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 April 2014 review of the project is given in the "Response to Feedback" that accompanies this submission [1].

2 Introduction

The MICE demonstration of ionization cooling will be carried out using the configuration sketched in Figure 1 [2]. To implement this configuration, two single-cavity modules are required in addition to the equipment that has already been constructed, commissioned and delivered to the Rutherford Appleton Laboratory. The configuration required for the demonstration of ionization cooling will be assembled following the completion of Step IV data taking in June 2016.

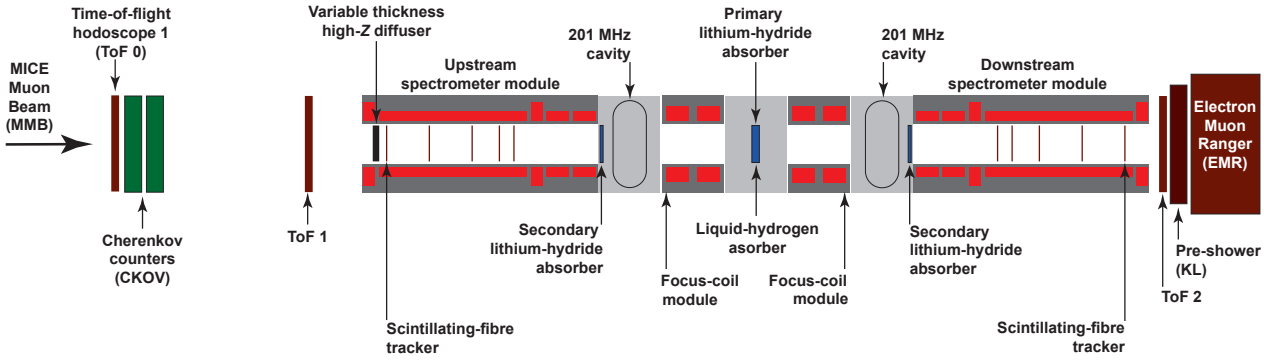
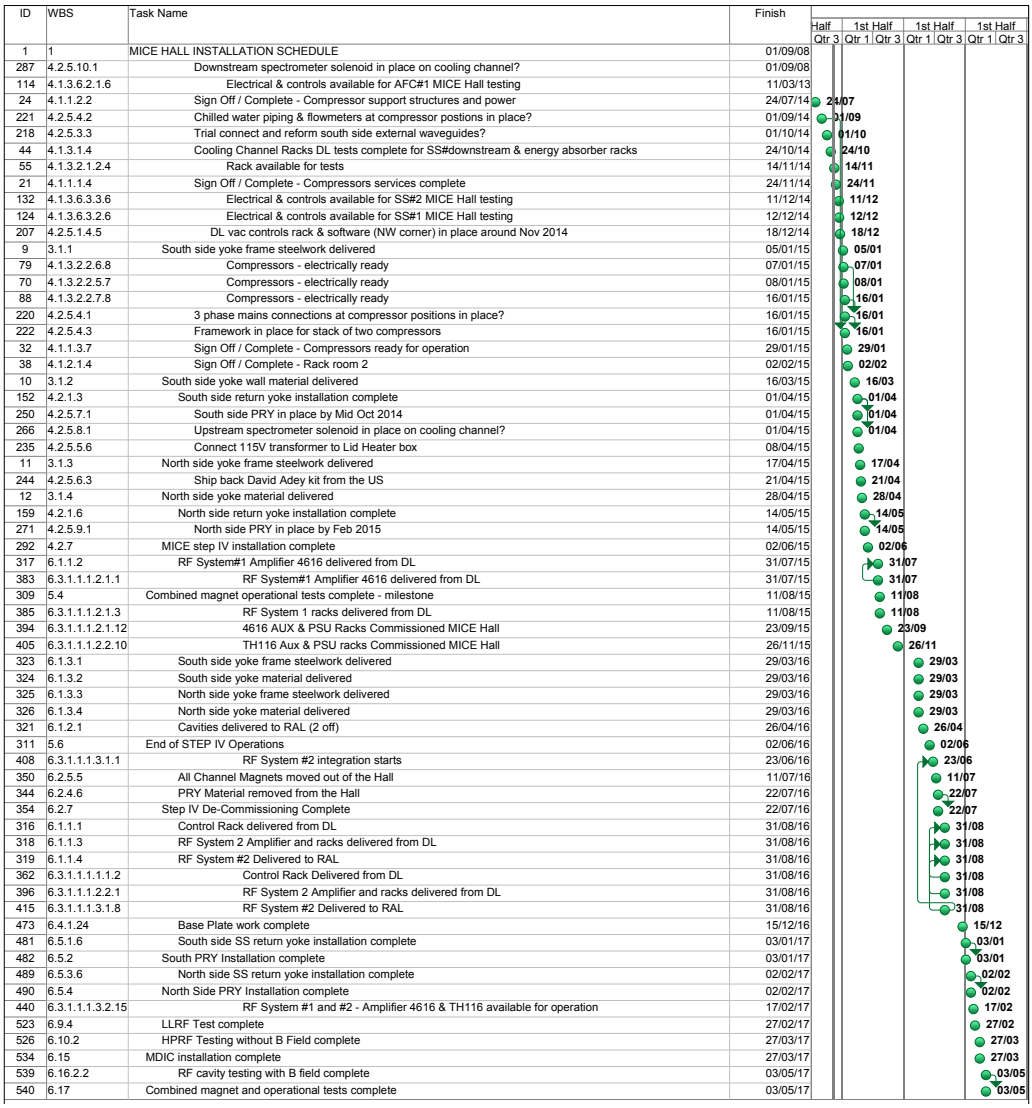


Figure 1: Schematic diagram of the configuration that will be used for the MICE demonstration of ionization cooling. Two single 201 MHz cavity modules and a focus-coil module will be added to the Step IV configuration. The central lithium-hydride absorber is sandwiched between the focus-coil and single-cavity modules. Two secondary lithium-hydride absorbers placed between the cavities and the spectrometer modules increase the cooling effect and protect the trackers from x-rays and dark-current electrons.

