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Development of Rail Transport Solution to Support Transport of Large Nuclear Packages on Restricted Rail Routes

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ABSTRACT

For many years BNFL (now Sellafield Ltd) has transported spent nuclear fuel to Sellafield via Barrow using specially designed rail vehicles. Since the time of first transport (1960s), packages have developed and grown increasing in capacity, size and weight, thereby reducing the number of transports required and increasing efficiency. Unfortunately the UK rail infrastructure has not developed and to this day has a much lower, narrower loading gauge than the neighbouring continental European networks.

The reprocessing market has now matured to the point where spent fuel packages are no longer the main transport stream for Sellafield Ltd, and instead the focus is on the preparation for export of high level waste and MOX fuel from Sellafield. The high level waste packages in particular are designed for the larger continental European rail networks and as such will be the largest, heaviest nuclear packages ever to be transported in the UK, exceeding the capabilities of the existing rail vehicles and challenging the infrastructure.

Initially it was believed that the transport of these packages would be impossible without dramatically modifying the existing infrastructure or the transport packages, both very expensive and time consuming solutions. International Nuclear Services (a subsidiary of Sellafield Ltd) have worked extremely closely with rail industry experts and UK rail regulators to develop a rail solution, which pushes the bounds of the vehicle design within the existing rail infrastructure to accommodate these large packages. Previous UK rail vehicle designs allow for packages of up to 2.5m diameter and 116te max payload whilst the new development of rail vehicle design allows for up to 2.8m diameter packages and 126te max payloads. The new generation of rail vehicles will improve the transport capabilities of International Nuclear Services Ltd and increase the possibilities for future transport flask designs.

This development in new rail vehicle design has been achieved through the use of computer aided engineering tools, project integration and the challenging of the UK rail regulations resulting in concessions, all of which have been approved by the UK rail vehicle licensing authorities. The new vehicles are scheduled to be ride-tested in December 2007 and to be in operation from 2008 onwards.

INTRODUCTION

International Nuclear Services Ltd. (formerly British Nuclear Fuels, International Transport) have developed a rail transport solution, which is capable of carrying larger, heavier packages on restricted rail routes without the need for modification to the existing rail infrastructure. This has been achieved through the utilisation of Computer Aided Engineering Design Tools, Value Engineering and close relationships with the UK rail regulators and other UK rail bodies. The first vehicle is now under manufacture and is expected to be commissioned on the Sellafield to Barrow line before the end of 2007.

HISTORY

For many years British Nuclear Fuels Ltd (BNFL) has transported spent nuclear fuel to Sellafield via Barrow using specially designed rail vehicles (see Figure 1 below). Since the time of first transport (1960s) packages have developed and grown, increasing in capacity, size and weight, thereby reducing the number of transports required and increasing efficiency. Unfortunately the UK rail infrastructure has not developed and to this day has a much shorter, narrower loading gauge than the neighbouring continental European networks.

