MICE-UK report to the Oversight Committee

Executive summary

Liquid hydrogen absorber installation:

The hydrogen absorber installation was completed over the summer period of 2017. The programme started with the successful liquefaction of approximately 2 litres of neon and the stable operation of the system for a period of several days. A re-analysis of the possible consequences of freezing hydrogen in pipes serving the absorber vessel showed that it might be possible for a large pressure rise in the hydrogen-safety volume in the event of a catastrophic rupture of the hydrogen window. Modifications were agreed that removed the risk of such a pressure rise. After a successful HAZOP review of the system in May 2017, there were no outstanding issues that would prevent the commissioning of the system with liquid hydrogen. The MICE liquid-hydrogen absorber is filled by condensing hydrogen gas. The condensation rate is such that it takes roughly one week to fill the 22 litre volume of the absorber vessel. The vessel was filled for the first time late in the evening of the 25th September 2017. The liquid hydrogen system remained cold without any issues during the ISIS 2017/02 period until data-taking with the full absorber was completed on 16th October and then we emptied the absorber of LH$_2$ to begin data-taking with the empty absorber.

Step IV data-taking:

Data taking has been carried out during the ISIS Cycles 2017/01 (02/05/17-01/06/17) and 2017/02 (19/09/2017-27/10/2017). The original ISIS Cycle 2017/02, scheduled for June-July 2017, was cancelled and so the September-October 2017 run was re-labelled as 2017/02. A request made to the STFC Executive to run during ISIS Cycle 2017/02, in order to perform MICE liquid hydrogen running, was granted. The 2017/02 run was very successful and a large amount of liquid hydrogen running was carried out. However, a fault in the ISIS accelerator during 2017/02 meant that we lost about one week of data-taking, so another request to the STFC executive, seeking permission to finalise the MICE Step IV programme during 2017/03 (14/11/2017-20/12/2017) was made. This will be the final MICE Step IV run and was also granted.

During these data-taking periods, the collaboration has performed measurements of muon multiple Coulomb scattering with an empty target, with a LiH absorber and with a liquid hydrogen (LH$_2$) absorber without magnetic fields. Further physics data was taken with a LiH and with a LH$_2$ absorber with the magnetic fields over a range of emittance and momentum settings for the investigation of normalised-transverse-emittance evolution with the magnets in solenoid and in flip-mode. The M2 coil in the downstream spectrometer solenoid (SSD) was turned on for the first time during the ISIS Cycle 2017/02. It was quickly found that the polarity of the coil was reversed with respect to the other coils, so the leads in the coil had to be reversed. After re-connecting the leads, M2 has been operating without problems and a number of settings with M2 on have been taken.

The final data-taking runs during ISIS Cycle 2017/03 will require finalising the programme of emittance evolution with both empty hydrogen vessel, empty target, LiH running and, if time permits, a novel configuration with a wedge-shaped absorber, with and without the M2 coil of the downstream solenoid on.
Feedback and Actions from MICE Oversight Committee meeting held on 28th April 2017

1. The Committee would like to offer its congratulations on the 100 million events data recorded and the smooth running of MICE, particularly in March 2017.

2. The Collaboration appears to have managed the movements of personnel attached to the project and is responding well to technical difficulties as they arise.

3. Impressive progress has been made on analysis of the data, and the Collaboration has a good plan in place for future publications. The imminent Physical Review Accelerators and Beams (PRAB) publication is particularly notable.

4. The Committee welcomes the STFCs decision to support the MICE data run planned for September/October 2017. This will allow the Collaboration to get a comprehensive set of data and complete Step IV.

5. The UK Collaboration should write down their plan to achieve the completion of operations in September/October 2017, including an analysis under different scenarios and accompanying decision points. The Committee believes this will help planning under most eventualities.

6. There continue to be commissioning and operational issues. There are likely to be a number of issues where support from the US part of the Collaboration will be essential for the successful completion of step IV data taking in September/October 2017. The Committee questions the priority of expediting the delivery of the RF cavities over providing the necessary personnel to ensure the successful completion of step IV.

7. The Committee sees the forthcoming HAZOP review as an essential part of the planning for liquid hydrogen operations. Ensuring the safety of personnel must be the highest priority for experimental operation. The Committee would like to see the report as soon as it is available.

Action: The Collaboration

The HAZOP report was not circulated to the Oversight Committee in May 2017, but a summary of its conclusions were included in the Bi-monthly Report of June 2017. The HAZOP report is now included with the documentation for this Oversight Committee.

8. It is imperative that the project maintains strict financial supervision to ensure that the project is completed within the remaining allocation.

9. The Committee acknowledges and understands the Collaborations desire to move to a cooling demonstration project, but also notes the official statement from STFC that there is no funding available for the upgrade, which was presented in the recent Statement of Interest to the Accelerator Strategy Board. The Collaboration is therefore encouraged to plan accordingly.

10. The Committee encourages the STFC to commission a Lesson Learned exercise, under external leadership, to provide guidance for future projects.

11. The Committee believes that MICE data will provide a source of future publications and PhD theses and recognises the commitment of the academics in supporting the new students throughout their PhD studies.

12. The next meeting of the Committee was agreed to take place on 21 November 2017.
1 Introduction

Since the collaboration reported to the Oversight Committee in April 2017, the ISIS User Cycle 2017/01 has been completed. The focus for this User Cycle was the preparation of the liquid-hydrogen (LH$_2$) absorber and its ancillary systems so less time was allocated to data-taking than in previous Cycles. To allow work to focus on the preparation of the LH$_2$ system, it was decided that all data taking in Cycle 2017/01 would be for the field-off scattering programme. The decision not to run the superconducting cooling channel magnets allowed key personnel to devote their time to the preparation of the LH$_2$ system. In parallel to the LH$_2$ preparation work, straight-track, calibration and alignment data were taken. At the end of the Cycle, when the test of the liquefaction system was successfully underway, a data-set using cold, gaseous neon as the absorber material was also taken.

In the run-up to the start of Cycle 2017/01, routine maintenance was carried out on the cold-heads serving the tracker cryostats. This involved the warm-up of the cryostats. The first cryostat to be cooled down after maintenance (Cryo 2) showed a large number of dead channels. This was believed to have been due to water ice freezing in the VLPC assembly. The cryostat was warmed up and evidence of substantial water contamination was identified. All cryostats were subsequently tested and all exhibited the same degree of water contamination. The cause of the contamination is now assumed to be the use of a bottle of contaminated helium gas. Diagnosis and recovery from this problem took up a significant fraction of the available data-taking time. Data was taken while the tracker was not operational for TOF calibration and the alignment of the upstream instrumentation. Data-taking with all detectors was only possible in the last week of the 2017/01 User Cycle when a 24-hour/7-day programme was executed.

