Felix S&C Laser Profile Measuring System

AUTHORS:

Phil Winship
CEng, MIET, MPWI

Principal Engineer, Asset Enhancement Team, part of Track and S&C team in the Technical Authority, Network Rail.

Lisa Secrett
MPWI

Engineer, (Switches & Crossings), Technical Authority, Network Rail.

James McNamee
MPWI

Senior Engineer, (Switches & Crossings), Technical Authority, Network Rail.

Wei Khang Lim
MPWI, AMIMechE

Engineer (Track and S&C), Technical Authority, Network Rail.

Phil is a Chartered Mechanical Engineer and member of the IET and PWI. He joined the railway in 2002 on the Track Conversion Course as Railtrack transformed into Network Rail, spending 5 ½ years in track maintenance on the East Midlands. In 2007 Phil moved to the role of Senior Track Design Engineer role within HQ Engineering, and in 2009 transferred to the S&C team in engineering as Senior Engineer (S&C). From March 2018 to the present Phil has worked in the Asset Enhancement team as Principal Engineer.

Lisa is an Engineer in the Switches and Crossings team, part of Track and S&C team in the Technical Authority, Network Rail. She is a Civil Engineer and member of the PWI. Lisa Joined the railway in 2004 with Bletchley maintenance DU, where she remained until 2016 in the PWay Technical team and the Performance and Assurance, gaining a HNC in Civil Engineering. In 2016 Lisa moved to role of Track Drawings Engineer with the Switches and Crossings team within HQ Engineering

James is a member of the PWI, and joined the railway in 2002 as a Trackman in the Central P-way maintenance team at Leicester. In 2008 he was promoted into technical roles working for TME Leicester and then became ATME, and in 2010 moved on to Nottingham to become Track Maintenance Engineer. From September 2018 to the present James has worked in the S&C team in Technical Authority.

Wei is an Engineer in the Track Systems Engineering team within the Technical Authority, Network Rail. He joined NR's Graduate Scheme in 2015 and proceeded to take on a role as an Assistant Engineer in the Mobile Monitoring team, in which he has contributed to the delivery of new trainborne remote condition monitoring systems. Since 2019, he has joined the Technical Authority's Track team and has been leading the delivery of several R&D projects for NR's internal R&D and Shift2Rail portfolio.

BACKGROUND

Dimensional measurements and derailment hazard inspections of switches and crossings have for many decades been carried out by using various types of manual gauges and have relied heavily on the user's interpretation of the readings obtained.

Two derailments, one at Princess Street Gardens in Edinburgh in 2011 and the other at Shrewsbury in 2012, both occurred on switches. The resulting RAIB recommendations from these incidents highlighted problems in the use of manual gauges and consistency of the obtained results. The reports recommended that Network Rail (NR) should consider 'developing alternative means of assessing the flange contact of switch rails'. This resulted in NR seeking potential new technology to assess the wheel / switch rail contact angle. In 2013 the Felix system (an Automated Measurement Trolley, AMT) was being developed by Loccioni in Italy for RFI (Rete Ferroviaria Italiana), the Italian railway infrastructure manager. The requirements of the system included the measurement of the switch rail contact angle, among the measurement of many other parameters within a switch and crossing unit. Early prototype development rigs of the AMT are shown in figure 1. Loccioni are predominantly a metrology company, who until RFI approached them, had no experience of the railway market. This worked to their advantage in not having any preconceived ideas of how parameters were measured using manual gauges and how this should be transferred to an automated platform.

WHAT'S IN A NAME?

A question often asked is 'Why is it called Felix?' Well, in Italy they have a number of track recording vehicles that are named after famous mathematicians such as Galileo and Archimedes. The name Felix comes from a renowned German mathematician from the early 20th Century, Felix Klein. Not a name you may be familiar with, but nonetheless well known in his field!

Over the next few years, we kept an interest in how the technology was developing. After reviewing the system during testing on the Italian high-speed network in 2015 it was decided to carry out a feasibility study of the system on Network Rail infrastructure.

THE FELIX SYSTEM

Felix is an automated measurement trolley primarily designed to record multiple parameters through switch and crossing units, but is also capable of recording certain plain line parameters in its current format. During the NR development of the system, in parallel Loccioni developed a plain line module for another customer which could, with some software developments, record all of the plain line parameters currently required by Network Rail.

The Felix is made up of six main modules as shown in figure 2. Each of the modules are less than 50kg in weight and are easily assembled/disassembled by two people. When not in use these are stored in two transportation units as shown in figure 3.

The assembly of the modules take approximately 2 - 3 minutes to complete and consists of the following;

- Central module
- Measurement module
- Left hand wheelset
- Right hand wheelset
- Front bumper
- Rear bumper

The system is powered by a rechargeable lithium-ion battery pack which has six hour capacity if worked continuously. In practise this time is longer due to the Felix generally not being used continuously for that length of time during a shift.

When recording the Felix travels at a speed of 1.2km/h and scans the rails at a 2mm frequency using a combination of lasers and cameras. When transiting on site it travels at a maximum speed of 5km/h. The system is operated by two people: one operates the Felix movements by a hand-held radio control and the other operates the Felix software on a tablet device. The fully assembled Felix can be seen in figure 4.

Trials have shown that when operated with a fully trained and competent team, Felix can record a full turnout, (both through and turnout routes), in just over ten minutes. An example of the potential productivity of Felix was shown during trials at St Pancras station in 2020. In one shift Felix inspected 10 point ends in a two hour possession. The Delivery Unit staff supporting the shift stated that this would usually take them three shifts to complete using manual gauges.

FEASIBILITY STUDY

In 2017, a Prior Information Notice (PIN) was issued along with a high-level specification, for interested parties to submit an expression of interest in supplying/developing a laser profile system for switches and crossings to NR. A small number of responses were received which were all evaluated against the high-level requirements specification. Among these was a submission from Loccioni. This proved to be far more advanced in meeting the specification requirements than any of the other submissions and they were the supplier selected.