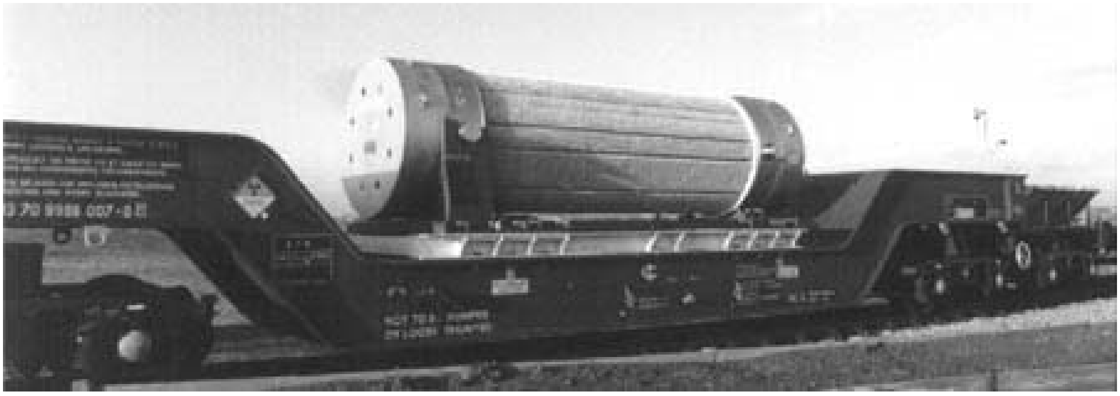

Figure 1 - BNFL Swan-neck Rail Vehicle with Spent Fuel Package

The reprocessing market has now matured to the point where spent fuel packages are no longer the main transport stream for now International Nuclear Services Ltd. (formerly BNFL), and instead the focus is on the preparation for export of high level waste from Sellafield. The high level waste packages in particular are designed for the larger continental European rail networks and as such will be the largest, heaviest nuclear packages ever to be transported in the UK, exceeding the capabilities of the existing rail vehicles and challenging the rail infrastructure.

The largest packages carried to date are up to 116t in weight and 2.5m in diameter. These packages when analysed are just inside the UK loading gauge (see Figure 2 below) and on the limit of the track/axle loading limits of the route.

The largest of the new High Level Waste packages is up to 122te in weight and 2.8m in diameter. Changes to the infrastructure to increase these limits to meet the demand were negated early due to the large number bridges/tunnels/viaducts on what in reality is a relatively short stretch of track (50 miles/80km).

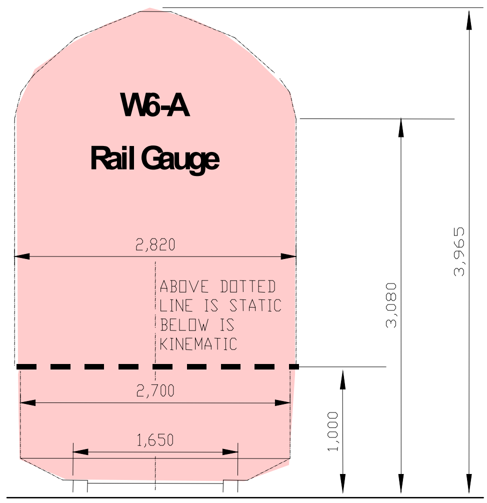

Figure 2 - Sellafield to Barrow Rail Loading Gauge

PROJECT STRATEGY

The project strategy was to develop a rail transport solution capable of carrying the proposed High Level Waste flasks on the Sellafield to Barrow route whilst minimising the need for capital investments on the infrastructure.

This was a phased approach which comprised of the following: -

Phase I - Evaluation of Existing Rail Vehicle Capability
Phase II - Feasibility Studies
Phase III - Concept Design for New Rail Vehicle
Phase IV - Detailed Design & Manufacture of New Rail Vehicle

In tandem a parallel study took place with the rail industry to identify and cost the possible requirements for altering the existing rail infrastructure to accommodate a large wagon and package envelope. Conclusions were drawn early, that this would be prohibitively expensive and not economical solution, hence the optimum way forward was to challenge the rail vehicle design in order to accommodate the new packages within the constraints of the existing Sellafield to Barrow rail loading gauge.

PROJECT IMPLEMENTATION

The project was initiated in early 2003 and is due for completion in mid 2008.

Phase I - Evaluation of Existing Capability

The scope of Phase I was to review the existing UK rail assets. The conclusion reached was that there were two wagons types within the BNFL fleet, which could potentially be adapted for use with the new packages.

Phase II - Feasibility Studies

The scope of Phase II was to analyse the existing designs against latest UK rail Group Standards for the new larger, heavier packages. The existing assets were evaluated and a structural analysis carried out for both. It was shown at this stage that there were minor issues with each design, therefore a new design of vehicle would be required and re-substantiation of existing assets would not be possible. It was felt that the issues could be overcome by re-development/optimisation of the existing structures (see Figure 3). At this stage a decision was made to take only one of the concepts forward. The decision was made on the basis of risk, complexity, operability and cost sharing with another rail transport project.