The next User cycle, 2017/02, ran from the 19th September 2017 until the 27th October 2017. The ISIS 2017/02 run was originally scheduled in June-July 2017, but ISIS delayed this run. Permission was requested to STFC for MICE to run during this cycle, at no extra cost, and this was granted. The LH$_2$ system was prepared during the summer, after a successful HAZOP in May 2017. The sequence to fill the liquid-hydrogen absorber was initiated on Sunday the 17th September 2017. The absorber vessel was full on Monday the 25th September 2017. The hydrogen volume was stable from this time until the vessel was emptied to allow empty-channel data-taking. Production data taking for the Step IV liquid-hydrogen programme started immediately after the absorber was full and continued in a routine and efficient manner. The empty sequence was initiated on the 16th October 2017 when an adequate data set had been accumulated with the LH$_2$ absorber full. A total of 92 million triggers were collected during the ISIS 2017/02 data period.

Section 2 covers the status and progress of each of the MICE-UK Work Packages, with a special focus on the liquid-hydrogen system. Section 3 briefly summarises the interest by a group in Protvino (Russia) to carry out a muon ionization cooling demonstration. Section 4 includes the financial summary, schedule and risk. The appendices include the list of UK authors, an up-to-date list of publications, talks and posters and a list of UK PhD theses.

2 Status of work packages

In this section, we detail the status and progress of each of the MICE-UK Work Packages since the previous Oversight Committee meeting and highlight some of the main achievements. Most of the hardware work was concentrated on delivering the liquid hydrogen system, maintaining the trackers and preparation for the 2017/01 and 2017/02 data-taking runs.
2.1 MICE Muon Beam

The MICE muon beam and the MICE target have been operating successfully. The Decay Solenoid has been working well since the repair to the refrigeration plant, in December 2016. However, the shield supply pressure was found to be falling, contaminating the adsorber. A limited warm-up procedure with a 10 hour turnaround, was carried out to back-flush the adsorber. There was a controls issue and the Linde plant of the Decay Solenoid which had to be run in local mode. The power supply and magnet are OK. The separation of the new roof water chiller circuit to allow cooling of the beamline magnets using the chiller in the loading bay has been working without any problems.

The problem in which some of the leaves of the diffuser stick when the magnets are powered up was fixed. However, occasionally, the leaves stick after a diffuser setting change, normally when all the leaves have been closed for long periods. By limiting the time by which all the diffuser leaves are closed in a given run, we can mitigate this problem. This can be achieved by changing the diffuser settings typically once every two hours, which is how we have run during the last two ISIS data-taking periods.

There has been a gradual deterioration in the laser power that feeds the optic fibres that perform the precision control of the target position. An increase in the laser power temporarily fixed the problem during the 2017/02 data run. The fibre tails attached to the moving target suffer deterioration from the target actuation. These have now been replaced prior to the ISIS 2017/03 run.

2.2 Integration

The infrastructure in the MICE hall is now in maintenance mode. A routine maintenance was carried out on the cold heads for the tracker cryostats which involved the warm up of the cryostats in preparation for the 2017/01 cycle. The first cryostat to be cooled down showed that there were a large number of dead channels which was believed to be a result of water freezing in the VLPC assembly. There was evidence that the helium gas had been contaminated by water vapour, and all other cryostats also showed this level of water contamination. The cause of this is assumed to be due to the use of a contaminated bottle of helium gas. The diagnosis and recovery of this took up a significant amount of the time available for data taking during the 2017/01 run. Data taking with all of the detectors was only possible during the last week of the user cycle when the shifts were covered 24 hours a day.

During the summer period, all the cold heads for the tracker cryostats were replaced. As a consequence, the cooling headroom was improved. The vacuum processing for water was completed, but there was no improvement in the dead channels. The optimal solution that was found was to perform connector swaps. The swaps fixed the problem. As a consequence, extensive work was required by the tracker team for a manual re-calibration of all the channels.

The super-conducting cooling channel magnets were also re-commissioned in August 2017. There was a smooth re-start of the spectrometer solenoids and some problems with the change in current ($\frac{dI}{dt}$) sensors was remediated. As a consequence, the data-taking run-up for the magnets in September, was carried out without problems. During data-taking in 2017/02, there was a gradual increase in the vacuum pressure in the downstream solenoid (SSD) at high currents (around 200 A), due to a small liquid helium boil-off. This only affects 3 T operations, but not operations at 2 T, in which the central coil current is around 144 A. There were no problems also with the Focus Coil magnet, except for a slight leak from the helium volume into the insulation volume. However, this is not considered to be problematic.

Pulser runs, prior to data taking showed that there was an intermittent issue in the EMR which was possibly related to one of the eight circuit boards. Although this problem has now gone away and the system is fully operational, colleagues from Geneva provided assistance to help debug the system.
2.3 Liquid-hydrogen delivery system

Since the last Oversight Committee meeting, the design details of the windows that contain the hydrogen safety volume that surrounds the absorber was revisited. Significant safety concerns were raised in the analysis of the structure. The problems related to the potential for pressure build-up in the safety volume and the cryogenic pipework. The pipework within the cryogenic part of the system was such that there existed a possibility of freezing liquid hydrogen. This ice-creation could have blocked the gas-release paths and pressure could have built up in the circuit between the condenser and the absorber. This meant that the absorber could have fractured at around 8 Bar and such a violent event would have created a high pressure in the safety volume. In addition, the exhaust line from this insulating vacuum was found to have too small a diameter to vent gas effectively in the case of a rapid boil-off of hydrogen.

Two steps were taken to avoid the danger of pressure build-up: first, a by-pass pipe was introduced that connected the vapour above the liquid in the absorber to pipework held at a temperature well above the freezing point of liquid hydrogen at around 40 K. Even if the condenser freezes, blocking the inlet and outlet pipes to the absorber, the bypass will still be open. Secondly, the exhaust pipework from the insulating vacuum (the safety volume) in the magnet bore to the cabinet on the roof was modified. Restrictions for pumps and other valves were removed, the entire “quench line became part of the insulating vacuum and the outlet of this quench line was sealed by“lift-off lids that were only held down by gravity and the vacuum. Extensive calculations were performed to ascertain that ingress of cryogenic liquid into the safety volume could not cause further damage and any pressure build-up would be safely released.

In the light of these changes to the system, a third HAZOP of the system was performed in May 2017. The HAZOP considered all changes made to the system since 2012. No significant obstacles for the progress of the project were identified.

The system was cooled down to operating temperature at the end of May 2017. On the 24th May 2017, the system was tested by liquefying neon. A volume of neon was successfully liquefied and the system was operated to keep the volume of liquid neon constant for a period of several days. The volume of neon liquefied was limited by the safety case to ≈ 2 litres. This volume is sufficient to fill the pipework below the absorber and to cover the bottom surface of the absorber vessel with liquid. Data was taken in this configuration to study the apertures introduced in the system by the liquid-hydrogen vessel and to allow a scattering measurement with cold neon gas to be attempted.