After obtaining the required investment funding and approvals to use the Felix system on NR infrastructure, the feasibility study was undertaken. This was carried out at Clapham and Bletchley Delivery Units and proved that the Felix system could operate successfully on NR infrastructure including in third rail areas. A number of engineers from various NR routes, including Crossrail and HS1, attended some of the trials which were well received with plenty of interest in the new technology and its capabilities.

During the trials at Clapham, it became clear that utilising the Felix system was going to need careful planning due to strategic challenges of accessing the track at various station locations in the Clapham Delivery Unit area.

After the completion of the feasibility study, we were impressed with the capabilities of the system and the potential for improving the way in which we carry out S&C inspections on Network Rail infrastructure. The next phase was to seek to engage with Loccioni to develop the Felix system to meet Network Rail's requirements. This resulted in a full specification for NR's requirements to be developed. This had to consider the geometry parameters of S&C that are currently inspected using traditional manual gauges.

However, it also gave us an opportunity to consider adding new parameters to the Felix measurement capabilities that were not present in its Italian format. Parameters that were added included;

- Measurement of switch rail seating gap, (Commonly known as hogging)
- Squareness of switch toes
- Residual switch opening
- P8 wheel/switch rail contact angle
- Gauge 1 & 2 assessment
- NR4 sidewear
- Dip angle
- Crossing nose to wing rail height
- Free wheel clearance
- Free wheel passage
- Back-to-back gauge measurement

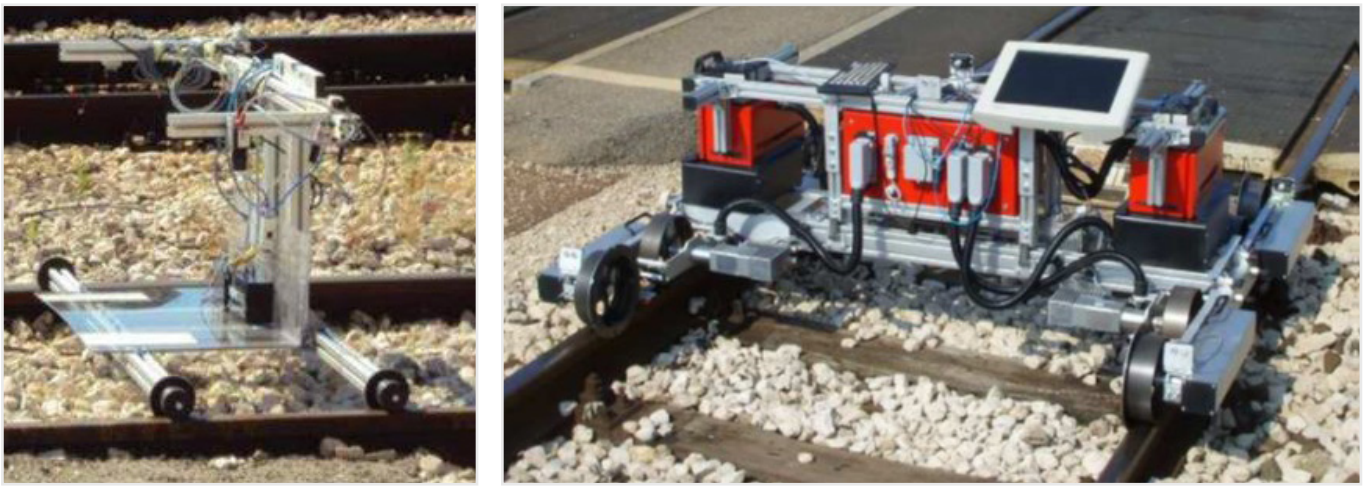
Many other parameters followed the requirements of current S&C and track standards. A number of parameters that are recorded are also checked by S&T staff as part of their inspections are available to be shared with them.

CONTRACTS AND PROCUREMENT

During the early discussions with Commercial and Procurement colleagues they were conscious about where this project could lead. Questions were asked, such as 'How much are the Felix to buy?' My slightly frustrated response was 'I have no idea at this stage as we haven't developed the final solution!'

'How many will we buy?' Again, my response was a 'I have no idea, perhaps one per route?' The conversation continued, as due to the pre-Brexit EU rules, if a contract value would exceed £320k then we would need to complete the full OJEU process (Official Journal of the European Union). This is a 9 - 12 month process and legal requirement that we needed to follow. For those of you who have not had the pleasure of completing this exercise, it is a very time consuming, costly and extensive-in-detail process to ensure we have given potential suppliers every opportunity to submit a proposal to meet our requirements.

After considering responses from companies ranging from a clean sheet of paper stating 'Yes, we could design something for you', to a fully detailed proposal we ended up back with Loccioni as the preferred supplier. Not too surprising really, as at the time they were the only company globally that appeared to have a solution developed to such a high TRL, (Technology Readiness Level). After the evaluation of all of the proposals in line with the OJEU



Figures 1: Early prototype developments.