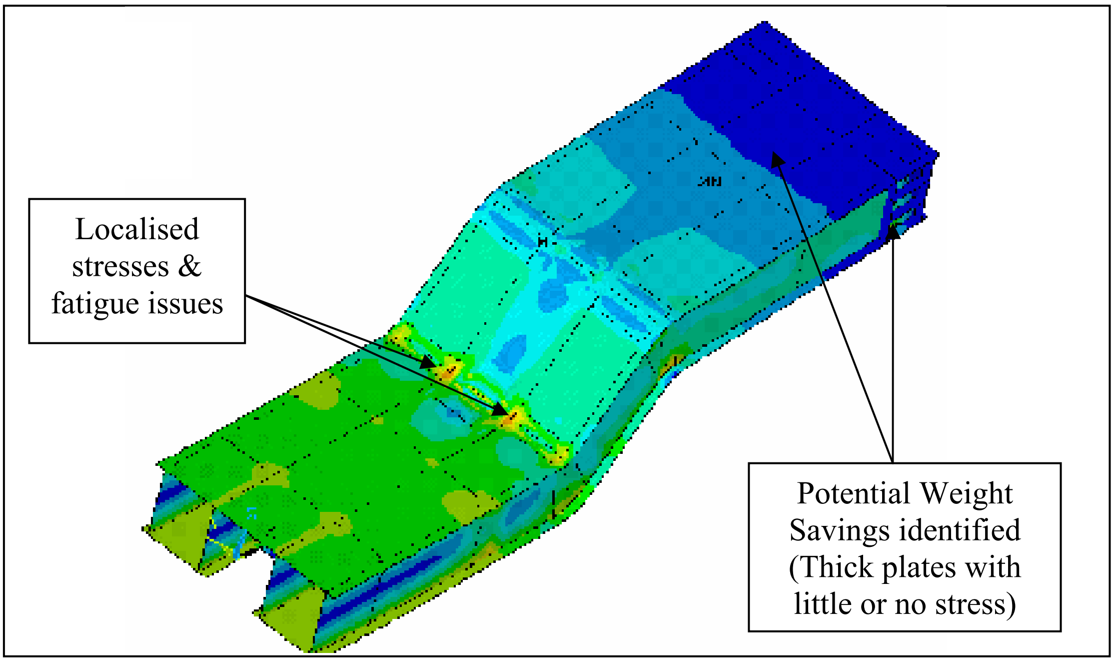

Figure 3 - FE Analysis of Swan-neck Vehicle

The design taken forwards is the one shown in Figure 1 and Figure 3 and is based on the existing swan-neck style flat bed rail vehicles. This design enables the transfer of packages without detaching the shipping transport frames, thus simplifying operations.

Phase III - Concept Design

The scope of Phase III was to optimise and redevelop the vehicle design to meet the requirements of the UK Railway Group Standards. In phase II, two constraints with the existing design were highlighted; one the structure was too heavy for the existing route and two there was a shortfall in the fatigue life of the main structure. On this basis the scope of Phase III was to optimise the existing design by removal of weight and local strengthening of the structure to increase the fatigue life. The Finite Element model from Phase II was interrogated and a concept design prepared. The new concept was 6te lighter thus enabling a payload increase from 116te to 122te. This resulted in a concept design that was capable of carrying the heavier packages within the existing track/structures loading limits. The fatigue life of the concept, although improved from Phase II, still fell short of the Railway Group Standard Requirements.

At this stage the fatigue life issue was a real concern and could have potentially stopped the project. Taking a value analysis approach the fatigue life requirement was challenged, and in comparison to other freight vehicles it was discovered that Sellafield Ltd. vehicles do very short infrequent journeys, and hence the full fatigue requirements of the Railway Group Standards need not apply. This was discussed with the UK Rail Standards and Safety Board and a derogation on this requirement was agreed in principle, subject to completion and substantiation of the detailed design.

In parallel with this activity a loading gauge analysis (see Figure 4) was initiated by Laser Rail to build confidence that the larger packages would fit on the Sellafield to Barrow line, on the proposed rail vehicle concept design. At this stage some areas of concern were highlighted for one particular flask type, however, it was felt there was a high chance that detailed analysis and small design changes could eliminate this risk. The design was progressed as the route was shown to be capable for the majority of the main flask types.