On the 7th June 2017 the focus coil (FC) was ramped to quench to address three points:
1. Is the cold absorber in the bore affected mechanically by the eddy currents created by the quench?
2. Can the pressure rise in the absorber be controlled?
3. What is the stand-alone quench current of the FC in flip mode on the beam line?

The ramp progressed normally with a staged ramp rate (25 mA/s, 15 mA/s, 10 mA/s). Once the ramp rate reduced to 10 mA/s at 70 A the pressure in the helium reservoir stopped rising (1118 mBar) and started to fall (to 1100 mBar). From about 165 A the pressure started to increase again very slowly (to 1104 mBar). The magnet quenched at 184.9 A. This is in line with the quenches it had in stand-alone testing at R9 and is significantly higher than the current of 160 A at which it quenched in the presence of the field from the upstream solenoid. The quench happened within the coils, not in the leads. Indications are that the upstream coil quenched first. The vacuum around the absorber was $2.1 \times 10^4$ mBar before and after the quench, i.e. there was no disturbance of the mechanical structure which could have caused a leak. The fixing rods for the absorber were examined when the FC was taken off the beam line.

The absorber, including the pipework, contained approximately 1.7 litres of liquid neon before the quench. The temperature of the absorber was 27.8 K, more or less uniformly across the absorber. The cold-head was about 1 K lower, being controlled by heaters between 25.5 K and 27 K. The system ran stably for two days
in that setting, with the pressure hovering between 1140 mBar and 1145 mBar. Immediately after the quench, the pressure rose to 1155 mBar, i.e. an increase of approximately 15 mBar within a volume of slightly more than 1000 litres (buffer tank) and well below the release pressure of the system. This means that approximately 11 cm$^3$ of liquid were evaporated by the quench. The temperature in the absorber remained constant at the bottom (where liquid was present). It rose to 30.11 K at the top of the absorber. After about 5 minutes the pressure was back to 114 mBar again.

The work on the liquid hydrogen continued over the summer. It was found that the silicon O-rings were porous to helium, causing a small leak. This was rectified and there are now no leaks in the system. The H$_2$ detectors were calibrated on 8th September and the cool down of the system commenced on 13th September, in time for the start of the 2017/02 ISIS cycle which began on 19th September. The cool-down was a bit slower than expected, with the liquid hydrogen filling taking about a week. The filling of the liquid hydrogen absorber occurred between 22nd September until 27th September. This is illustrated in Figure 1 by the energy loss observed by muons traversing the absorber as a function of time throughout the filling process. Once the hydrogen was liquefied and the absorber was full, it remained liquid and the temperature was stable throughout the liquid hydrogen data-taking in the ISIS 2017/02 period.

The full engineering and operation of the system was carried out by M. Hills, A. Nichols, S. Watson, M. Courthold, T. Bradshaw and lately by V. Bayliss and J. Boehm of the Technology Department at RAL and by M.Tucker of the Particle Physics Department. The critical control system was delivered by P. Warburton from the Electrical Engineering Group in Technology Department at Daresbury Laboratory (DL). The DL Control Systems and Safety Interlocks Group made critical contributions to the integrated safety-engineering approach that was adopted from the outset and delivered through a close collaboration between personnel from Technology and ISIS Departments. M. Tucker, supported by S. Balashov, delivered the critical vacuum and gas-handling systems.

Figure 1: Energy loss by muons traversing the absorber as a function of time, while the absorber is being filled with liquid hydrogen.
2.4 Focus-coil module and superconducting soldenoids

All the super-conducting magnets were re-commissioned during the summer (9th-18th August) in preparation for the ISIS 2017/02 data taking run in September and October 2017. The re-starting of the magnets went smoothly. The only issue was an increased amount of noise on the quench-protection system (QPS) of the downstream spectrometer solenoid (SSD). The noise reduced as the system was run. There was also a problem in the current-change ($\frac{dI}{dt}$) system, which was traced to a faulty connector and was remediated. There were no problems in the commissioning of the Focus Coil magnet, except for a slight leak from the helium volume into the insulation volume. However, this is not considered to be problematic.

All super-conducting magnets operated without problems during the 2017/02 data run. When operating SSD at high currents (205 A) required for 3 T operation, a gradual increase in the vacuum pressure was observed. The pressure would rise asymptotically from 1.095 Bar to about 1.18 Bar, due to a small amount of liquid helium boil-off, probably due to the worse thermal performance of this magnet. For 2 T operations, in which the SSD current is 144 A, no increase in pressure was observed. The M2 coil in SSD was turned on for the first time during the ISIS Cycle 2017/02 (5th October). It was quickly found that the polarity of the coil was reversed with respect to the other coils, so the leads in this coil had to be reversed. After re-connecting the leads, M2 has been operating without problems and a large number of triggers, with M2 powered, which give better matching and improved transmission rate, were taken.

On Thursday 2nd November 2017, SSU suffered a mechanical failure in one of the cryocoolers. Staff worked to mitigate the issue and stabilised the magnet temperature and pressure that day. Tests to date have demonstrated operation of SSU without issues at 100A in all coils. Further tests aimed at improving performance will be conducted 8/11/17 before testing to full operating current. Provided these tests are successfully concluded, no intervention will be required. To mitigate the risk of further compromise of performance to the damaged cooler, a plan has been developed to replace the affected part without warming the magnet. Parts required for the cooler swap are in fabrication.

2.5 RF power

All work on the two 201 MHz single-cavity RF modules has been stopped. MICE-UK agreed the sale of four tetrodes and three triode glasses to ISIS during calendar year 2017 to fund the operations in September/October (ISIS 2017/02 data period) and in November/December (ISIS 2017/03 data period). This has generated income of £194.73k, for the operation of the experiment.

2.6 Software and Computing

There has been further progress in the Controls & Monitoring (C&M), Online and Offline Software. There have been personnel changes within the computing group. D. Rajaram (Illinois Institute of Technology) leads the Computing Project, with A. Kurup (Imperial) leading the C&M sub-project. E. Overton (Sheffield), who was leading the Online group, left the collaboration during the summer. A. Dobbs (Imperial College) left the collaboration in November 2017. A combination of D. Rajaram, P. Franchini and C. Hunt will take up the work.

The first draft of the MICE software publication, covering technical details of the MAUS framework, the simulation and the reconstruction software, has been put together. A first series of comments are being implemented. It is expected that the paper will be submitted before the end of the year.
2.6.1 Controls & Monitoring

There has been a big reduction in the number of alarms experienced by personnel on shift. This is due to major improvements to the alarm limits and the Alarm Handler implementation. All hard-coded settings were removed from the state machines and there is an automated way to upload to the Conditions Database and to generate Alarm Handler and Archiver configuration files consistently from the alarm settings spreadsheet. There were numerous hardware fixes, bug fixes and improvements, including the beam information from ISIS, communication errors with SSU, SSD and FCD, implementing new tracker vacuum gauges, current alarms monitoring, organisation of alarm handler and shifter instructions, monitoring of stale read-back from security probe sensors and luminosity monitor voltage monitoring. There is a better layout of the alarm handler and use of the alarm history window. Now there are very infrequent spurious alarms and the shifters can see new alarms clearly. The Run Control has been stable during running, but there are still some bugs that remain, and it is sometimes slow. It would require a complete re-write and very careful and extensive testing to fix the issues, so we will continue to work with the current Run Control without major changes until the end of the run.