A single, resource-loaded, schedule that contains all activities required to complete the MICE project has been prepared. The date at which Step IV data taking ends and the decommissioning of the Step IV experiment starts has been determined by making the Step IV data-taking period as long as possible while preserving the completion of the ionization-cooling-demonstration configuration by May 2017. Figure 2 shows a waterfall plot of the milestones that must be passed to complete Step IV and to implement the MICE ionization-cooling demonstration. The waterfall plot shows Step IV completion in June 2015 and the completion of the configuration required to demonstrate ionization cooling by summer 2017.

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



ID	WBS	Task Name	Finish
1	1	MICE HALL INSTALLATION SCHEDULE	01/09/08
287	4.2.5.10.1	Downstream spectrometer solenoid in place on cooling channel?	01/09/08
114	4.1.3.6.2.1.6	Electrical & controls available for AFC#1 MICE Hall testing	11/03/13
24	4.1.1.2.2	Sign Off / Complete - Compressor support structures and power	24/07/14
221	4.2.5.4.2	Chilled water piping & flowmeters at compressor postions in place?	01/09/14
218	4.2.5.3.3	Trial connect and reform south side external waveguides?	01/10/14
44	4.1.3.1.4	Cooling Channel Racks DL tests complete for SS#downstream & energy absorber racks	24/10/14
55	4.1.3.2.1.2.4	Rack available for tests	14/11/14
21	4.1.1.1.4	Sign Off / Complete - Compressors services complete	24/11/14
132	4.1.3.6.3.3.6	Electrical & controls available for SS#2 MICE Hall testing	11/12/14
124	4.1.3.6.3.2.6	Electrical & controls available for SS#1 MICE Hall testing	12/12/14
207	4.2.5.1.4.5	DL vac controls rack & software (NW corner) in place around Nov 2014	18/12/14
9	3.1.1	South side yoke frame steelwork delivered	05/01/15
79	4.1.3.2.2.6.8	Compressors - electrically ready	07/01/15
70	4.1.3.2.2.5.7	Compressors - electrically ready	08/01/15
88	4.1.3.2.2.7.8	Compressors - electrically ready	16/01/15
220	4.2.5.4.1	3 phase mains connections at compressor positions in place?	16/01/15
222	4.2.5.4.3	Framework in place for stack of two compressors	16/01/15
32	4.1.1.3.7	Sign Off / Complete - Compressors ready for operation	29/01/15
38	4.1.2.1.4	Sign Off / Complete - Rack room 2	02/02/15
10	3.1.2	South side yoke wall material delivered	16/03/15
152	4.2.1.3	South side return yoke installation complete	01/04/15
250	4.2.5.7.1	South side PRY in place by Mid Oct 2014	01/04/15
266	4.2.5.8.1	Upstream spectrometer solenoid in place on cooling channel?	01/04/15
235	4.2.5.5.6	Connect 115V transformer to Lid Heater box	08/04/15
11	3.1.3	North side yoke frame steelwork delivered	17/04/15
244	4.2.5.6.3	Ship back David Adey kit from the US	21/04/15
12	3.1.4	North side yoke material delivered	28/04/15
159	4.2.1.6	North side return yoke installation complete	14/05/15
271	4.2.5.9.1	North side PRY in place by Feb 2015	14/05/15
292	4.2.7	MICE step IV installation complete	02/06/15
317	6.1.1.2	RF System#1 Amplifier 4616 delivered from DL	31/07/15
383	6.3.1.1.1.2.1.1	RF System#1 Amplifier 4616 delivered from DL	31/07/15
309	5.4	Combined magnet operational tests complete - milestone	11/08/15
385	6.3.1.1.1.2.1.3	RF System 1 racks delivered from DL	11/08/15
394	6.3.1.1.1.2.1.12	4616 AUX & PSU Racks Commissioned MICE Hall	23/09/15
405	6.3.1.1.1.2.2.10	TH116 Aux & PSU racks Commissioned MICE Hall	26/11/15
323	6.1.3.1	South side yoke frame steelwork delivered	29/03/16
324	6.1.3.2	South side yoke material delivered	29/03/16
325	6.1.3.3	North side yoke frame steelwork delivered	29/03/16
326	6.1.3.4	North side yoke material delivered	29/03/16
321	6.1.2.1	Cavities delivered to RAL (2 off)	26/04/16
311	5.6	End of STEP IV Operations	02/06/16
408	6.3.1.1.1.3.1.1	RF System #2 integration starts	23/06/16
350	6.2.5.5	All Channel Magnets moved out of the Hall	11/07/16
344	6.2.4.6	PRY Material removed from the Hall	22/07/16
354	6.2.7	Step IV De-Commissioning Complete	22/07/16
316	6.1.1.1	Control Rack delivered from DL	31/08/16
318	6.1.1.3	RF System 2 Amplifier and racks delivered from DL	31/08/16
319	6.1.1.4	RF System #2 Delivered to RAL	31/08/16
362	6.3.1.1.1.1.1.2	Control Rack Delivered from DL	31/08/16
396	6.3.1.1.1.2.2.1	RF System 2 Amplifier and racks delivered from DL	31/08/16
415	6.3.1.1.1.3.1.8	RF System #2 Delivered to RAL	31/08/16
473	6.4.1.24	Base Plate work complete	15/12/16
481	6.5.1.6	South side SS return yoke installation complete	03/01/17
482	6.5.2	South PRY Installation complete	03/01/17
489	6.5.3.6	North side SS return yoke installation complete	02/02/17
490	6.5.4	North Side PRY Installation complete	02/02/17
440	6.3.1.1.1.3.2.15	RF System #1 and #2 - Amplifier 4616 & TH116 available for operation	17/02/17
523	6.9.4	LLRF Test complete	27/02/17
526	6.10.2	HPRF Testing without B Field complete	27/03/17
534	6.15	MDIC installation complete	27/03/17
539	6.16.2.2	RF cavity testing with B field complete	03/05/17
540	6.17	Combined magnet and operational tests complete	03/05/17

