ISIS TS1 Project Summary

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Abstract. Following a feasibility phase which began in 2012, the TS1 upgrade project entered its implementation phase in April 2016. The project is, in essence, a circa £16.25M sustainability project for target station 1 (TS1) of the ISIS facility, Rutherford Appleton Laboratory (RAL), which has been in operation since 1984. Its aims are: to secure the future of TS1 and enable it to operate for many more years, to improve flexibility and future upgradability, to make operation of the target station easier, a neutron performance increase of up to a factor of 2 (on some instruments), as well as providing a strong technical foundation on which the facility can continue to build and develop in the coming years.

This paper will provide a summary of the project structure and progress to date, as well as covering some of the encountered challenges and successes. It will further detail the motivations behind the project’s inception, including the critical success factors.

The implementation phase includes design progression, procurement, verification and validation testing, pre-installation testing, along with a large number of other supporting activities. It is currently envisaged that a long operational shutdown of ISIS will occur in a window of 2019-2021, with the project looking to exploit this opportunity for the strip-out, installation and commissioning work required to bring to fruition the planned changes.

1. Introduction

1.1. Background
Target station one (TS1), first produced neutrons in December 1984. Originally designed with a depleted uranium target and with a proton beam repetition rate of 50Hz. With the construction and operation of Target station 2 (TS2) in 2009, TS1 now takes 4 out of 5 proton beam pulses. The many years of operational experience from both target stations, new design techniques (simulation tools for example) and with TS1 being optimised for a uranium target, it was felt that some significant improvements could be made with only moderate expenditure (relative to an accelerator upgrade needed to achieve the same increases).

The project was initiated in 2012 with the creation of a project brief stating the general aims and providing initial estimates of timescales and costs. A 3.5-year definition phase followed, leading to the presentation of a business case to the ISIS management committee in October 2015, who recommended the project be implemented. The first project board meeting, was held in April 2016, where the project management plan was formally approved and moved the project into the implementation phase.
1.2. **Project overview**

The TS1 project is part of ISIS’ commitment to ensuring the sustainability of the facility, utilising the operational experience from TS1 and TS2 as well as other spallation facilities, coupled with the latest simulation techniques and engineering best practice to secure the future of TS1 and enable it to operate for many more years. The project also aims to; provide improved flexibility for future target or moderator changes, make operation of the target station easier, provide a neutron performance increase (of up to a factor of 2, on some instruments), provide confidence in the ongoing operation of TS1 to enable future instrument upgrades and finally to improve the knowledge and skills of staff for future projects, such ‘ISIS 2’.

The project was costed using both ‘bottom up’ and ‘top down’ approaches, incorporating actual delivery experience of similar projects; phase II instruments and the construction of TS2. The final value has value added tax (VAT) at 20%, a contingency of 10% (which is expected to be spent as part of the project) and no overhead on labour. For the cost of the project to be easily compared to a ‘do nothing’ option, cost estimates accounted for the disposal of active components deemed to be outside of normal operations (for instance the reflector assembly). This led to an overall total cost of £16,254k at 2015 (Pre-Brexit) prices.

The project includes a complete refurbishment of the internals of the target station, incorporating: the target, reflector and moderators (TRAM) assembly; the fluid systems (water cooling, cryogens for the moderators and inert purge gases) which sit behind the TRAM, the connected instrumentation and controls systems needed for correct operation of the target station. The scope of this work is visually demonstrated by Figure 1, below. The project does not include any significant changes to the TS1 neutron or muon instrument suite, although the development of instruments will carry on in parallel. Several other supporting activities are also required to bring the vision of the project to fruition.

![Figure 1 - A 3D CAD model showing the TRAM assembly on the complete target trolley, with the surrounding shielding and infrastructure removed for clarity. This is a representation of the current ISIS TS1 arrangement](image)

The implementation phase is scheduled to be completed in the latter part of 2021, with the hand over to operations. This can be crudely segregated into several sub-phases; design (2016-2017), procurement and delivery (2018-2019), on-site testing and pre-installation checks (2019-2020), strip-out of existing equipment (2020-2021), installation (2020-2021), pre-beam commissioning (2020-2021), with-beam commissioning (2021) and close-out (2021). The long operational shutdown is constrained to be no more than 12 months in duration, during this time there is the potential to have some period of beam operations to TS2 only.

1.3. **Project constraints**

During the definition phase the high-level constraints were identified and these are as follows; optimise the design (neutronic and engineering) for a beam power 200µA on TS1 target, maintain...
normal operating parameters currently adhered to for beam position or profile, maximum allowed operational shutdown duration is 12 months, low-risk solution (no increased technical risk during operation), no instrument should be worse off in terms of performance after the project when compare to the present and the existing infrastructure (current beam line inserts face where they do, no significant changes to the biological shielding, accelerator height is unchangeable and the irradiation tube which was installed but never used and now back filled with steel shot as shielding, is to remain untouched. With these constraints in place, it applied bounds for the subsequent neutronic and engineering design work. Although some of these constraints proved challenging to navigate, ultimately it was fundamentally important to have them clearly defined, in order to focus the limited design efforts in the most effective manner.