We have also now implemented and tested an IOC for remote monitoring of the hydrogen system. This includes setting up a dedicates machine, network bridge and gateway, providing a secure way to monitor the hydrogen system by isolating the network on which the PLCs are on. There is a new Input/Output interface and user interface (GUI) and an expert panel available for people on shift and for use by the experts (see Figure 2).

2.6.2 Online

The Trigger and Data Acquisition (DAQ) readout software has remained stable. There was a major intervention in April/May with the tracker cryostats. Several dead channels and waveguide reconfigurations were required to optimize their settings. There was also an issue with the EMR readout during the start of the ISIS 2017-02 run. The EMR VME readout boards failed to initialize, then later died on the first event. It is still not clear if the issue is with the readout board or with its communication. The problems have now been resolved, without understanding its origin.

The DAQ sometimes automatically stops when the readout drops out. The tracker veto timing is not optimized, which results in a readout mismatch causing unpacking errors at high instantaneous rates. Most of the time, the DAQ recovers from these errors, but occasionally, the shifter is required to restart the run to fix the

![Figure 2: Liquid-hydrogen user interface for shifters (left) and expert panel (right) now available to monitor and control liquid hydrogen system in the control room.](image-url)
errors. The Online Monitoring has been working well to catch these errors. It traps unpacking/corrupt data errors and raises alarms, requiring shifter intervention to stop the run if the alarm status remains "serious. The Online Reconstruction runs automatically during data taking. It runs in a multi-threading mode, which causes occasional crashes which are not seen in single-threaded mode. However, it restarts by itself after a crash.

2.6.3 Offline

The Reconstruction version is currently MAUS v3.0.0. There exists a rolling review of the tracker reconstruction software to focus on improving the efficiency. There have been changes to the tracker pattern recognition fitter. MINUIT is now the default fitter, replacing a least squares algorithm. Five-point efficiencies improved from 91.7% to 97.9% in the upstream tracker and from 81.4% to 94.0% in the downstream tracker. Four-point efficiencies (the minimum required to fully reconstruct a track inside the magnetic field) have remained more or less constant at 98.8% in the upstream tracker and improved from 97.2% to 98.1% in the downstream tracker. Issues with the tracker calibrations post-remapping are being addressed. However, there is a mysterious excess of tracks reconstructed around $p_z = 50\text{ MeV/c}$ (Figure 3).

There was an issue with the time-of-flight reconstruction, in which it was found that $\Delta t$ was found to depend on the position. It led to a low efficiency and a TOF2 $\Delta t$ offset, causing a momentum discrepancy. This has been fixed by new TOF calibrations. There are still some small discrepancies between data and Monte Carlo and between TOF and tracker.

Global reconstruction is now part of the official offline processing. Global track matching is now available, with upstream, downstream, through-tracks and decays available as well as particle identification (PID), log-likelihoods and confidence levels are provided. There have been improvements in the geometry and the
magnetic field descriptions. Bugs in the diffuser description (in the thickness and the description of the material) have now been resolved. An issue with the interpretation of the alignment corrections has been fixed, but needs to be introduced into the production geometry.

The offline reconstruction is routinely done in the MICE Local Control Room (MLCR), automatically triggered at the end of each run and is available to analyse about one hour after the data is taken. The online reconstruction plots are bundled with the output. Recently, a “globals” version of the reconstruction was added as a second parallel production task. Reprocessing is currently being carried out in the MLCR. It takes about a week. The full Step 4 data will be reprocessed with the new versions of MAUS after the data taking is complete and the tracker calibrations are finalised.

The current job scheduling interface with the Grid is being retired. D. Maletic is the Monte Carlo production manager, which is carried out on the Grid. Monte Carlo productions are now being launched using the DIRAC framework. The job turnaround on the Grid is about one day. New beam libraries have been generated for the now standard pion-beam currents and tuned currents. The Monte Carlo production for the LH$_2$ still needs to be carried out. The framework also needs to be checked for running non-standard Monte Carlo (for example, to simulate analysis systematics).

### 2.6.4 Infrastructure

Need to ensure the availability of hot-swappable spares for a number of components. We need working left and right AFE boards for the tracker. Spares are available, but they need to be flashed, which can only be done from the hall. During the start of ISIS Run 2017/02, we were hampered by a lack of working spare readout modules. However, we have now identified spares at INFN Trieste. A failover data acquisition computer is in place and up-to-date but requires tweaking for the switch-over. The Conditions Database failover has been tested and documented in case it is required.

### 2.7 Commissioning and Operations Plans

In preparation for the 2017/01 cycle, routine maintenance was carried out on the cold heads for the tracker cryostats which involved the warm up of the cryostats. There was evidence that the helium gas had been contaminated by water vapour, with all cryostats showing water contamination. The cause of this is assumed to be due to the use of a contaminated bottle of helium gas. As a consequence, the diagnosis and recovery took up a significant amount of the time available for data taking during 2017/01. Data taking with all of the detectors was only possible during the last week of the user cycle when the shifts were covered 24 hours a day. The super-conducting channel magnets were not run during this cycle, and only straight-track calibration and alignment data were taken. A test of the liquefaction system was successfully carried out at the end of the cycle and a data set was taken using cold gaseous neon as the absorber material.

The ISIS cycle 2017/02 was shifted from June/July to the period 19th September to 29th October 2017. The goals of the user cycle were to take data with the liquid-hydrogen (LH$_2$) absorber for the first time, energise the downstream spectrometer solenoid (SSD) M2 coil and take data with LH$_2$ and, finally, take data with the empty LH$_2$ vessel in the same configurations, to complement the LH$_2$ absorber settings. The MICE Operation Managers were P. Franchini, D. Rajaram and M. Uchida.

Cycle 2017/02 was very successful. The LH$_2$ system worked flawlessly, thanks to the LH$_2$ team. Many superconducting solenoid current settings were able to be accomplished, thanks to the support from the magnet team.
Figure 4: The integrated number of particle triggers collected by the MICE experiment during the Step IV data-taking period in 2015-2017. MICE has collected $230 \times 10^6$ particle triggers and $92 \times 10^6$ in the last 2017/02 user cycle.

from the UK (J. Boehm, J. Cobb) and the USA (A. Bross, S. Feher, M. Palmer). Data-taking was very smooth, except for instabilities in the ISIS accelerator at the end of the cycle. On the night of 17th October 2017, the day after the liquid-hydrogen vessel had been emptied and evacuated in preparation for empty-channel data taking, the main dipole magnet in ISIS sector 5 failed. The magnet exchange and recovery took more than 36 hours. Initial attempts to recover ISIS operation at 700 MeV were unsuccessful. Eventually, ISIS operations resumed but in an unstable situation and the run had to be cut short. All the data with the LH$_2$ was taken, but there still remains quite a large amount of empty vessel data to complement the LH$_2$ data. For this reason, we requested to take data during the 2017/03 cycle, to finalise the Step IV physics programme.