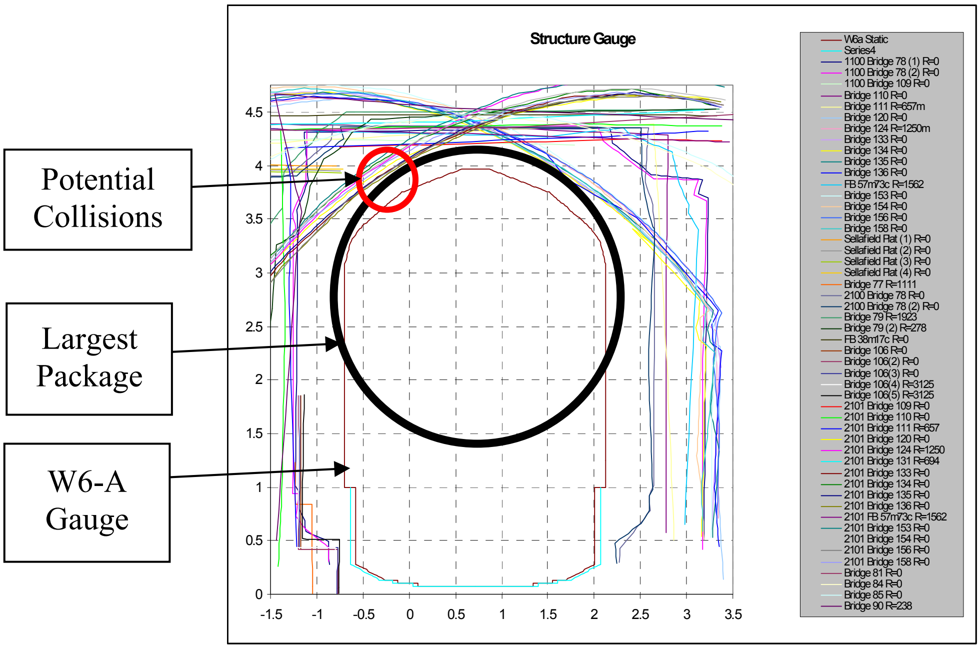

Figure 4 - Laser Rail Analysis of Sellafield to Barrow Route

Phase IV - Detailed Design & Manufacture

The scope of Phase IV was detailed design and build of the Phase III concept. A contract for the detailed design and build of 6 off vehicles was tendered for using the output from Phase III above. The successful contractor used a variety of integrated CAED tools (see discussion on CAED below) to develop a design which exceeds INS requirements and allows for payloads of up to 126te and 2.8m in diameter to travel within the limits of the track and W6-A loading gauge.

Throughout the detailed design phase the main priorities were to save weight and to increase strength. At the early stages anomalies with the concept were found and as a result further design iterations were required. The design house challenged some key features of the existing design and suggested a few design changes.

The original (1980s) design is a flat bed, stainless steel clad vehicle of uniform width (see Figure 1). The uniform width allows man access to the bed from the platforms (radiological surveys etc.) and the stainless steel cladding allows for ease of decontamination, particularly pertinent for operating Excellox type spent fuel flasks, which are operated in a ‘Wet’ environment. The new design (Figure 5) has a wasted neck, lightening holes and no stainless steel cladding. The reasons for this are that when the value of the features was analysed there was more benefit in lightening the structure than keeping the features. On evaluation the wagons can and are surveyed from the platforms at the side and no man access is given as there are no handrails, etc. To add to this the new generation of packages are dry storage casks and are therefore highly unlikely to provide the same risk of contamination. To mitigate the risk of possible contamination a paint system has been chosen, which has excellent decontaminability factors and track side platforms are being procured, which assist with the surveying of the new wagon. These changes were accepted by all key stakeholders as value added, removing any anomalies from the concept.

Manufacture of the new vehicles began in early 2007 and the first vehicle is expected to be tested before the end of 2007.

