise would result in an extended period of re-training. The UK project team is in discussion with the STFC to identify mechanisms by which this eventuality can be avoided.

The project is moving toward an operational period during which there is a requirement to have collaboration members at the Laboratory to operate the experiment and to serve on shift. Many of the collaborators are not nationals of EU member states and will therefore require the papers necessary to enter the UK. Overly complicated bureaucratic processes could cause a shortfall in staffing for the operation of the experiment and lead to a reduction in the effective period of operation and a reduced exploitation of the valuable resource that MICE will represent.

References

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