Figure 4 shows the integrated number of particle triggers collected between 2015 and 2017 ($230 \times 10^6$ triggers). The stable operation of the full channel during most of the ISIS 2017/02 channel and 24 hour data-taking allowed for $92 \times 10^6$ triggers to be taken. However, the problems with the ISIS accelerator at the end of the cycle, impeded the completion of the empty vessel data. A summary of the data taken during 2017/02 can be seen in Figure 5.

Between ISIS cycles 2017/01 and 2017/02 the following maintenance tasks were carried out:

- Replace filters in the compressors in the Hall;
- Test the AMI controller;
- Partial warming of the Decay Solenoid;
Review current alarm limits in the alarm handler;
• Change patch fibres for the target;
• Restart conventional magnet control crate; and
• Perform maintenance on the Hall Air-conditioning system.

2.7.1 Planning for cycle 2017/03

A proposal was put forward to the STFC to operate in the ISIS Cycle 2017/03 (14th November to 20th December 2017) to complete the approved scientific programme of Step IV. The principal objectives for data taking in Cycle 2017/03 will be to:

1. Complete the empty-vessel data taking for the analysis of the liquid-hydrogen (LH2) absorber data. This data is essential to complete the analysis of the liquid-hydrogen data;
2. Take empty-channel data to allow the systematic uncertainties in the study of the evolution of normalised transverse emittance with a lithium-hydride absorber to be evaluated. To date, lithium-hydride-absorber data for this study has been taken with match coil 2 in the downstream solenoid off. A complementary empty-channel data set is required to quantify the systematic uncertainties; and
3. Take data with a lithium-hydride absorber and with SSD(M2) energised to exploit the improved optics and enhance the lithium-hydride-absorber emittance-evolution study. The empty channel data taking described in 2 will include data taking with SSD(M2) on.
4. If time permits at the end of the run, it may also be possible to make a first study of emittance exchange using a plastic wedge absorber provided by the University of Mississippi and demonstration of 6D emittance change (Figure 6). Analysis of this data may provide valuable information for the optimisation of the g - 2 experiment at FNAL, which is considering the use of such a wedge, and for 6D-cooling considerations for a muon collider.

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<td>Channel</td>
<td>Run</td>
<td>Solenoid/ Flip?</td>
<td>M2D</td>
<td>Particle triggers (k)</td>
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Figure 5: Particle triggers and their type collected during the ISIS 2017/02 user cycle.
Figure 6: The simulated six-dimensional (top) and longitudinal (bottom) emittance change in the MICE beam line. The solid red circle shows the position of the tracker reference surface.
The detailed data-taking plan can be seen in Figure 7. It is a complicated running period with at least two absorber changes and many different cooling channel settings. Data taking in ISIS Cycle 2017/03 will not require investment from the STFC above the current approval for financial year 2017/18 due to the sale of the RF triodes and tetrodes to ISIS. The data taking will increase both the quality and the quantity of publications from MICE.

2.8 Analysis

The publications and conference contributions made by UK members of the collaboration, including those in 2017, can be found in Appendix B. A summary of the Step IV data-taking so far includes:

- June/July 2015: Tracker commissioning;
- September/October 2015: Magnet commissioning;
- December 2015: Scattering in Xenon;
- February/March 2016: Straight tracks scattering programme (LiH);
- July 2016: Single magnet powering studies;
- September/October 2016: Field-on material physics studies;
- November/December 2016: Field-on emittance evolution studies;
- February/March 2017: Flip-mode LiH emittance evolution studies;
- May 2017: Straight tracks scattering programme (Ne);
- September/October 2017: Liquid hydrogen emittance evolution and scattering programme.

A more detailed summary of the data taken during the ISIS 2017/02 user run includes:

- 19-21 September: Straight track alignment and calibration;
- 21-27 September: Beta ~800 mm; p = 140 MeV/c; solenoid mode; LH2 filling;
- 27-28 September: Beta ~800 mm; p = 200 MeV/c; solenoid mode; LH2 absorber;
- 28-29 September: Straight track running at 170, 200 MeV/c; LH2 absorber;
- 29 September - 2 October: Beta ~700 mm; p = 170, 200, 240 MeV/c; flip mode; LH2 absorber;
- 2-3 October: Beta ~1200 mm; p = 140 MeV/c; sflip mode; LH2 absorber;
- 3-4 October: Beta ~700 mm; p = 170, 200, 240 MeV/c; flip mode; LH2 absorber;
- 4-5 October: Straight track running at 170, 200 MeV/c; LH2 absorber;
- 5-6 October: Beta ~800 mm; p = 140 MeV/c; solenoid mode; wrong M2D polarity; LH2 absorber;
- 6-7 October: Straight track running at 170, 200, 140 MeV/c; LH2 absorber;
7-9 October: Beta ~800 mm; p = 140 MeV/c; momentum scan; solenoid mode; M2D on; LH₂ absorber;
9-10 October: Beta ~800 mm; p = 140 MeV/c; solenoid mode 3T; M2D on; LH₂ absorber;
10-11 October: Straight track running at 240 MeV/c; LH₂ absorber;
11-12 October: Beta ~800 mm; p = 140 MeV/c; flip mode 2T; M2D on; LH₂ absorber;
15-16 October: Beta ~800 mm; p = 170 MeV/c; flip mode 2T; M2D on; LH₂ absorber;
16-17 October: Beta ~800 mm; p = 170 MeV/c; flip mode 2T; M2D on; empty absorber;
17-23 October: Beta ~800 mm; p = 140 MeV/c; flip mode 2T; M2D on; empty absorber;
23-24 October: Beta ~800 mm; p = 170 MeV/c; flip mode 3T; M2D on; empty absorber;
24-25 October: Straight track running at 170, 200 MeV/c; empty absorber.

The main analyses currently being pursued, which will lead to a publication, include:
- Measurement of emittance;
- Straight tracks multiple Coulomb scattering with LiH;
- Phase space density and emittance evolution;
- Performance of the MICE diagnostic systems (including energy loss measurements);
- Multiple Coulomb scattering with field on.

Furthermore, there are other technical papers to support the analyses:
- The MICE Analysis and User Software (MAUS) Framework;
- Description of the Muon Ionization Cooling Experiment;
- The MICE RF system;
- The MICE magnetic channel;
- The MICE liquid hydrogen absorber.