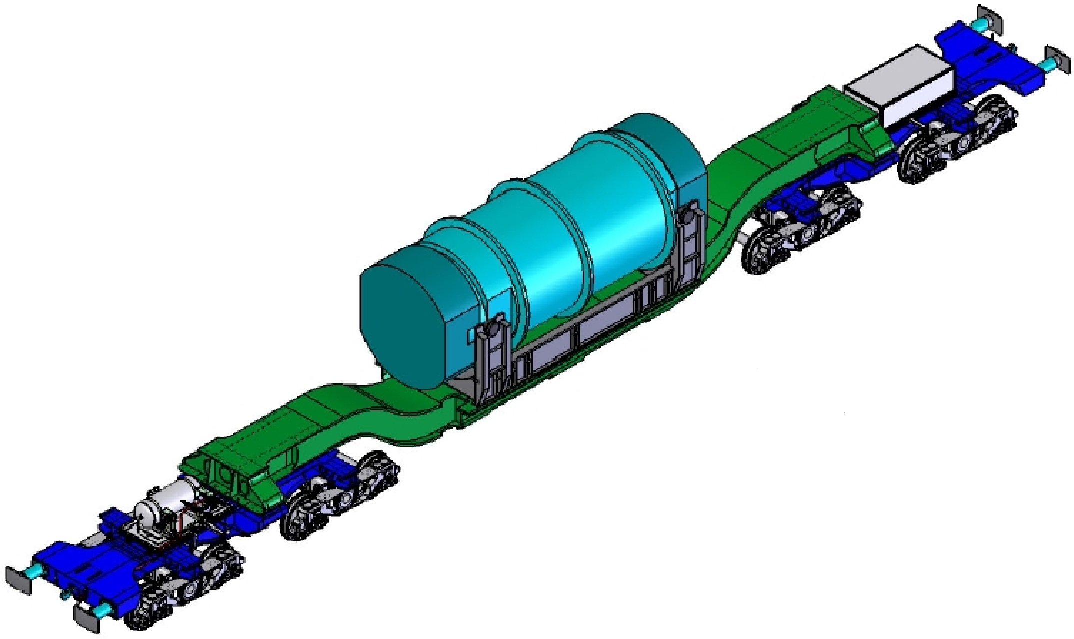

Figure 5 - New optimised Swan-neck Vehicle Design with large package

COMPUTER AIDED ENGINEERING DESIGN (CAED) TOOLS

The Detailed Design was completed and approved successfully by the utilisation and integration of a number of Computer Aided Engineering Design tools. The tools and their interactions are highlighted in Figure 6 and described below.

Solidworks - A 3-dimensional CAD system, which enables the designer to develop the structure exactly as it would be constructed. The solid models are shared with the client and the manufacturer via the e-drawings portal. This is fully interactive and comments/ideas can be shared either way. The solid models are also exported to the Analysts via STRAND7 the Finite Element analysis tool, thus ensuring that the geometry is maintained and that there are no errors in building the analysis model. Once the design is finalised the tool is also capable of automatically generating manufacturing drawings with little design input.

e-Drawings - Free Web based tool which enables the designer to send 3D files to the Manufacturer, Clients etc. for interrogation and comment. The tool allows the user to interrogate and annotate the design for interaction with design house.