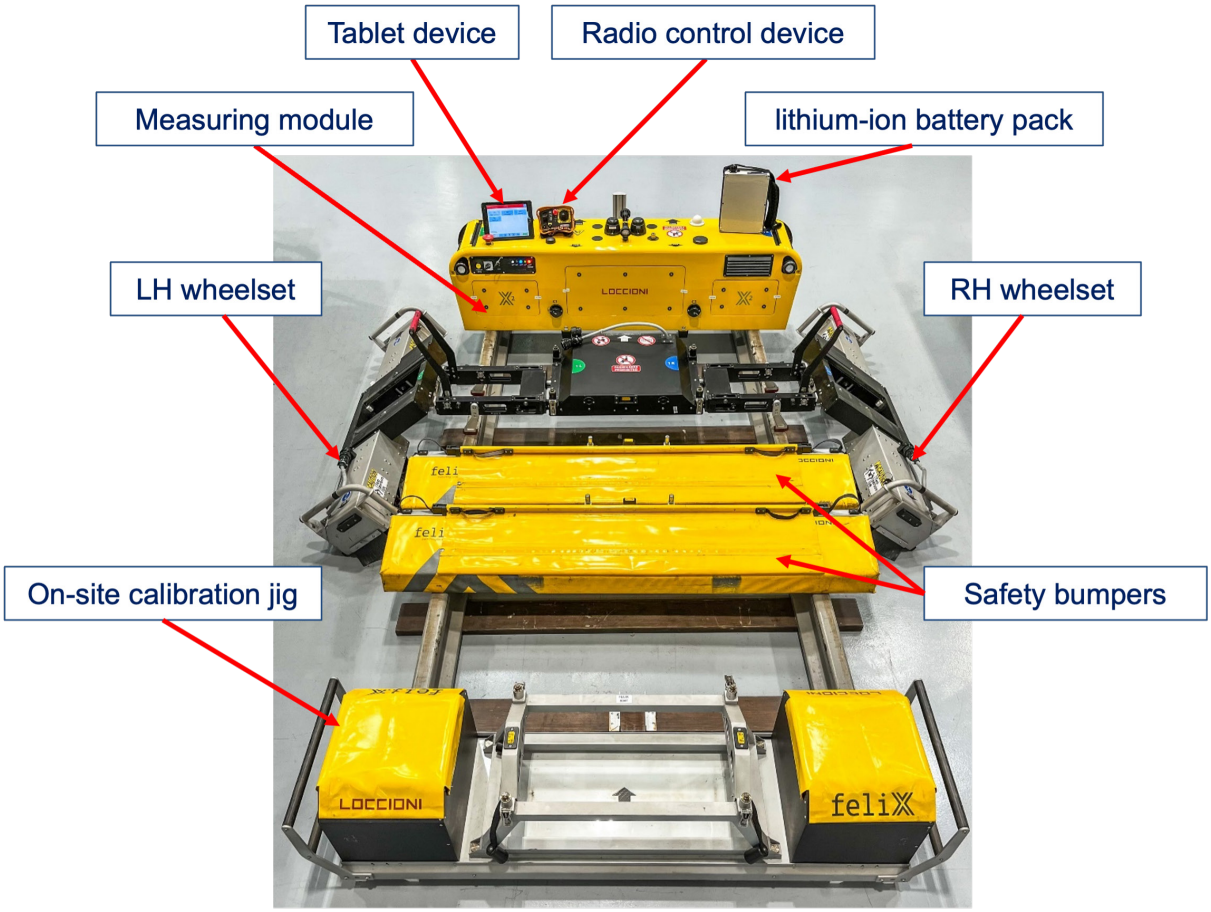


Figure 2: Felix modules.

Figure 3: Felix module transportation units.

requirements a contract was awarded to Loccioni to work with NR to develop the Felix system to meet our specific requirements.

There was one silver lining in this process; to avoid delaying the project too much a trip to Italy to visit the Loccioni factory was arranged. This was important to allow us to discuss the detail of the NR technical specification requirements and the planning of the trials with Loccioni engineers. It also allowed us to review the operational requirements of the Felix system using RFI infrastructure and to discuss the experience of introducing the Felix system with RFI track engineers. We were also able to carry out the required ergonomics assessment that had to be completed as part of the trial product acceptance requirements.

PRE-TRIALS PREPARATION

The Felix system had gone through a very rigorous development process to meet the RFI specification requirements which provided a wealth of information to use as part of the requirements to introduce the Felix onto NR infrastructure.

There were two main areas that we needed to complete to enable us to begin the trials on NR infrastructure; a) obtain a trial product acceptance certificate and b) the machine needed an Engineering Certificate of Conformity (ECC) to be able to operate on the UK infrastructure.

The ECC needed to be completed as part of the trial product acceptance. This is an in-depth check of the machine systems and capabilities to meet the plant requirements to operate on the UK railway infrastructure. Loccioni engaged with an assessment body in the UK to carry out this work, which took several months to complete. The basis for the ECC was RIS 1530 PLT, a mobile Plant standard which contains information for the use of trailers through to RRV's and large On Track Plant.

Figure 4: Felix fully assembled.

The problem was the standard does not cater for trolley-based systems such as the Felix AMT, which made this an interesting exercise!

The trial product acceptance required sign off by both the then Head of Plant and Head of Track. Both required different information to satisfy the trial PA requirements for each discipline.

PLANNING OF FELIX TRIALS

The S&C in the UK rail network has developed over many decades, and as such we have a large number of various S&C design variants installed on the network. The Felix system needed to be run over S&C units to allow it to be programmed to recognise specific positions and attributes of each design in order to deliver consistent results. After being programmed this would then enable the system to be used repeatedly and consistently over similar S&C units.

To carry this out for all S&C designs on NR infrastructure would be very difficult and time consuming. We decided to take the 80 / 20 rule and identify the most commonly used S&C designs used on the higher category tracks. This reduced the number of designs we needed to record and program the Felix to recognise down to a manageable 35 S&C units, (a combination of design, switch lengths and crossing angles). In addition to this, we needed to identify the more common complex junction types and program the Felix to


Figure 5: Felix during trials at Waterloo Station.

recognise these. These ranged from double junctions and tandems, through to switch diamond double slips and scissor crossovers. Having narrowed down the design types and sizes of S&C we would include in the trials, we needed to identify suitable sites to take the Felix to record data and program the machine. A trawl of the S&C design types and junctions was carried out using available data from NR's S&C database to identify possible sites to take Felix to and run it over the S&C to program it to recognise individual unit types. To do this we contacted a number of Delivery Units across the country to firstly check the information we had was correct, and then request the Delivery Unit's help to allow the project team to run the Felix system over the identified S&C units to program the system.

This sounds relatively straightforward; however it was far from the case. Firstly, we needed the Loccioni engineering staff to operate the machine, which was part of the contract conditions as no NR staff were trained to operate the system at that time. The logistics of moving the Felix from Italy to the UK, storing Felix when not in use, transporting it to each selected Delivery Units for the shifts required and then arranging the transport to suitable access points to for each site were challenging. Other complications included requiring Track Visitor Permits (TVP's), for the Loccioni staff, and then helping them arrange and complete a PTS course to continue the trials. Even lifting the Felix transportation units on and off the transport used proved quite a challenge at times!