Figure 2: 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.

that will take place at the Rutherford Appleton Laboratory (RAL) on the 24^{th} of November 2014. 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`

3 Schedule

An overview of the schedule for the completion of MICE is shown in Figure 3. 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 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

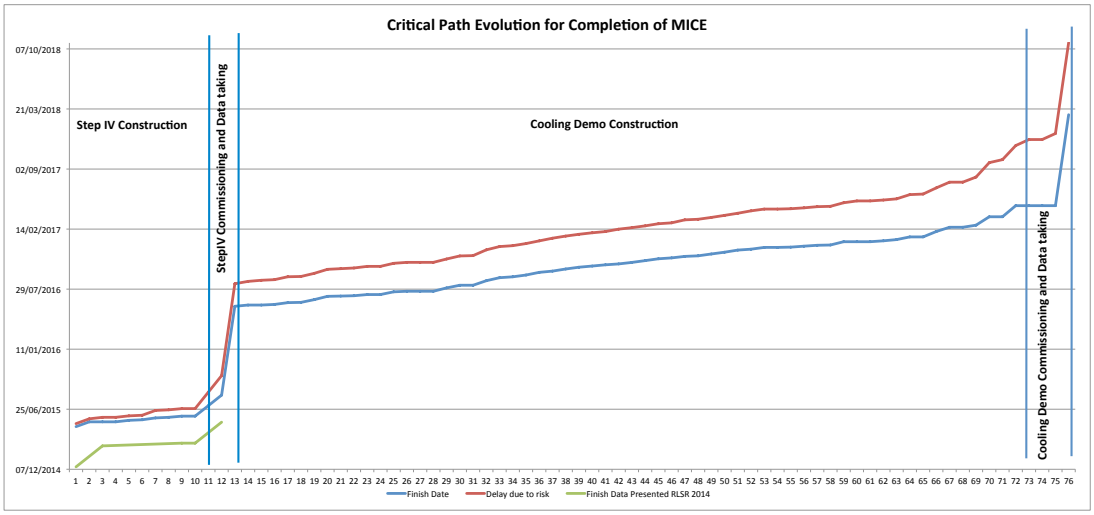


Figure 3: Critical path for the construction of the MICE experiment. The critical path that arises including the risk analysis described in the text is shown as the red line. The baseline critical path is shown as the blue line. The green line shows the critical path to Step IV presented at the April 2014 review. The various critical paths do not necessarily pass through the same tasks as re-scheduling has been performed to mitigate and manage the delays resulting from the late delivery of components of the PRY. The data taking periods for both the Step IV and Cooling Demonstration are shown.

which has been added to all tasks. "Baseline" refers to the schedule that results from the tasks with the 35% time-contingency added. In addition to the risk level, the probability that the risk will occur is estimated. 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. 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 baseline schedule shows Step IV integration complete in June 2015 and the completion of the configuration required to deliver the ionization-cooling demonstration late in April 2017. The Step IV completion date that is derived from the risk analysis is October 2015, while including the risk analysis, the completion date for the final MICE Step is December 2017. For comparison, the green line shows baseline critical path for the integration of Step IV that was presented at the April 2014 review.

Table 1 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.

3.1 Step IV

Over the reporting period the focus has been the delivery of Step IV and the development of the revised configuration by which ionization cooling will be demonstrated. All components of the partial return yoke (PRY) for Step IV have now been ordered. The schedule reflects the revised delivery dates for the components of the yoke above floor level. Delays in procurement have resulted in a slip of approximately three months in the delivery of these components. Risks associated with the various PRY-implementation tasks have been identified and

Table 1: Interface points identified in the MICE baseline-schedule analysis. The dates associated with the interface points at November 2014 are also shown.