2. How the project is structured

2.1. Work breakdown structure

The project has been broken down into 20 work packages (WPs) which are managed by 13 work packages managers (WPMs). The often highly-interlinked WPs were selected in such a way that all aspects of the project are covered, from the design of key components to the safety activities and on to the project hand-over and transition to operations.

The project manager, Stephen Gallimore is supported by a technical lead engineer, David Jenkins, and a lead scientist, Rob Bewley. The main bodies providing oversight, challenge and support are; a project board, a technical advisory board and a safety working group. The composition of these bodies was chosen as to provide a broad range of experience and knowledge in scientific, technical and administrative fields from within ISIS, greater STFC and the external community the facility serves.

Over 50 ISIS and other STFC staff have been directly involved with the project so far, with this number likely to grow further as it progresses. This resource has been and will continue to be supplemented with contractors in several areas, such as design, planning and waste management. The project has a dedicated radiological protection advisor (RPA) embedded in the project team.

3. Key areas of work and progress to date

The TRAM assembly, shown in Figure 2, represents the key components of the project in terms of scientific performance. The technical details of these components are covered in more detail by [1].

![Figure 2 - A schematic 3D cut-away model showing the target at the centre, surrounded by the different moderators, which in turn surrounded by the reflector.](image1)

![Figure 3 - A CAD model of the proposed TRAM assembly, support frame and void vessel back door for the TS1 Project. The reflector assembly is in its closed position, so the internal components are not visible.](image2)
The TRAM assembly is supported by a frame which is cantilevered from the ‘back door’, as shown in Figure 3. This support frame is the only item that operates inside the void vessel (pressure vessel surrounding the TRAM assembly that contains the helium atmosphere during operation) that has not been replaced or modified in some way since its initial installation. The analysis work carried out as part of the design phase is covered by [5].

As previously mentioned, the TS1 project is far more than just the re-optimisation and redesign of the TRAM assembly it also includes a significant amount of work in many other supporting areas, such as controls and instrumentation, as well as large scale replacement and redesign of the services (inert gas, vacuum, water and cryogenic fluids) [6] that feed the TRAM assembly and allow it to operate under its desired parameters. All of this is supported by neutronic and scientific evaluation; better understanding the current situation [7][8][9], often including empirical measurements and assessing the impact of the proposed changes using suite of simulation tools. In addition, there are a number of other activities, for instance, overseeing the construction and utilisation of the planned full-scale mock-up of the TRAM inside the remote handling cell (RHC) [10], communications (both internal and external to ISIS), safety related work (for example production of prior risk assessments and overseeing HAZOPs) and planning and preparation for the dealing with and disposal of the active waste that will be generated.

4. The long shutdown
The long operational shutdown will be when the vast majority of strip-out and installation work is carried out. The plan is currently to have approximately 9 months with the beam off and then 3 months of with beam commissioning. During the long shutdown, other projects across ISIS will be carried out, so good communication and robust planning will be essential to minimise conflict in terms of resource utilisation and requirements for running. Systems are being designed in a modular fashion (where possible) and allow for as much testing and commissioning prior to installation as possible.

Another critical aspect during the long shutdown will be the management of radioactive waste. The TS1 project will generate a significant volume of material that will need to be size-reduced, categorised and containerised prior to either storage and/or disposal.

5. Challenges and benefits

5.1. Challenges
As with any project of this technical complexity, duration and budget, there are numerous challenges faced throughout its life; this project is expected to be no different. Below are some of the challenges already experienced or expected:

- Staff resources – e.g. availability of operational staff, constraints on staff numbers
- Procurement & Production – e.g. production delays and contract placement issues
- Physical space (for testing and the management waste)
- Waste management (how to deal with the various waste streams and volumes of waste)
- Scheduling of the long shutdown
- 30+ year old surprises (with the age of the facility these are almost inevitable)

5.2. Benefits already realised
Many of the benefits from this project will only be realised after the successful completion of the long shutdown and some will require years of post-project operation to truly assess. However, the project has already delivered some benefits:

- Better understanding of what we have than probably at any time since TS1 was built
- Have already up-skilled staff – knowledge sharing as well as technical exposure
- Have been able to diagnose and correct existing issues – an example of this is detailed in [11]
- Better records of decisions and the reasons behind them

The project will hopefully continue to maintain these benefits and deliver more throughout its lifetime.
6. Summary

The TS1 project is a major project being undertaken by ISIS to secure the future of the facility. By 2021 it aims to have delivered on time and on budget:

- Extended target station lifetime
- Improved operations
- Increased performance for some beam lines
- Increased the knowledge, skill and experience level of staff
- Provide confidence for the future

The project is currently on track to complete on schedule and on budget. The project is a major activity for the ISIS design division with significant support from a wide variety of staff across ISIS and STFC.

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