OPERATIONAL TRIALS

While the Felix machine has been in use as part of the BAU S&C inspection process by RFI in Italy for several years, there is still a significant amount of adaptation necessary to introduce the machine onto NR infrastructure. This is due to the differences in S&C designs, layouts, and maintenance standards between the two railway organisations. Many functions performed by the Felix data processing algorithm, such as the identification of the switch toe and crossing nose, requires "training" using actual recorded data. As such, a large-scale trial of the Felix machine was conducted in order to capture as much data as possible for the commonly used S&C designs, lengths, and layouts on the UK rail network (see figure 5).

The trial sites were carefully selected to optimise the logistics of moving the machine around the country, while making sure the shifts aligned with existing inspections on the S&C units that are of interest to the project. The success of the trial was heavily dependent on working closely with the Delivery Units to ensure the right vehicles, personnel, equipment, and possessions are in place. The logistics of moving the machine to site had to be customised for each individual site due to the varied access conditions, (eg access via platforms, access points, stairs, and steps). Figure 6 shows the two methods of transporting Felix to site.

To date, the team has successfully conducted trials at 21 sites, with the majority of them being near terminal stations due to the higher concentration of S&C units and the availability of complex layouts for testing. The main goal of the trial has been achieved, with majority of the S&C types (designs, layouts, lengths etc.) in use on the network measured, with the exception of H-switches and Bullhead S&C. In addition to that, the trial has also been useful for the promotion and demonstration of the machine to the end users and key stakeholders, while providing the opportunities for the project team to gather many useful feedbacks and implement the necessary changes to improve the system/process.

Below are some key examples of the changes implemented as a direct result from the trial:

- Site access risk assessment has been developed to help the Delivery Units in developing a good logistical arrangement for moving the machines from depot to site.
- Transportation kit has been strengthened to prevent damage during transport.
- Manual handling and safety risk assessment carried out for the different methods of loading & unloading the machine from a truck.

The potential of the efficiency improvements that Felix could deliver has also been demonstrated at Cardiff Central and London St Pancras station, where both shifts managed to record ten S&Cs in a single night shift.

APP DEVELOPMENT

The existing version of Felix used in Italy requires two people to operate the Felix machine. One will use a radio control device, (shown in figure 7), to control the movements of the machine, while the other will be operating a tablet connected wirelessly to the PC within the Felix machine to execute key tasks such as calibration, inputting parameters, initiating measurements, viewing results, and shutting down Felix. As part of the development to adapt Felix for use in the UK, Loccioni and NR set out to develop an iPad app to replace the current tablet. There are several benefits to this, firstly being the fact that many of the Delivery Units are already familiar with using iPads as part of their work, making the transition easier. Secondly, the design philosophy for an iPad app is more user friendly with better display scaling such as bigger buttons and texts, as iPads are meant to be operated with fingers instead of stylus.

COVID 19 AND BREXIT IMPACT

With the UK being a member of the EU when the project started, the transportation of the Felix equipment to and from Italy was very simple, however with the advent of Brexit all of that changed! From January 2021 a number of hoops appeared that we needed to jump through. The paperwork and approvals to bring the equipment to the UK after modifications was quite a task to get organised as it was new to everyone.

Then in March 2020 the Covid pandemic hit and all physical work on track with Felix had to stop. However, just because we were now working from home didn't stop the project continuing. With the Loccioni engineers also working from home in Italy things were still able to progress to a degree. The software and hardware developments were able to continue, albeit at a slightly reduced pace. The added complication of restrictions in both the UK and Italy being at different levels at different times caused the delays to be quite extensive. The project trials were paused for approximately 10 months altogether. To mitigate against the effects of restrictions on travel both from the UK and Italian point of view, we took the decision with Loccioni to train some of the NR project engineers to operate the Felix. This enabled us to continue with the remaining site trials we needed to complete with remote support being provided by the Loccioni engineers.

HARDWARE AND SOFTWARE MODIFICATIONS

The hardware modifications were primarily completed at the start of the project to meet the requirements for the Plant trial product approval. One area that was identified later on in the project by the ergonomics specialist was to meet the requirements of future standards for audible and visual warning when the system being about to move. The audible warning needed modifying to take into account the ambient noise in which the Felix would be working in. This satisfied the audible aspect, but the visual aspect needed the addition of a flashing beacon to provide a visual indication at the same time. This was done remotely by Loccioni engineers with the machine in Italy but with the NR project engineers checking in on progress through frequent MS Teams meetings with an ergonomics assessment of the changes also being completed this way.

Extensive software modifications have been undertaken to meet the requirements of the Network Rail specification. This was both with the computer system on the machine and in the Felix App that had been developed by Loccioni but needed updating to a bespoke design to meet the NR specification.

FELIX DATA CAPTURE AND DATA INGESTION

The Felix system captures a wide spectrum of data about each S&C unit it records. This is readily available to the user on site and can be locally downloaded from the Felix to a laptop or PC.

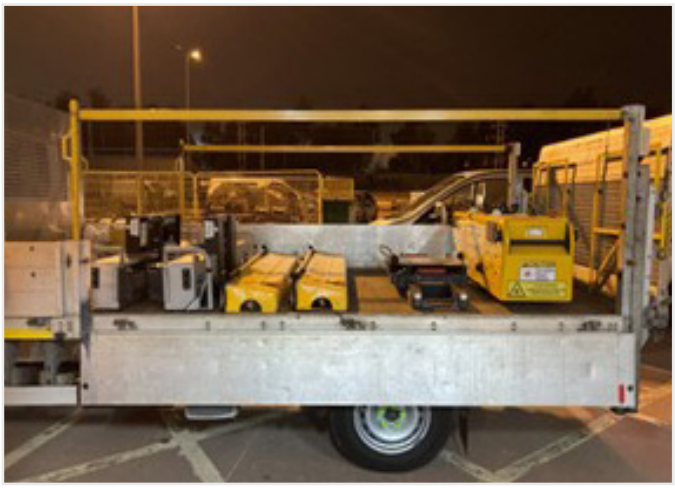


Figure 6: Two methods of transporting the Felix machine to site. Left - the modules are kept in the transport kit and the entire kit is loaded onto a truck using forklift or tail lift; right - only the individual modules are loaded.