	Nov-13		Apr-14		Nov-14	
Description	**Delivered**	**Required**	**Delivered**	**Required**	**Delivered**	**Required**
Step IV						
Spectrometer Solenoid 2 Upstream - Complete						
Spectrometer Solenoid 1 Downstream - Complete	08-May-14	10-Jan-14	16-May-14	19-May-14	16-May-14	19-May-14
Mapping equipment	03-Jan-14	10-Dec-13	15-May-14	02-Jun-14	15-May-14	02-Jun-14
Focus Coil 1	03-Oct-14	10-Dec-13	07-Aug-14	12-Nov-14	07-Aug-14	12-Nov-14
Liquid Hydrogen A	16-Apr-14	16-Apr-14	09-Feb-15	04-Mar-15	09-Feb-15	04-Mar-15
Step IV integration complete	30-Jan-15	29-Jan-15	04-Mar-15	17-Mar-15	02-Jun-15	17-Mar-15
Cooling Demonstration						
RF Cavities and associated chambers					24-Apr-16	01-Nov-16
South PRY Plates					29-Mar-16	26-Oct-16
North PRY Plates					29-Mar-16	10-Jan-17
Focus Coil 2						
Cooling Demonstration integration complete					27-Mar-17	*27-Mar-17*
Decision Points						
Magnetic Sheilding decision Step IV						

Table 2: Tasks that lie on the critical path for the completion of Step IV. The Finish Date is the date the task is scheduled to complete in the baseline 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. The baseline finish date reported at the last RLSR is presented in the column headed "Finish Dates Presented RLSR Apr 2014".

WBS	Name	Finish Date	Risks_Level	Risk_Impact	Risk Level Duration	Probability	Delay due to risk	Finish Dates Presented RLSR Apr 2014
3.1.4	North side yoke material delivered	28/04/2015	(RISK)-(R2)	Contractor late delivery	40	0.25	08/05/2015	15/12/2014
4.2.1.5	Fit North side yoke plates	14/05/2015					24/05/2015	
4.2.1.6	North side return yoke installation complete	14/05/2015	(RISK)-(R4)	Installation time extension	10	0.5	29/05/2015	23/02/2015
4.2.5.9.1	North side PRY in place by Feb 2015	14/05/2015					29/05/2015	
4.2.5.9.2	Cryostat stands - North side in place	19/05/2015					03/06/2015	
4.2.5.9.3	Move North side cryostats to hall and place in position	21/05/2015					05/06/2015	
4.2.5.10.3	Reform and connect external waveguides to fit from PP to Cryostat - After North PRY installation	27/05/2015	(RISK)-(R3)		20	0.5	21/06/2015	
4.2.5.10.4	Errect trellis to support external waveguides - After North PRY installation	29/05/2015					23/06/2015	
4.2.6	Re-install TOF2, KL, EMR	02/06/2015					27/06/2015	04/03/2015
4.2.7	MICE step IV installation complete	02/06/2015					27/06/2015	04/03/2015
5.2	Spectrometer Solenoid preparation for lattice operation	07/07/2015	(RISK)-(R2)	Items found to be non operational in field ramping	40	0.5	21/08/2015	
5.3	Combined magnet operation	11/08/2015	(RISK)-(R2)	Extended period for training all magnets together - delay stepIV	40	0.5	15/10/2015	13/05/2015

steps are being taken to expedite the installation of the yoke when the components arrive at the laboratory.

The tasks that lie on the baseline critical path for Step IV are shown in Table 2. Figure 4 presents the baseline critical path and the critical path including risk. For comparison, the baseline critical path presented at the April review is also shown. Work continues to mitigate the risks with particular attention being paid to tasks on the baseline and including-risk critical paths. Table 3 contains a summary of the Step IV milestone dates that result from the analysis.

The Step IV integration schedule has slipped since the last RSLR because the procurement of components of the PRY has been delayed. The integration of the PRY, and the related infrastructure work in the MICE Hall, is on the critical path. Once the equipment has been integrated the commissioning of the MICE magnets, the detectors and then the data taking can begin. In the commissioning phase, magnet training is on the critical path and detailed consideration of the optimisation of the magnet-commissioning process is being carried out by a task force led by the Beamline Integration Scientist (J. Pasternak, Imperial).

Both spectrometer solenoids are now installed in the MICE Hall and are under vacuum. While focus-coil (FC) module 1 has been shown to support a good science programme at Step IV, focus-coil module 2 has now been shown to outperform FC1; it is able to achieve the design current in both solenoid and flip mode. The