### 2.8.1 Emittance measurement

The paper entitled “Direct measurement of emittance using the MICE scintillating-fibre tracker will document the techniques used to measure the emittance of an ensemble of muons and report the precision of the measurement. During the reporting period, a study has been made of aperture defined by the material contained in the diffuser mechanism with the plates retracted. In addition, progress has been made to complete the detailed study of systematic uncertainties in the measurement that must be completed before the data can be published. A preliminary plot of the emittance measurement with the upstream tracker (TKU) is shown in Figure 8.

### 2.8.2 Multiple Coulomb scattering with LiH

Progress on the analysis of multiple Coulomb scattering with the LiH absorber has resumed following the appointment of J. Nugent at Glasgow. The measured RMS of the projected scattering angle distribution of muons on lithium hydride is measured as a function of momentum. The analysis compares different models of multiple scattering (Moliere, GEANT4 and a parameterisation of the Wenzel scattering cross-section carried out by Carlisle and Cobb), shown in Figure 9, with the data.

The comparison is carried out by performing the convolution of the model with the empty absorber data and is compared to the LiH absorber data. A deconvolution method based on Bayes theorem is used to extract the underlying distributions from the data. The projected $\theta_x$ and $\theta_y$ projection angle distributions are shown as a
Figure 8: Emittance measurement with the upstream tracker.

Figure 9: Projection angle multiple Coulomb scattering distributions for different models (Moliere, GEANT4 and a parameterisation of the Wenzel scattering cross-section carried out by Carlisle and Cobb.)
Figure 10: Multiple Coulomb scattering distributions for the projection angle \( \theta_x \) (left) and \( \theta_y \) (right).

The data is compared to the predictions of the PDG parameterisation of multiple scattering

\[
\theta_0 \approx \frac{13.6 \text{ MeV}}{p_{\mu} \sqrt{\mu_{rel}}} \left[ 1 + 0.0038 \ln \left( \frac{\Delta z}{X_0} \right) \right],
\]

and to the expectations of Geant4. Neither model gives a good description of the data. An attempt has also been made to describe the data using a fit to a function motivated by the momentum and velocity dependence of multiple Coulomb scattering. The fit gives a poor description of the data. Further investigation of the data analysis, the simulation and the discrepancy between the measurement and the simulation is underway.

Progress has been made in the study of energy lost by muons as they pass through the absorber. Artefacts have been observed in the deconvolution analysis that indicate that the longitudinal-momentum resolution of the diagnostic system may be insufficient for a satisfactory deconvolution analysis to be made. Good agreement has been found between the energy-loss distribution obtained in data taken with the LiH absorber and the distribution obtained by convoluting a Landau distribution with the distribution obtained in data taken with no absorber present (Figure 11).

2.8.3 Emittance evolution

To investigate the evolution of emittance, the distribution of amplitude upstream and downstream of the absorber has been measured. Reduction in RMS emittance can also be caused by scraping, so the two effects are difficult to disentangle. Figure 12 shows the change in emittance between upstream and downstream of the LiH absorber for a 10 mm beam. The increase in emittance in the tracker is due to the unmatched beam caused by the absence of the M1 and M2 coils in the downstream tracker. This produces beam filamentation in the downstream beam that causes apparent emittance growth.

An unambiguous way of observing cooling consists in an increase in the number of muons (muon density) with low transverse amplitude. The amplitude distribution measured upstream and downstream of the absorber is shown in Figure 13 for 140 MeV/c muon beams with initial normalised transverse emittance of 10 mm. The amplitude distribution of muons measured in the upstream tracker which are not observed in the downstream tracker (“scraped muons”) is also shown. The number of muons scraped out of the beam in the sample presented here is small but non-negligible. This observation is qualitatively consistent with cooling since the muon density at low amplitude is larger downstream than upstream.
Figure 11: Measured energy loss in lithium hydride compared to the Bethe-Bloch formula.

Figure 12: Emittance evolution observed in the LiH absorber.
Pseudo-matched beams can be generated by selecting a sample of the beam where scraping is negligible and measuring its sub-emittance (Figure 14). This approach seems to clean up the distribution in the downstream tracker and the emittance is shown to be flat downstream, which would be a sign that this beam has been selected to be matched. This approach can be used to demonstrate cooling, but care has to be taken to ensure that one does not artificially generate cooling through a biased sampling of the beam. The systematic errors associated with these selections still need to be determined.

Some of the settings taken with LiH in ISIS user runs 2016/04 and 2016/05 are summarised in Figure 15. Systematic errors have not been determined.

3 MICE Upgrade: Ionization Cooling Demonstration

The Collaboration acknowledges that STFC has made an official statement that there is no funding available for the MICE upgrade, which was presented as a Statement of Interest to the Accelerator Strategy Board.

There have been conversations with A. Zatsev (Deputy Director, responsible for experimental physics) and V. Garkusha (Head of Beam Department) to deploy MICE or an upgrade of MICE at IHEP, Protvino in Russia. The feasibility of the implementation of the MICE cooling demonstration at the 70-GeV machine at IHEP in Protvino was discussed. A possible layout was identified (Figure 16). Ken Long visited IHEP on 24th August 2017 and had a tour of the accelerator and experimental area, had a discussion with designers and engineers, and met with N. Tyurin (ex-director in lieu of present director who was on holiday).

There are issues of moving the equipment to Russia and establishing a new experimental collaboration, as well as issues of safe execution of the installation and operation of the equipment. IHEP wishes to have a strong international collaboration and would like to have CERN involvement since they want to see collaboration, resources and scientific activity flow from west to east as well as from east to west.

P. Snopok, from IIT, investigated a possible 6D-cooling experiment at Protvino and presented it at the last Collaboration Meeting. He proposes that the simplest and most feasible configuration would include a vacuum
Figure 14: Sub-emittance of a selection of muons, as a core fraction of the parent 10 mm beam traversing a LiH absorber.

Figure 15: Reconstructed changes in emittance for a variety of beam settings (solenoid and flip mode) taken during ISIS user periods 2016/04 and 2016/05, for 6 mm and 10 mm initial beams traversing a LiH absorber.
rectilinear cooling channel, with alternating wedge absorbers. This design is close to the early stage of the cooling channel capable of handling the beam from the phase rotator at a muon collider. The magnetic coils are tilted in the same plane and the wedge absorbers could be either liquid hydrogen or LiH. There should be enough space in the facility as the overall length will be approximately 20-30 m (Figure 17). This channel has been studied in detail as part of the MAP effort into a muon collider.

4 Financial and Risk Summary

4.1 FY 2017/18

After the Cost-to-completion review, the final settlement for MICE from FY 2016/17 until FY 2019/20 is found in Table 1. The total cost to STFC of finalising MICE up to the end of the Step IV programme is £5.7M.