The data recorded by Felix provides extensive information about the condition of an S&C unit and is much more than just replicating dimensional checks that are currently captured using manual gauges. To get the maximum benefit from the data, this needs to be analysed and can be used to trend deterioration rates of the componentry in an S&C unit.

To get the benefits of the S&C data pool created by Felix runs, we have worked with NR Asset Information and the Infrastructure Monitoring teams to find a way of ingesting the data into the NR Insight tool. This is a decision support tool for track and S&C. This work is still progressing but is due to be trialled during the pilot of the Felix system at Euston Delivery Unit in the coming weeks.

The Felix system records many parameters to help a Delivery Unit to understand the condition of the S&C assets and replicates the parameters measured using the following manual gauges;

- Track gauge
- P8 profile
- Gauge 1 & 2
- Switch radius gauge
- NR4 sidewear gauge
- Protractor gauge
- S&T confirmation gauge
- Back-to-back gauge
- Welders straight edge

The system also measures additional parameters including;

- Gauge
- Twist
- Cross level & cant
- P8 wheel profile contact angle
- Switch rail sidewear
- Switch toe squareness
- Residual switch Opening (RSO)
- Check rail gauge
- Check rail flangeway

DEVELOPMENT OF PARAMETER LIMITS AND TOLERANCES

The utilisation of Felix in S&C inspection offers an increase in accuracy when recording critical measurements such as wheel to rail contact point using TGP8 profile. Calibrated, precise readings, even down to 1mm, can make a real difference to maintenance planning in high-risk locations of S&C layouts. The precision available with Felix not only removes human error or misreading of critical measurements, but also presents the possibility of extending the timescale of predictive maintenance interventions following successive inspections. Data parameters can be recorded to one decimal place with Felix if required, whereas current standard intervention limits are primarily defined with whole numbers designed for use with hand-tool gauges. This finite measurement recording allows maintenance engineers so see gradual asset condition deterioration and determine a more accurate rate of decline.

Using Network Rail standards and inspection forms, we created a traffic light system that gives Felix operators clear indications of actions within the data outputs, with green (within specification, no action required), amber (plan maintenance), and red (immediate action). The amber and red actions clearly alert the user that action is required, allowing them to determine the correct course of action in line with S&C inspection standards. For parameters that require a combination of visual and measured inspection such as dip angles, we worked on a worst-case scenario for an amber alert, where upon detection of 1mm dip angle the operator would, in the first instance confirm the location and determine if this was measured over a weld or an IBJ, which has a lower tolerance value compared to other locations. A conversion of the standard dip angle unit of measure from mrad, (milliradians), to mm, aids S&C inspectors with fault verification and an uncomplicated reference point for standard mitigation action requirements. Tables 1 and 2 illustrate the dip angle limits and conversion values.

R&D IS AN UP AND DOWN JOURNEY!

As part of the initial detailed specification, we wanted to include the measurement of the switch rail seating gap, (commonly referred to as hogging). When we initially discussed the additional parameters we wanted to include in the Felix capabilities, it was thought that a new module would be needed to measure other parameters such as switch toe squareness, RSO and the switch rail seating gap. However, during the development of the new module to measure these, it became apparent that all of the additional parameters other than the switch rail seating gap could be achieved through some additional hardware and software modifications. This left the technical challenge of measuring the seating gap. By this time a module had been designed and developed to test for sensing this parameter. The module was brought over to the UK and fitted to the development Felix and tested at NR's Whitemoor site as shown in figure 8. The trials proved that the module and software could indeed assess the seating gap but with some caveats, which included variations due to issues such as grease or dirt on the switch foot or slide plate.

Due to the challenges of the other parameters that the module was originally being designed for being solved mainly by software modifications, the business case and benefits of the new module proved to be uneconomic due to the additional costs that would be incurred. This was not seen as a failure, but part of the R&D journey of developing Felix to meet NR's requirements. The development work proved that it was possible to measure the seating gap, but the additional cost that would be incurred for one measurement proved to be uneconomic against the time taken and ease of the current manual method of measuring the seating gap. Including

the requirement to measure this parameter within the visual switch inspection that is still required when using Felix would have little effect on the inspection time. Therefore the decision was made to stop any further development of the module.

COMMON SAFETY METHOD – RISK EVALUATION ASSESSMENT (CSM-REA)

When introducing any new equipment to Network Rail infrastructure an assessment of the affect this may have on the safety of the railway has to be undertaken. The depth of this assessment is decided upon depending on the significance of the change being introduced. The CSM-REA is a common mandatory European risk management process for the rail industry.

The introduction of the Felix AMT was assessed as a significant change, therefore the full CSM-REA process had to be followed. This included an in-depth process of identifying potential hazards that the introduction could bring and how these have been mitigated. Various reports had to be written to support the process that was followed, and these had to be assessed by an independent assessment body (AsBo) appointed by the project.

This is a very thorough and in-depth process to prove we are not introducing the Felix AMT without assessing and mitigating against the risks this may introduce to the safety of the railway. The process generally takes a number of months to complete before the AsBo is satisfied that we have correctly followed the CSM-REA process and issue a Safety Assessment Report to that effect.

FELIX HARDWARE & SOFTWARE VALIDATION

Over the last three years our team have undertaken over twenty site trials, which helped to programme Felix with rail profiles, assess accuracy against human inspections and support the subsequent product approvals. The work done on Common Safety Method goes arm in arm with the other product acceptance requirements found in NR/L2/RSE/0005 “Product Design for Reliability”, which was managed by the team.

DESIGN FOR RELIABILITY (DfR)

This is a structured process for identifying minimum requirements for suppliers to demonstrate they have designed reliability into controlled products and have addressed potential reliability risks using proven tools. As part of the development of Felix we needed to take the system through the DfR process to provide evidence that we have met the requirements and document changes made to meet the NR specification. The Design for Reliability (DfR) process provides documentation proving the product and manufacturing reliability, and in terms of inspection equipment repeatable accuracy. There is an assumption that using lasers and imagery tooling will be more accurate than the human inspector - the DfR work would have to assure this was the case before introducing automated or semi-automated inspection equipment.