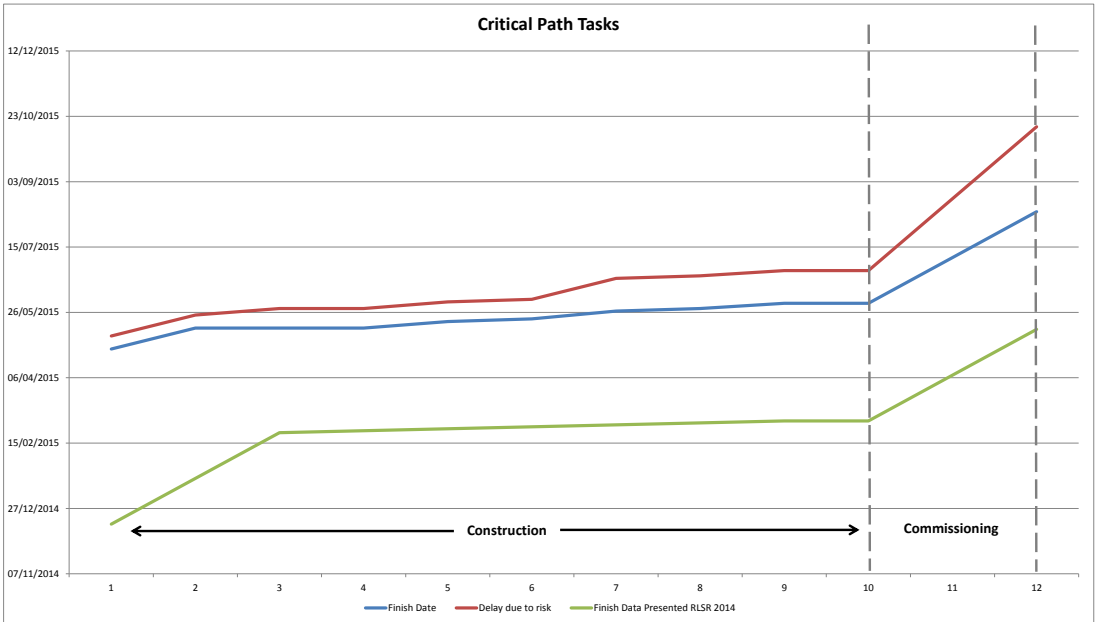


Figure 4: Step IV critical path. The green line shows the projected finish date critical path presented at the April review. The critical path that arises including the risk analysis described in the text is shown as the red line. The baseline critical path is shown as the blue line. The various critical paths do not necessarily pass through the same tasks as re-scheduling has been performed to mitigate and manage the delays resulting from the late delivery of components of the PRY.

Table 3: Step IV completion dates.

	Baseline completion date at RLSR Apr14	**Step IV integration complete (baseline)**	**Step IV integration complete (including risk)**
Step IV installation	04Mar15	2Jun15	27Jun15
Step IV magnet commissioning	23Jun15	11Aug15	14Oct15

Table 4: The critical path for the construction of the ionization-cooling demonstration experiment. The table shows the tasks which lie on the baseline critical path.

ID	Task Name	Finish	Duration	Predecessors	Probability	Risk Level	Risk Impact
294	**Commissioning**	**02/06/16**	**287.9 days**				
311	End of STEP IV Operations	02/06/16	0 days	310	0.5	(RISK)-(R3)	Additional data runs required to complete matrix
313	**MDIC**	**02/03/18**	**967.09 days**				
327	**Step IV De-Commissioning**	**27/07/16**	**38.75 days**				
330	**Tracker Systems**	**09/06/16**	**5.7 days**				
331	Disconnect Northside Waveguides	06/06/16	2.7 days	311	0.75	(RISK)-(R5)	Expert Personnel not available
333	Disconnect Southside Waveguides	06/06/16	2.7 days	331SS	0.75	(RISK)-(R5)	Expert Personnel not available
335	**TOF, KL & EMR**	**15/06/16**	**5.4 days**	**334**			
336	Remove TOF1 & KL & EMR	14/06/16	4.05 days	334	0.75	(RISK)-(R5)	Expert Personnel not available
338	**Partial Return Yoke**	**27/07/16**	**29.3 days**				
339	Remove North side PRY	24/06/16	6.75 days	337	0.25	(RISK)-(R5)	Lifting equipment missing / damaged
341	Remove South side PRY	20/07/16	6.75 days	350	0.25	(RISK)-(R5)	Lifting equipment missing / damaged
343	Remove Downstream underfloor supports	22/07/16	2.7 days	341	0.25	(RISK)-(R5)	Lifting equipment missing / damaged
355	**Installation**	**17/02/17**	**404.63 days**				
356	**RF system**	**17/02/17**	**404.63 days**				
441	**Waveguides**	**13/02/17**	**138.59 days**				
442	**System#1**	**13/02/17**	**138.59 days**				
443	Install waveguides	11/08/16	6.75 days	450	0.25	(RISK)-(R5)	Expert Personnel not available - clash with current equipment
445	**System#2**	**13/02/17**	**138.59 days**				
446	Install all waveguides	11/08/16	6.75 days	450	0.25	(RISK)-(R5)	Expert Personnel not available - clash with current equipment
474	**Return Yoke**	**02/02/17**	**35.16 days**				
475	**South PRY Frame Legs and Plates - Cavities and SSD**	**03/01/17**	**13.5 days**				
478	Install frame legs (inc drilling plates)	22/12/16	2.7 days	477	0.1	(RISK)-(R4)	Inacuracy of the frame / floor drillling
480	Fit south side yoke plates	03/01/17	6.75 days	479	0.1	(RISK)-(R4)	Inaccuracy of the plates / frame setup
481	South side SS return yoke installation complete	03/01/17	0 days	480	0.3	(RISK)-(R3)	Additional machining or replacement of parts
505	**Cavity Installation**	**27/02/17**	**703.09 days**				
518	**Move into cooling channel**	**27/02/17**	**26.35 days**	**517**			
519	Place online and couple to magnets	06/02/17	11.35 days	527	0.25	(RISK)-(R4)	Delays in delivery of shielding
520	Vac Pump/LLRF tests	20/02/17	2 wks	519	0.5	(RISK)-(R4)	Pump and bake needs additional time
522	LLRF Tests	27/02/17	1 wk	440,521	0.5	(RISK)-(R3)	Additional testing time required
524	**HPRF tests**	**27/03/17**	**20 days**				
525	HPRF tests	27/03/17	4 wks	440,522	0.5	(RISK)-(R3)	Additional testing time required
527	**Spectrometer Solenoid #2 installation**	**19/01/17**	**12.15 days**	**482**	**0.2**	**(RISK)-(R4)**	**Expert Personnel not available**
530	Install Spectrometer Solenoid #2 and align	19/01/17	6.75 days	493,529	0.5	(RISK)-(R4)	Expert Personnel not available
534	MDIC installation complete	27/03/17	0 days	525	0.5	(RISK)-(R2)	Delay due to currently non-dritical items reaching critical path
535	**Commissioning**	**03/05/17**	**27 days**				
536	Cooling Channel magnet Commissioning	03/05/17	27 days	534	0.25	(RISK)-(R2)	3 of the 4 magnets have been commisioning together in Step IV
537	**RF Testing**	**03/05/17**	**20 days**				
538	Test and condition cavities, with B field, 1MW	03/05/17	4 wks	534,536FF	0.5	(RISK)-(R2)	Additional testing time required - testing in the MTA
540	Combined magnet and operational tests complete	03/05/17	0 days	539	0.5	(RISK)-(R2)	Delay due to currently non-dritical items reaching critical path

decision has therefore been taken to use FC2 in Step IV. The modules will be exchanged before the end of December 2014.