The latest spend data for MICE-UK for financial year 2017/18 indicates an underspend on the resource line in the region of £130K. This underspend is attributable to the following effects:

- Capital income to the project from the sale of assets purchased for the RF project: MICE-UK agreed the sale of 4 tetrodes and 3 triode glasses to ISIS during calendar year 2017. The income of £194.73k has been transferred to the capital budget because the RF components were originally purchased using capital funds;
- Reduced demand on the resource budget to support the capital project due to the income to the capital line: has allowed the project team to continue to fund the STFC staff involved in the development of the liquid-hydrogen-delivery system and absorber from the capital budget; and
- Over the year to date, operation of the spectrometer solenoids has not required the level of electrical expert resource that had been anticipated: as none of the risks identified have yet been realised and the new QPS system has effectively protected the magnets in operation. This has had the effect of lower than predicted hours booked for electrical works and reduced spend to date.

The cost to STFC of the MICE-UK project through to the end of ISIS Cycle 2017/02 is shown in Table 2. The
Figure 17: Layout of the vacuum rectilinear cooling channel in the 70 GeV accelerator at IHEP in Protvino.
Table 1: Settlement after the MICE Cost-to-completion Review from FY 2016/17 until FY 2019/20.

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Table 2: Cost to the STFC of the MICE-UK project cost at end July 2017 with the projected cost to end October 2017.

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Table 3: Cost to STFC of the MICE-UK project at end July 2017 with projected cost to end December 2017. The cost to December includes the cost of operation in Cycle 2017/03.

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<td><strong>695.76</strong></td>
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table shows a projected underspend of £137.53k. It should be noted that these figures do not include allowance to make the experimental Hall safe at the conclusion of operations. The transfer of funds from ISIS for the tetrodes and triodes is in progress and the asset numbers is almost complete. It would be wise to allow for a minimum of two weeks additional work from a small team to ensure equipment is left in a safe state, ISIS is not inconvenienced by the MICE interlock systems and degradation of valuable assets is minimised. Costs to cover such additional works should not exceed £20k.

Table 3 shows the projected MICE-UK budget including ISIS Cycle 2017/03. Staff numbers have been adjusted to reflect the current booking rate. Staffing levels required for running during ISIS 2017/02 have been used as a guide to workload, with some contingency for additional works that may arise. For instance, the absorbers in the Cryomech compressors used for the spectrometer solenoids are all near the end of their life and replacements are on hand. These absorbers should be fitted at the earliest convenient time to protect the investment in the magnets whether the extension is granted or not. Additional provision is made in the travel budget to allow for the cost associated with UK staffing for Cycle 2017/03. The cost projection shows that the MICE-UK project remains within the approved spend profile and a reduced underspend remains.

Table 4 shows the projected MICE-UK budget including ISIS Cycle 2017/03 until March 2018. Extra cost is added for STFC staff to tidy up the MICE hall and leave it in a secure state. The MICE hall will remain in a standby state until June 2018, in order to be able to react in case any extra data-taking is required due to some unforeseen contingency. The capital spend up to March 2018 is now complete. Administrative staff remains until March 2018, to cover the collaboration meeting in February. Additional travel costs are added for November to December to cover the ISIS 2017/03 run. The cost projection shows that the MICE-UK project still remains within the approved spend profile.

4.2 Risk

There have been several changes to the Risk Register over the reporting period. Key risks from the project risk register are presented in Table 5. A summary of the principal changes to the risk register follows:
Table 4: Cost to STFC of the MICE-UK project with projected cost to end of March 2018. The cost to March includes the cost of operation in Cycle 2017/03, staff cost to tidy up the MICE hall to leave it in a secure state and travel to the collaboration meeting in February.

<table>
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- **MICE 19, Failure of M2 in SSD and MICE 20, Failure of helium space feed-through in SSD:**
  These risks are reduced in likelihood as operation with SSD(M2) has not been problematic to date. To the extent that past performance is a guide to future operation, the risk that SSD(M2) will fail on operation at currents above 50 A has not been realised.

- **MICE 23, Risk of equipment failure/breakage:**
  The risk associated with the failure of equipment continues to be relevant as the equipment ages. The graceful degradation of the cryo-coolers for the tracker followed by the failure of one cooler on Cryo 4 is a good example. Most of the costs related to maintenance and replacement of equipment had been anticipated and it was therefore possible to manage the costs so incurred within last years budget.

- **MICE 30, Insufficient international manpower available:**
  This is reduced in likelihood as discussion in the US and realisation of funds from the sale of excess superconductor has eased the previous financial situation.

- **MICE 38: Decreased in-depth knowledge of controls and monitoring system:**
  This risk is retired as new staff are fully embedded and there is now demonstrable improvement in controls operation and problem solving.

- **MICE 39: Reduced ISIS beam-time during 2017/02:**
  Failure of the ISIS dipole in super-period 5 at 03:30 on 17th October 2017 has required significant effort to repair and as of 18:51 on the 18th October 2017, work to diagnose and resolve related failures continues. Stable operations were re-established but had to finish run early. As a consequence, MICE could not collect the vital empty-channel data that is required for all publications using the liquid-hydrogen data taken this Cycle. Operation during ISIS 2017/03 would allow the collaboration to recover the beam-time lost due to the failed ISIS dipole.

- **MICE 40 SSU CC5 further degradation:**
  Risk that CC5 performance is further compromised during ISIS 2017/03. This risk, if realised, could wipe out several days of data taking. Preparations have been made to allow for a rapid replacement operation, however this is not without risk itself. It is likely some data-taking time would be lost to assessment in any case. As the data-taking plan can fill the available time, it is likely that the realisation of this risk would leave some tasks incomplete.

The risks associated with the Step IV programme are shown in Table 5. The major risks are much reduced due to the removal of all risks associated with RF power and cavity work and the hydrogen system.
Table 5: MICE UK Risk Register November 2017.