Other managed human factors would need to be negated as part of this introduction such as data management, data analysis and inaccurate recording.

GAUGE REPEATABILITY AND REPRODUCIBILITY

The Felix AMT uses lasers to record profiles of rails and components at 2mm intervals, which when mapped together give a three-dimensional image of the asset scanned, as can be seen in figure 9. The measurements for each profile are then calculated through algorithms based on critical hazards for the many recorded parameters. These parameters include the risk of derailment in S&C for static requirements found in Network Rail standards but not negating the human inspector looking for cracks or inadequate components through visual inspection.

Previous testing had proved most of these parameters to be accurate, but we needed to repeatedly reproduce the same accurate recordings. Finding examples of all of the derailment hazards that we needed to prove Felix was capable of identifying would clearly be difficult and of course undesirable in the live NR infrastructure! We knew that obtaining access for the time we needed to carry out these repeated tests would be difficult, so we had to find an alternative means of testing this. The solution was to ask our colleagues at the Whitemoor Recycling Centre if they could build a switch panel that we could use to replicate these hazards. This panel was also used to prove that lubrication and detritus needs to be removed to record accurate measurements in the same way the human inspector does today. The panel is shown in figure 10.

Previous in-track testing had found some of the more common 053 faults, but we needed to assure all faults could be detected by Felix. The switches on the panel were in good condition but not able to be reused, so we asked a tame grinder from the local Delivery Unit to ‘model’ the derailment hazards into the switches. We also simulated wide gauge and twist faults on the panel to help validate the Felix system.

We repeated the inspections with Felix to establish the level accuracy which, due to its 0.1mm resolution was far greater than any other tool current used. These recordings were compared with manual gauge inspections measured on the same panel. Felix reflected all faults manually identified with some positive differences.

Dip position	No Action (mm)	Plan Maintenance
At Weld	< 3	3 ≥
At IBJ	< 2	2 ≥
Any other point	< 10	10 ≥

Table 1: Dip angle limits.

Figure 7: Radio control device.

Dip angle (mrad)	Actual measured dip (mm)
5	1.3
10	2.5
15	3.8
20	5.0
25	6.3
30	7.5
35	8.8
40	10
45	11.3
50	12.5
60	15.0
70	17.5
80	20.0

Table 2: Dip angle conversion chart.

Figure 8: Felix fitted with the newly developed module.

For example; figure 11 shows crosslevel readings recorded both manually and by Felix. They graph shows they are comparable, following a similar pattern but with some differences.

After some deliberation and repeated inspections with the same output we realised that Felix has a wider wheel seat which resembles a train wheel. Figure 12 shows how the track gauge foot is only sat on the switch rail, Felix spans both switch and stock rails. This makes Felix more accurate than current track gauges which, was reflected in other similar testing.

There has only been one parameter that requires further testing which we intend to analyse in the Euston pilot, this is the Switch Radius Gauge. This gauge detects sharp edges or sudden changes in profile along the planing on top of the switch rail, a tool commonly known to be very subjective.

Our testing found that due to the granularity of digital recording it is more accurate than our existing tools, which was expected. Moving to digital recording will support optimisation of inspection frequency and with that intervention frequencies. When carrying out the Gauge R&R we identified that some of the parameters Felix can record, such as check rail flangeway and crossing wing rail to nose height difference, are currently not measured and could be used to improve switch and crossing performance.

TRAINING

To realise the full benefit of the automated measurement trolley a bespoke training package is needed to pass on the knowledge and understanding required to both operate the Felix system and interpret the recorded data from the inspections. This also includes manipulating the software to focus on specific areas of concern that are highlighted in the measured parameters.

As an interim measure, the training course provided by the manufacturer Loccioni has been approved to be used as a basis for training the project team and the staff at Euston Delivery Unit who will operate the Felix during the pilot.

The NR training course for Felix will incorporate a mixture of real-life and computer-generated imagery to provide a more interactive experience when learning how to operate the machine and interpret

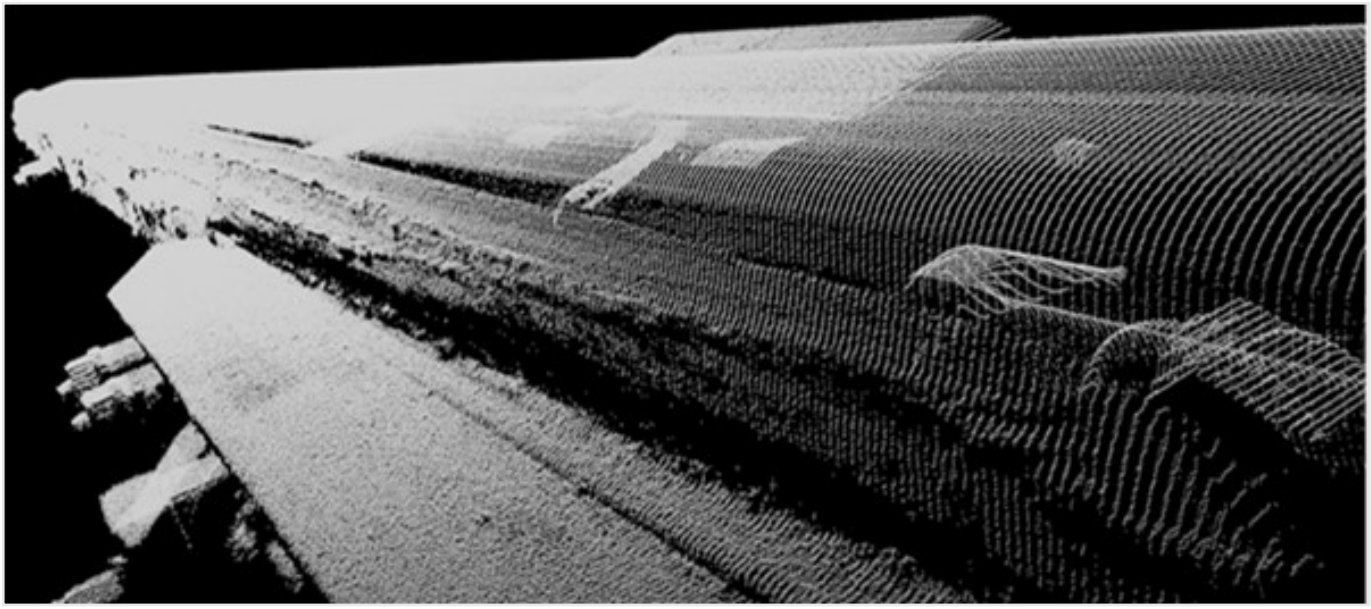


Figure 9: 3D scanned image.

the results. This will be combined with on-site practical training with the Felix and a period of mentoring. The course design will be completed and trialled later this year in preparation for Felix to be available for Network Rail Routes & Regions to introduce to the wider business.