3.2 Ionization cooling demonstration

Table 4 lists the tasks on the critical path for the completion of the MICE experiment. By construction, the list starts with the milestone marking the end of Step IV data taking.

The analysis of the schedule shows that the main driver of the project's critical path is the installation and commissioning of the two RF systems required to drive the two RF cavities in the new layout. Preparatory work in advance of the installation of the amplifiers is being carried out at the Daresbury Laboratory, where the build up and initial testing to 2 MW into a dummy load will be completed. Following the power tests, the control racks and 4616 amplifier were removed and moved back to the Daresbury Laboratory for testing with the second TH116 amplifier.

The programme for the completion of Step IV places substantial demands on the DL Electrical Engineering Department. Previously, the schedule for Step V allowed the RF amplifiers to be prepared once Step IV installation was complete. To complete the integration of the experiment on the timescale presented in Table 4 requires the DL Electrical Engineering group to work in parallel on the completion of Step IV at RAL and the preparation of the RF amplifiers at DL.

Key dates and milestones

The date on which Step IV operations will end shown in Table 4 has been determined by maximising the Step IV running period while maintaining the June 2017 completion of the ionization-cooling-demonstration configuration. The construction and testing of the RF amplifiers at DL then drives the schedule; the second RF system being the last system to be delivered and installed on-site at RAL. Following the completion of the RF-system installation, testing of the RF systems at low and high power can commence. Commissioning of the magnetic lattice and the rest of the experiment will then follow. This analysis yields the latest date for delivery of the RF cavities and associated components and the extension of the PRY.

The following dates have been extracted from the schedule analysis:

- Construction and commissioning:
  - Step IV construction complete – 2^{nd} June 2015
  - Step IV commissioning complete – 11^{th} August 2015
  - Step IV De-commissioning start – 2^{nd} June 2016
  - Ionization cooling demonstration construction complete – 24^{th} March 2017
  - Ionization cooling demonstration commissioning complete – 2^{nd} May 2017
- Data taking periods:
  - Step IV Data taking – 12^{rd} August 2015 to 2^{nd} June 2016
  - Ionization cooling demonstration data taking period – 3^{rd} May 2017 to 31^{th} March 2018 (the end of the UK Financial year)
- Latest date for equipment delivery to RAL for the integration of the cooling-demonstration:
  - RF Cavities and associated chambers – 1^{st} November 2016
  - South PRY Frame – 15^{th} October 2016
  - South PRY Plates – 26^{th} October 2016
  - North PRY Frame – 1^{st} January 2017
  - North PRY Plates – 10^{th} January 2017
- Interface dates defined for the delivery of the equipment required – arrival at RAL:
  - RF Cavities and associated chambers – 26^{th} April 2016
  - South PRY Frame – 29^{th} March 2016
  - South PRY Plates – 29^{th} March 2016
  - North PRY Frame – 29^{th} March 2016
  - North PRY Plates – 29^{th} March 2016

As already stated, the delivery dates for the RF cavity modules and the partial return yoke and the latest possible consistent with completing the ionization-cooling-demonstration configuration by May 2017. The data-taking period for the demonstration of ionization cooling is presently scheduled to finish at the end of UK financial year 2017/18 (31^{st} March 2018).

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 in Figure 5. For both the UK and the US the budgets include support for the experimental collaboration.

Detailed budget estimates for UK financial year 2014/15 are shown in Table 5. The costs are broken down into capital and resource. The cost of ISIS Operations Group staff are also included. The figures do not take account "income" that arises from the Common Fund and a number of European Commission Framework

	FY 14/15	FY 15/16	FY 16/17	FY 17/18
UK (£k)	**3100**	**3267**	**3317**	**2788**
Cumalative UK (£k)	**3100**	**6367**	**9684**	**12472**
UK ($k)	*5301*	*5587*	*5672*	*4767*
Cumalative UK ($k)	*5301*	*10888*	*16560*	*21327*
US ($k)	**7970**	**6212**	**3663**	**1172**
Cumalatiuve US ($k)	**7970**	**14182**	**17845**	**19017**
US (£k)	*4661*	*3633*	*2142*	*685*
Cumalative US (£k)	*4661*	*8294*	*10436*	*11121*