<table>
<thead>
<tr>
<th>ID</th>
<th>Risk Description</th>
<th>Potential impact on project</th>
<th>Risk Score</th>
<th>Ownership</th>
<th>Proposed Action</th>
<th>Post-Risk Score</th>
<th>Comment / Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICE 3</td>
<td>Magnetic field effecting operation of electrical equipment relating to the continued operation of the cooling channel magnet systems and detectors.</td>
<td>Inability to operate the cooling channel</td>
<td>5 5 20</td>
<td>MICE-UK / MAP</td>
<td>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.</td>
<td>1 4 4</td>
<td>Much work has been completed. Non staff risk persists in the event of additional material being required.</td>
</tr>
<tr>
<td>MICE 4</td>
<td>Extended period of re-training for the lattice of magnets.</td>
<td>Timescales for the training period, cost of the amount of LHe required to carry out the training. Expert personnel required to be available for magnet operations over a protracted period of time.</td>
<td>4 5 20</td>
<td>MICE-UK / MAP</td>
<td>Magnet integration task force to define commissioning method to keep schedule and cost to a minimum.</td>
<td>3 4 12</td>
<td>Each re-cool and fill of the Spectrometer Solenoid can take up to 500 LHe, AFC remembers it's training. Each full lattice quench could cost in the region of £7K.</td>
</tr>
<tr>
<td>MICE 5</td>
<td>Resourcing issues from the STFC and national labs</td>
<td>Inability to complete significant sections of work on agreed time or cost scales.</td>
<td>4 5 20</td>
<td>MICE-UK / MAP</td>
<td>Realised. Escalation of the issue to the STFC and DOE.</td>
<td>2 4 8</td>
<td>Project scope has changed leading to a different labour profile required to complete the project.</td>
</tr>
<tr>
<td>MICE 16</td>
<td>Failure of a Focus Coil Magnet</td>
<td>Internal cold mass or associated equipment deep within the assembly. LTS leads.</td>
<td>3 5 15</td>
<td>MICE UK</td>
<td>Follow all specific operational aspects as defined by the experts for the superconducting magnet</td>
<td>1 5 5</td>
<td>Investigation and fix would be extremely costly and extensive with regard to schedule.</td>
</tr>
<tr>
<td>MICE 17.1</td>
<td>Failure of Upstream Spectrometer Solenoid Magnet</td>
<td>Internal cold mass or associated equipment deep within the assembly. LTS leads.</td>
<td>4 5 20</td>
<td>MAP</td>
<td>New quench protection system</td>
<td>1 5 5</td>
<td>Has the same design issues as SSD, confidence improving with operation and testing with forces.</td>
</tr>
<tr>
<td>MICE 19</td>
<td>Failure of M2 in SSD.</td>
<td>Reduction in scientific output and resulting cooling effect.</td>
<td>3 4 12</td>
<td>MICE-UK / MAP</td>
<td>Maximise data collection before running M2.</td>
<td>1 4 4</td>
<td>Consider completing data set for one absorber.</td>
</tr>
<tr>
<td>MICE 20</td>
<td>Failure of Helium space feedthrough in SSD.</td>
<td>Reduction in scientific output and resulting cooling effect.</td>
<td>3 4 12</td>
<td>MICE-UK / MAP</td>
<td>Limit number of quenches</td>
<td>1 4 4</td>
<td></td>
</tr>
<tr>
<td>MICE 23</td>
<td>Risk of equipment failure/breakage</td>
<td>Cost of repair/replacement. Time lost during recovery</td>
<td>3 3 9</td>
<td>MICE UK</td>
<td>Spares inventory / proper planned maintenance</td>
<td>3 1 3</td>
<td>To some degree inevitable due to age of equipment</td>
</tr>
<tr>
<td>MICE 24</td>
<td>Problems during magnet string commissioning</td>
<td>Further compromise of SSD / Delays to program</td>
<td>3 5 15</td>
<td>MICE UK</td>
<td>Conservative magnet settings.</td>
<td>3 3 9</td>
<td>Always recognised as a challenge - complicated and exacerbated by SSD situation</td>
</tr>
<tr>
<td>MICE 29</td>
<td>Further compromise of SSD performance</td>
<td>Slower data-taking, more remedial action required</td>
<td>3 5 15</td>
<td>MICE-UK / MAP</td>
<td>Power supply improvements, feedthrough heating improvements.</td>
<td>2 5 10</td>
<td>Anomalous earth leakage and noise seen - now absent, but as yet unexplained.</td>
</tr>
<tr>
<td>MICE 30</td>
<td>Insufficient international manpower available.</td>
<td>Delay in remeasurement of non-UK assets and associated reduction in effort on other tasks.</td>
<td>4 3 12</td>
<td>MICE-UK / MAP</td>
<td>Discussion with international management to maximise staff availability.</td>
<td>2 3 6</td>
<td>Long standing issue.</td>
</tr>
<tr>
<td>MICE 39</td>
<td>Reduced ISIS beamtime during 2017/02</td>
<td>Insufficient LH2 ‘empty’ data</td>
<td>3 5 15</td>
<td>MICE UK</td>
<td>Operation during ISIS 2017/03</td>
<td>1 5 5</td>
<td>Known ISIS dipole fix in delivery phase</td>
</tr>
<tr>
<td>MICE 40</td>
<td>SSU CCS further degradation</td>
<td>Loss of data during repair</td>
<td>3 4 12</td>
<td>MICE UK</td>
<td>Prepare for CC swap</td>
<td>2 3 6</td>
<td>Mechanical issue may deteriorate at any time</td>
</tr>
</tbody>
</table>
Appendices

A MICE-UK Collaboration

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B Communication


Proceedings and Talks by UK authors at Conferences and Workshops (2013-2017):

4. C. Hunt on behalf of the MICE Collaboration, “Current results from the study of emittance evolution in MICE”, 11th International COOL Workshop (COOL 2017), Bonn, Germany, 18th-22nd September 2017.
41. C. Hunt, “Simulating the Production and Effects of Dark Currents in MICE Steps V and VI”, International Particle Accelerator Conference (IPAC’14), Dresden (Germany), June 2014.
44. A. Dobbs, D.M. Kaplan, P. Snopok, “Progress Towards Completion of the MICE Demonstration of Muon Ionization Cooling”, International Particle Accelerator Conference (IPAC’14), Dresden (Germany), June 2014.
49. P. Hanlet, “MICE Controls”, 14th International Conference on Accelerator & Large Experimental Physics Control Systems, San Francisco, California, USA
52. C. Heidt, “Progress of MICE, the International Muon Ionization Cooling Experiment”, APS April Conference, 2013.
57. S. P. Virostek, D. Li, H. Pan, S. Prestemon, R. Preece, “Assembly and Test of a Modified Spectrometer Solenoid for MICE”, 4th International Particle Accelerator Conference (IPAC 2013), 12-17 May 2013, Shanghai, China.
58. K. Ronald et al., “The RF system for the MICE experiment”, 4th International Particle Accelerator Conference (IPAC 2013), 12-17 May 2013, Shanghai, China.
C MICE-UK PhD Theses

Theses by UK-based PhD students on MICE (2011-2017):


3. Celeste Pidcott, “Multiple Scattering and Particle Identification in the Muon Ionisation Cooling Experiment”, PhD University of Warwick, April 2017.


D Future PhD student support plan

Four PhD places have been funded using the funds for three full time equivalent PhD students, which were awarded to MICE in the Cost-to-completion review award (126 person-months). The students are as follows:

- Brunel University and RAL: share one full time student, jointly supervised by Paul Kyberd and Chris Rogers;
- Imperial College London: has one PhD student supervised by Jaroslaw Pasternak and Ken Long;
- Strathclyde University and Glasgow University: share one full time student, supervised by Kevin Ronald and Paul Soler;
- Warwick University: has one student, supervised by Steven Boyd.

The Brunel/RAL student, the Imperial College student and the Warwick student commenced their PhD studies in October 2017. Strathclyde and Glasgow are currently interviewing candidates and it is hoped that a student will commence in January 2018.