THE PILOT - FELIX APP DEVELOPMENT

Key to the development of Felix was the user friendliness of the system. Working with an external organisation, we researched the usability of the app and human behaviours in understanding the inputs required by a user and of course the ease of use.

Following our own team testing and reviewing app updates, we then worked with 053 inspectors at Northampton maintenance depot who volunteered to work through various app tasks such as survey set up and calibration. (The term 053 is commonly used to describe Network Rail switch derailment hazard inspection standard NR/L2/TRK/053 - 'Inspection and repair to control the risk of derailments at switches').

Users were able to feedback an indication of the clarity of use, as well as being observed carrying out these tasks, paving the way for adjustments and modification to the app. This type of research is key to the app development and targets end user requirements.

Following several iterations of changes, the app was deemed ready for the pilot trial at Euston Station. Screenshots of the iPad app are shown in figure 13 (note that this is still in development and will be subject to changes).

Future developments of the app are in progress, specifically the integration of the app with NR's Ellipse system, which would allow the app to communicate with the Ellipse database to perform tasks such as auto-population of asset details for S&C units, and to upload and assign the inspection results automatically to the right asset. The idea is to make the process as seamless as possible, minimising the admin work necessary and reducing changes for errors in data input, while freeing up resources to focus on the data analysis and works planning.

Figure 10: Felix test panel.

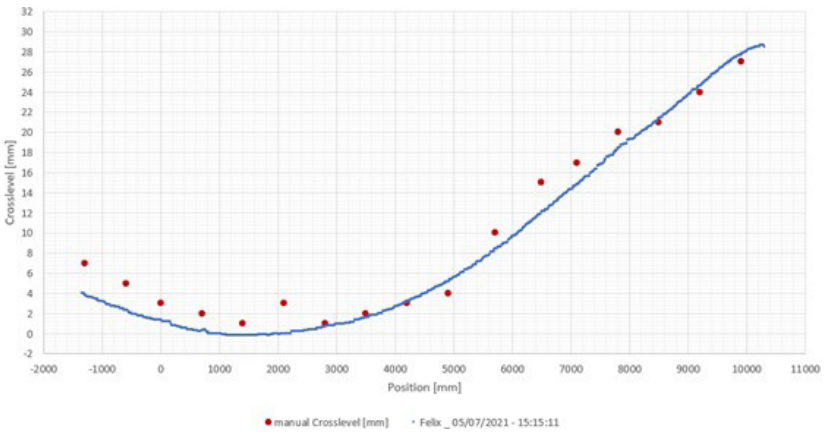


Figure 11: Crosslevel readings.

Figure 12: Track gauge foot registering only on switch rail.

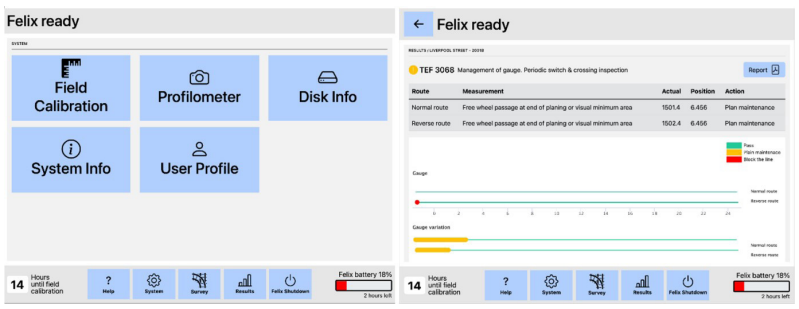


Figure 13: Screenshots of the Felix's iPad app - (left) home screen of the app showing the multiple tasks that can be performed using the app, (right) snapshot of a sample "Results" page after the completion of measurement and processing.

In preparation for the pilot at Euston Delivery Unit, a week of training for users was carried out at Stonebridge Park depot. The course covered all aspects of working with Felix through course modules including assembly, operation, maintenance, survey set up, and data outputs. Users also had the opportunity to then carry out these tasks on track. With plenty of opportunity to try for themselves, the users ended the course with the confidence to assemble and operate Felix over the duration of the pilot. Data outputs from the pilot will then be used to compare with the current manual 053 and S&C inspections.

This will provide an opportunity to compare the data and see the accuracy, repeatability and reproducibility that Felix offers in a live working environment. Throughout the whole pilot the outputs will be measured against the most recent S&C inspection for comparison. This is where the Delivery Unit staff will gain a more informed view of the accuracy in predictive deterioration of the S&C asset offered by Felix.

The pilot for the introduction of the Felix AMT was carried out at Euston Delivery Unit during May and June 2022 (see figure 14). The purpose of this was to assess the usability and operability of the Felix in a live working environment, and compare this with the manual inspection method currently employed for inspecting S&C. During the pilot a real time assessment of the usability of the Felix App was carried out and an assessment of the ease of use of the system by the Delivery Unit staff. Further data comparisons between the manual inspection methods and data recorded by Felix will also be carried out to further support the business case and full product acceptance approval of the system.

ROLL OUT OF FELIX

On completion of the R&D aspect of the Felix AMT project and the full product acceptance being approved, the system will be available for the Routes and Regions to introduce. The project team are very aware that this will not be the end of the line for this work but will be the start of a support phase, to help the Delivery Units to introduce and utilise Felix and realise the benefits that this will bring to the wider business through better asset management and fewer S&C component failures.