Exchange rates	
UK - US	1.710
US- UK	0.585

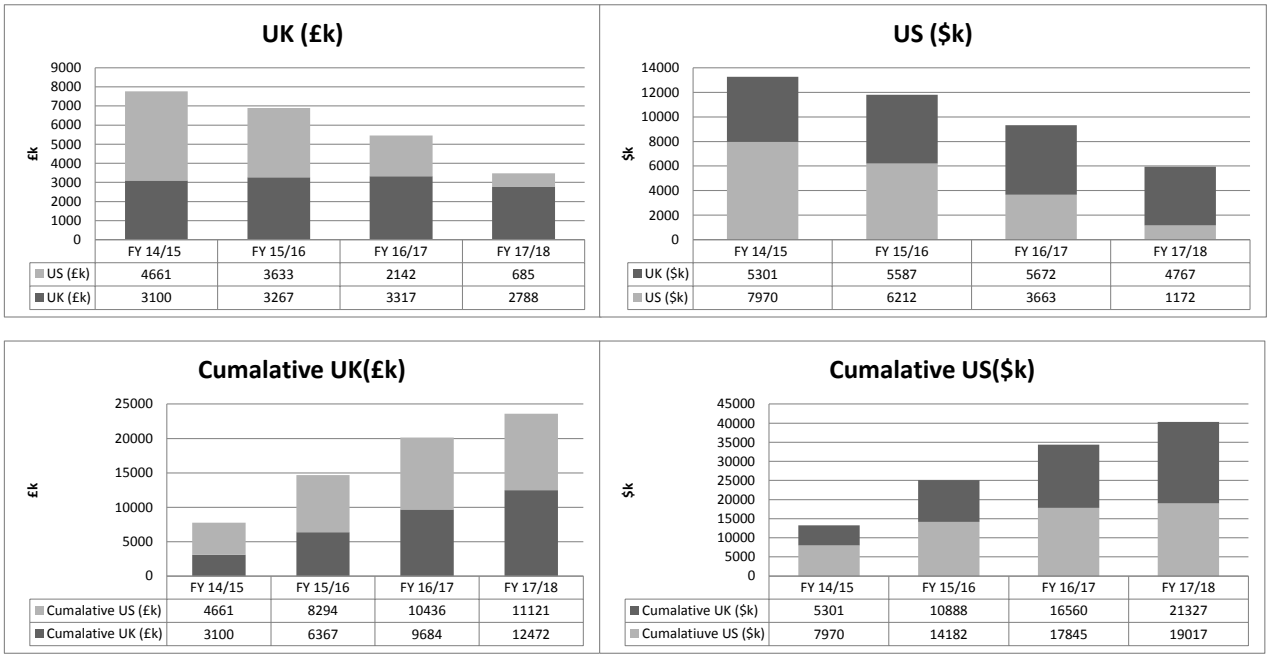


Figure 5: Top panel: Roll-up of the annual cost of the UK and the US of the MICE project to Step VI. The offset in the cells of the table are intended to indicate the staggered start to the financial year in the UK relative to the US. To aid in comparison, the cost to the UK recorded in £k is converted 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. In the case of the UK project, the costs include the cost of the operations and analysis work package.

Table 5: UK budget forecast and Current Allocation for financial year 2014/15.

Total Project Spend - Excluding University	**Spend Forecast**	**UK Allocation September 2014**
MICE Construction Project - (Capital)	1,393,855	1,423,000
MICE Construction Project -(Resource)	495,538	285,000
MICE Ops and Analysis Project (Resource)	320,270	481,000
Totals	2,209,663	2,189,000
Variance	-20,663	

Programme 7 awards. The shortfall between the current allocation and the resource-loaded-budget estimate for UK financial year 2014/15 is £21k. It is the project team's understanding that this shortfall is being regarded as contingency held centrally by the STFC. Table 6 summarises the profile derived from the resource-loaded schedule presented in section 3.

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 7. The top level risks identified within the tasks that make up the US contributions are presented in Table 8.

As noted in the response to the DOE Review Panel's recommendations [3] the revised configuration has substantially reduced the overall project risks. As the PRY has not yet been tested to demonstrate that the risk to equipment has been removed, the residual risk of failure of electronic items in the Hall must remain. The additional field-mitigation work of implementing Rack Room 2 has also significantly reduced the risk to the operation of power and control systems for the magnet lattice.

Insufficient staff for efficient completion of the project is a persistent risk but mitigation plans have been discussed and are being put into place. Integration with the ISIS operation team reduces manpower resource risk across many work packages, particularly during commissioning and operations leading to the completion of Step IV. At Step IV the higher risk to the project schedule and budget comes during the commissioning phase of the magnet lattice. Each magnet system will have been commissioned in isolation. When it comes to operating the magnets as a lattice, the interaction forces will cause many quenches possibly leading to a lengthy commissioning period and a large cost for liquid helium.

References

[1] The MICE Executive Board, "Actions and recommendations from the Resource Loaded Schedule Review panel and the MICE Project Board." `http://micewww.pp.rl.ac.uk/documents/94`, 2014.

[2] V. Blackmore *et al.*, "The MICE Demonstration of Ionisation Cooling: Technical Note." `http://mice.iit.edu/micenotes/public/pdf/MICE452/MICE0452.pdf`, 2014.

[3] The MAP collaboration, "Revised completion plan for the Muon Ionization Cooling Experiment (MICE) at Rutherford Appleton Laboratory."

Table 6: Cost to complete the MICE programme. Cost to the UK of the programme presented in section 3. The table shows the estimated requirement over the financial years 2015/16 to 2017/18. Overheads are not applied to the capital project (work packages 2, 3, 4, 5, 6, 7, 8 and 9. The grand total figure with and without risk mitigation costs is presented.