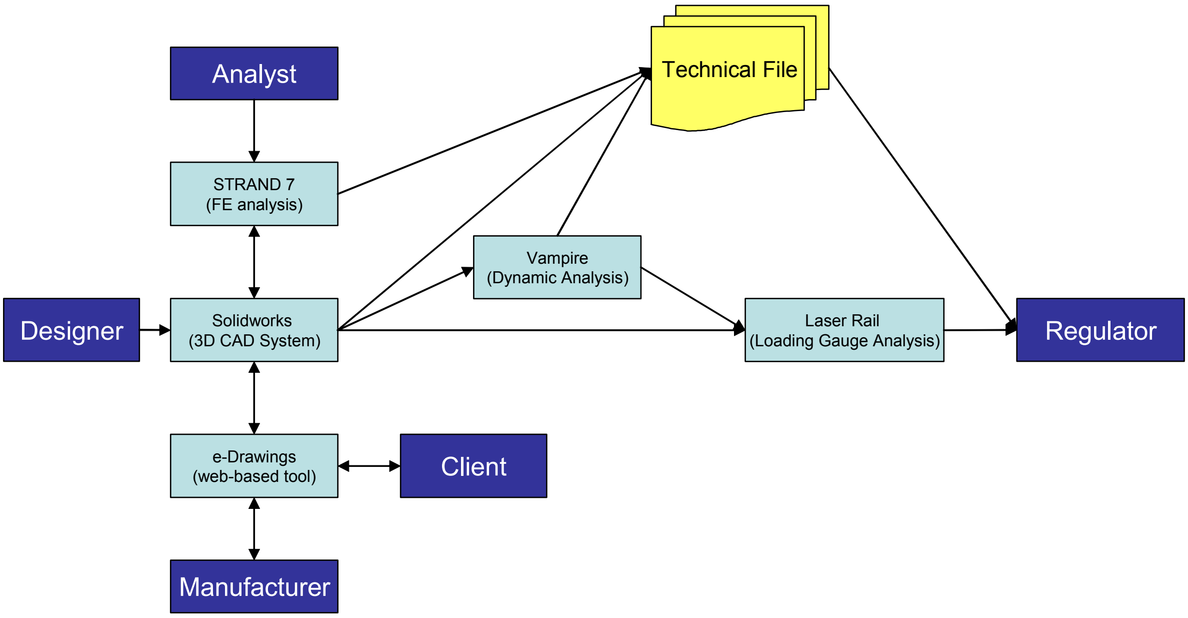

Figure 6 - CAED Tool Interfaces

STRAND 7 - Finite Element Analysis tool, which interacts with Solidworks and is approved by the UK rail regulator. The tool enables the Analysts to quickly import the geometry and perform the analysis. More importantly it allows the analyst to make detailed changes to the model and share them with the designer via Solidworks.

Vampire - Dynamic modelling tool, developed by Manchester Metropolitan University which enables the designer to analyse the ride performance of the vehicle at the concept stage. This tool uses the wagon and package geometry from the solid model to run a dynamic analysis of the vehicle. The results are used to give the designer, client and regulator confidence in the final ride performance of the vehicle. One output available from the Vampire analysis tool is data on suspension deflection, sway etc., which can then be used by Laser Rail to check the dynamic loading gauge.

Laser Rail - Measurement and Gauging tool, which enables the designer/ client/regulator to evaluate the route clearances on any track in the UK. The Solidworks model is used to show the gauging profiles of the vehicle at various sections. This information is then fed into the laser rail tool and an analysis of the specific route performed. The data used in the model is collected initially by Laser Rail using an approved vehicle equipped with laser measuring equipment and data loggers. The output is a simple series of charts demonstrating clearances and/or clash points with structures on a specific section of track. In our case the tool demonstrated that although the flask is outside of the widely accepted W6-A loading gauge, it does not clash with any structures on our specific route, allowing us to transport between Sellafield and Barrow only.

REGULATOR APPROVALS

Throughout the development of the design from Phase I to Phase IV INS ensured that the regulators were aware of the developments and where practicable invited to give input to the approach/design.

As stated above, this vehicle has a shortfall in the fatigue life from the UK Rail Group Standards. As soon as this issue was highlighted (Phase II), the regulator was approached for guidance/approval. Although the design was at the feasibility stage, INS were still able to apply for a derogation in principle. It was agreed with the Rail Standards and Safety Board that an increase in fatigue life would be targeted in Phase III & IV and that a lower value than that presented to them would not be accepted. This was approved and the project progressed with minimal risk.

The Computer Aided Engineering tools employed by the design house in Phase IV have all been regulator approved, enabling a quick and smooth approval of the final design.

SUMMARY

The choice between modifying the rail infrastructure or pushing the limits of the rail vehicle became an easy decision to make at an early stage due to the commercial viability and high risks associated with modifying the infrastructure. This enabled the project team to focus on optimisation of the existing Swan-neck (see Figure 1) vehicle design, which has proven to be the right concept to take forwards.

The Computer Aided Engineering tools utilised allow for fluent communications and sharing of ideas between the key stakeholders and ensures that any design changes filter through from one aspect of the approvals to another. The tools are still being utilised throughout manufacture and minor changes filtered back through the design house and analysis (where necessary) to ensure that the final Technical File represents the as-built status of the vehicle.

Without this approach it is highly unlikely that the detailed design, build and licensing would have been turned around in such a short timescale. Confidence in the tools and open communications with the regulator, have made it possible to license the vehicle concurrent with its design and manufacture.

CONCLUSIONS

Utilisation of the available Computer Aided Engineering Design tools, challenging of the base assumptions and a close working relationship with the Regulators enabled the transport of larger, heavier packages than ever envisaged removing the need for a major upgrade to the infrastructure or change to the business strategy.

DEFINITIONS

BNFL	British Nuclear Fuels Limited
SL	Sellafield Limited (formerly BNFL)
INS	International Nuclear Services Limited (formerly BNFL, International Transport and a subsidiary of SL)
CAD	Computer Aided Design
CAED	Computer Aided Engineering Design
FE	Finite Element Analysis