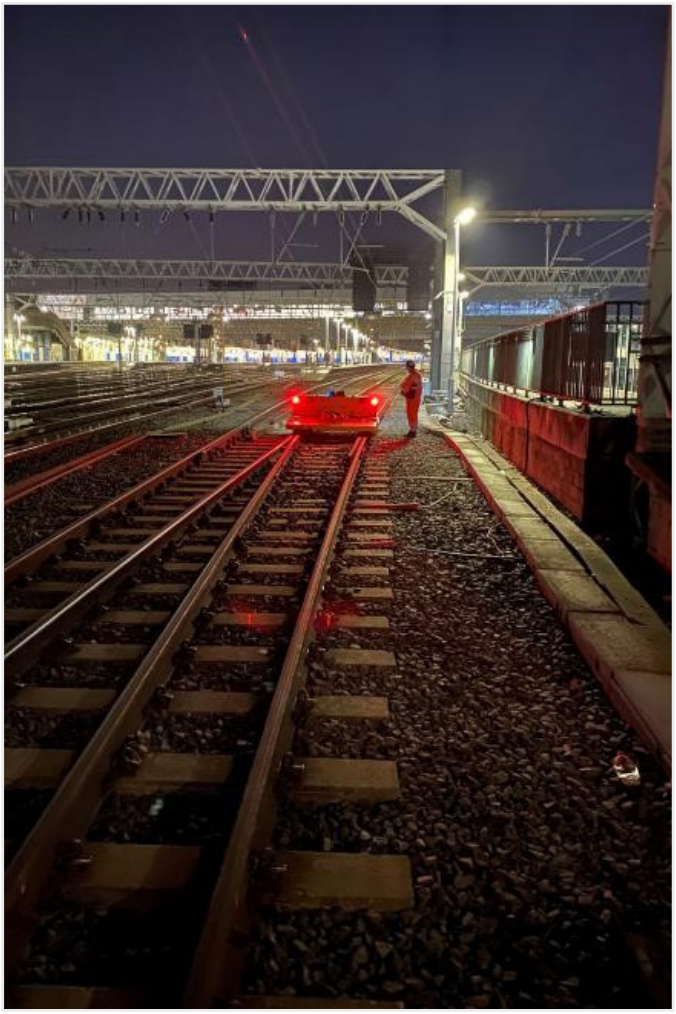
It must be stressed that during the trials it appeared that Felix has a reputation of ‘just’ being about 053 inspections; It is much more than that ! This is not simply a method of automating manual inspections - it will introduce a whole new way of managing S&C assets.

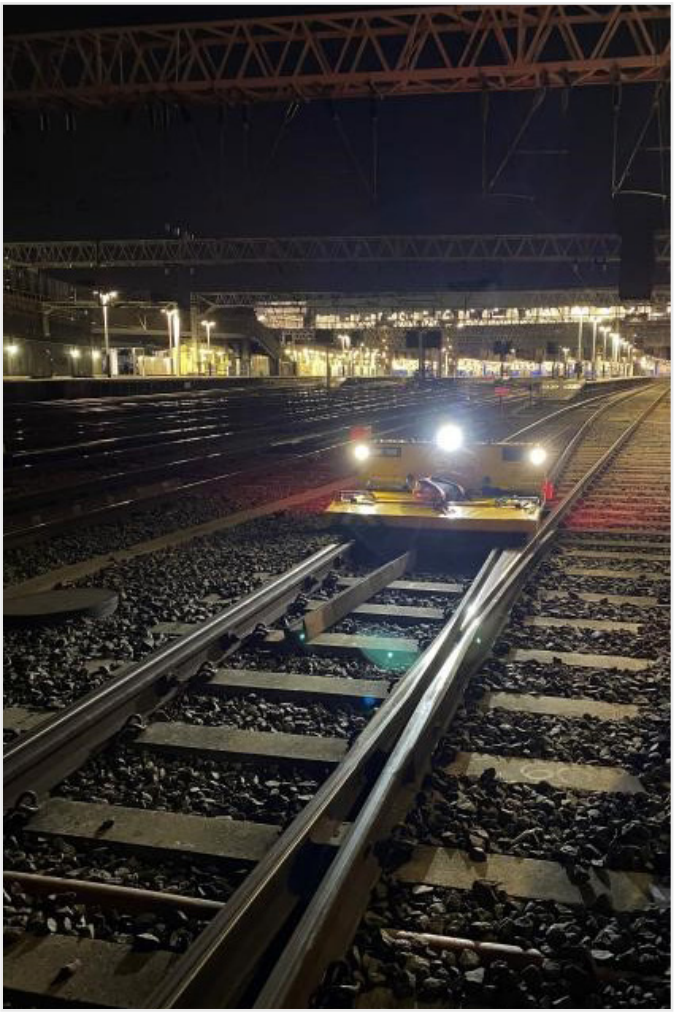
When planned and implemented correctly, this will help move away from the current focus of fixing at failure and firefighting, to strategic preventative maintenance, where deterioration rates can be trended and intervention introduced at the early stages of component deterioration which, if managed correctly will prevent failures from occurring.

AND FINALLY….

During the development of the NR specification Felix a number of NR engineers have asked ‘Why is it taking so long ?’. Well hopefully after reading this article, (and this is only the short version!), they may now realise how much work it takes to develop and introduce this type of equipment?

The project team would like to express our thanks to all of the many people, (both NR and non-NR), especially the Loccioni team, who have assisted and supported us with the development of the Felix over the R&D phase. This would not have been possible without your help. Thank you !





Figures 14: Felix operating at Euston station.

TECHNICAL ARTICLE

AS PUBLISHED IN

The PWI Journal
October 2022

VOLUME 140 PART 4

#thepwi

W thepwi.org

PermanentWayInstitution

PWInstitution

@the_pwi

@the_pwi

If you would like to reproduce this article, please contact:

Kerrie Illsley
CREATIVE MANAGER
The PWI
kerrie.illsley@thepwi.org

THE PWI
THE INSTITUTION FOR RAIL INFRASTRUCTURE ENGINEERING