MICE UK Cost to Complete		2015/16	2016/17	2017/18	Totals
		£k	£k	£k	£k
Staff effort					
MICE-UK					
1	*Project management and project office*	487.95	505.03	392.03	1385.01
2	*Mechanical integration*	175.08	146.75	85.45	407.28
3	*Electrical Integration*	133.87	209.48	97.07	440.42
4	*Focus-coil module*	126.25	130.67	135.25	392.17
5	*Hydrogn Delivery System*	34.68	21.85		56.53
6	*RF power*	342.33	350.03	302.13	994.49
7	*Vacuum*	29.48	30.51	31.58	91.57
8	*Magnetic Mitigation*	11.23	11.62	6.02	28.87
9	*Software and computing*	160.10	148.39	153.58	462.07
10	*Operations and analysis*	921.21	916.01	934.61	2771.83
	Staff totals	**2422.18**	**2470.34**	**2137.72**	**7030.24**
Non-staff					
MICE-UK					
1	*Project management and project office*	15.00	15.00	65.00	95.00
2	*Mechanical integration*	258.32	173.27	155.80	587.39
3	*Electrical Integration*	96.48	182.63	125.93	405.04
4	*Focus-coil module*	15.00	35.00	5.00	55.00
5	*Hydrogn Delivery System*	10.00	0.00	0.00	10.00
6	*RF power*	147.14	110.23	75.00	332.37
7	*Vacuum*	25.76	35.85	36.49	98.10
8	*Magnetic Mitigation*	107.53	55.00	0.00	162.53
9	*Software and computing*	15.00	15.00	15.00	45.00
10	*Operations and analysis*	153.68	224.67	171.95	550.30
	Non-staff totals	**843.91**	**846.65**	**650.17**	**2340.73**
Total staff and non-staff					
MICE-UK					
1	Project management and project office	502.95	520.03	457.03	1480.01
2	Mechanical integration	433.40	320.02	241.25	994.67
3	Electrical Integration	230.35	392.11	223.00	845.46
4	Focus-coil module	141.25	165.67	140.25	447.17
5	Hydrogn Delivery System	44.68	21.85	0.00	66.53
6	RF power	489.47	460.26	377.13	1326.86
7	Vacuum	55.24	66.36	68.07	189.67
8	Magnetic Mitigation	118.76	66.62	6.02	191.40
9	Software and computing	175.10	163.39	168.58	507.07
10	Operations and analysis	1074.89	1140.68	1106.56	3322.13
	Sub-totals	***3266.09***	***3316.99***	***2787.89***	***9370.97***
Grand totals	(Cost with time contingency and risk)	**3266.09**	**3316.99**	**2787.89**	**9370.97**
Grand totals	(Cost with time contingency)	**3096.09**	**3136.99**	**2557.89**	**8790.97**

MICE-UK	**Cost of risk mitigation**	**170.00**	**180.00**	**230.00**	**580.00**
	Staff element	20.00	10.00	10.00	40.00
	Non-staff element	150.00	170.00	220.00	540.00

Table 7: 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	Lxl			L	I	Lxl		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.	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 around 100L. 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	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		n/a	n/a	n/a				End of Step 3PI/2
MICE 10	Late delivery of the PRY and / or Cavities for Step 3PI/2 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.	2	5	10	Cost will need to be borne as releasing and then re-forming the team will be difficult with an unknown timescale.	£90k / Month		End of Step 3PI/2
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 Step 3PI/2
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 Step 3PI/2.	2	75	End of Step 3PI/2

Retired Risks

MICE 5	AFC Module #2 has the same type of fault as AFC module #1	Extended delay and uncertain cost burden.	4	5	20	MICE - UK	Bring forward test of module #2. Shorter timescale for training runs. Purchase of additional Lhe if required to shorten timescale	2	1	2	Testing of the second Focus Coil has been successful. Some thermal performance required investigation	0.2	15	End Sept 14 after final soak test.
MICE 13	Focus Coil 1 extended timescale for repairs to gain full operating current.	Repairs enabling the Focus Coil 1 to operate at the nominal currents for the experiment are not completed in time for installation and operation in the Step 3PI/2	4	5	20	MICE UK	Scientific substantiation for the need to run at the higher current. Discussions with the manufacturing company to gain realistic timescales and cost. MICE project interaction with the manufacturing company senior management and supply technical effort to expedite the repairs.	2	1	2	Following scientific substantiation there may not be the need to make repairs to the Focus Coil 1. This would remove the risk of late delivery back to the experiment. The current analysis for Step 3PI/2 uses the current rating that has already been achieved.	1	100	Decision point 15th November.

Table 8: Top level risks for the sub-projects for which the US is responsible. The total weighted risk is 145 working days and approximately $607k.

ID	MAP WBS	Risk Description	Potential Impact on Project	Risk Score L	Risk Score I	Risk Score L×I	Ownership	Proposed Action	Post-Action L	Post-Action I	Post-Action L×I	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 Step 3pi/2 production coupldlers 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	4/16/15	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	3/29/17	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	2/16/15	Active
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	4/14/15	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	3/29/17	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	3/29/17	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	8/3/15	Active
8	5.6.2.3.3	Step IV Partial Yoke Shielding Fit-Up 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	8/3/15	Active
9	5.6.2.4.3	MICE Final Step Partial Yoke Shielding Integration problems.	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	3/29/17	Active
												Totals for All Items (Active Risks Only)	560	500	675	1735			606.8	145		

Legend:

Sym	Definition	Range
L	Likelihood	1-5
I	Impact	1-5

Likelihood Translation:

Rank	Prob (%)
1	10%
2	30%
3	50%
4	70%
5	90%

Impact Translation:

Rank	Work Days
1	1-20
2	21-40
3	41-80
4	81-120
5	>120

http://map-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=4402&filename=DOE_Response_2014_0925_FINAL-docDB.pdf&version=1, 2014.