Keeping HF on track
A case study of the Hitachi Class 800/801 intercity express train
A version of this presentation was originally delivered at the CIEHF conference on the 14th of April 2015. This document has been reformatted to allow it to be read independently.
High level summary
Hitachi Class 800/801 trains

The Hitachi’s Intercity Express Trains has been designed specifically for the UK market to replace the fleet of Intercity 125 and 225 trains that operate on the Great Western Main Line (GWML) and East Coast Main Line (ECML). There are two variants of the train, the Class 800 bi-mode and the Class 801 Electric, which are faster, higher capacity and more environmentally sustainable, to improve the passenger experience and support growth along the corridors they serve, through their manufacture and supply chain.

The design of the train is complete and the first train arrived in the UK on the 12 March 2015. The first train is expected to go into service in 2017 on the Great Western Main Line. The trains are to be built in a new factory in Newton Aycliffe in the UK.
The project had multiple stakeholders, that include DCA’s client Hitachi along with their clients – Agility Trains, the train operating companies, (VTEC and First Great western) and the department for transport.

At a user level it also includes the staff, train drivers and crew along with maintenance and cleaners.

At a passenger level, the design also explicitly considers the whole UK population along with tourists, that includes commuters, families, cyclists, pushchair users, wheelchair users and a whole host of physical and cognitive impairments.

**Stakeholders**

**Staff representatives**
- Train drivers
- Train crew
- Maintenance
- Cleaners

**Passenger groups**
- Commuters
- Families
- Cyclists
- Pushchair users
- Wheelchair users
- Visually impaired users
The approach adopted throughout the project has been one of integrated and iterative design. This has involved a multidisciplinary team from DCA including designers, engineers, model-makers and human factors practitioners. The focus throughout the project has been on identifying and addressing any issues as early in the design process as possible. With regards to HF, we have followed a seven step process:

1. Review of all relevant standards and guidelines
2. Development of additional requirements based on analysis of the train user population
3. Desk-based assessment of initial train design using 2D drawings and 3D CAD models
4. Design, build and evaluation of low fidelity ergonomic mock ups (participatory design)
5. Evaluation of full scale ergonomic mock ups (task analysis, fitting trials, ethnographic, user surveys)
6. Evaluation of high fidelity full sized model (representative fit and finish – fitting trials, user surveys)
7. Document compliance
Methods employed

A wide range of traditional human factors methods have been applied throughout the project. These include:

• Ethnography – observation of drivers and passengers using in-service trains.
• Semi-structured interviews with drivers and train staff.
• Anthropometric assessments of the design against the target audience
• Task analysis – a full Hierarchical Task Analysis (HTA) was conducted to describe the driving task
• Participatory design exercises to evaluate and re-design early cab prototypes
• Expert reviews of mock-ups
• Passenger focus groups in the train mock up
• User surveys in the mock up including a range of passengers (cyclists, users of prams, wheelchair users, visually impaired user, etc.)
• Force assessments
• Environmental assessments (light levels)

In addition, we also developed two new methods to support the process:

• Glare assessment (published in Applied Ergonomics)
• Task-based control assessment (Published in Journal of Rail and Rapid Transport)
Exposure & promotion of HF

Journal Papers

Magazine articles

Conferences

Blogs
Detailed description
Detailed description
1. Cab
Step 1 – Contractual & regulatory requirements

In consultation with the Department for Transport and the train operating companies, a train technical description (or TTD) was written that outlines a specification for the train. This forms a relatively detailed description of what the train should be capable of. It includes details like the number of seats and luggage requirements. There is also a long list of applicable regulations and standards, however, the most commonly used ones are shown here.

These provide fairly detailed descriptions of what the cab should achieve in terms of a safe and effective driving posture. They include descriptions of external visibility requirements as well as clear zones to protect drivers in the event of a collision.
As part of digesting these requirements, we found it particularly useful to summarise them into a series of simple diagrams. This also helped to communicate the details to the remainder of the project team.
Step 2 – Derive additional requirements based on anthropometry

In a number of cases, the requirements provide generic statements, for example the cab shall be useable by 5th to 95th percentile driver. While this is a useful starting point, more measurable and testable requirements are needed to feed the design process. Accordingly, the next step of the process is to detail up the requirements using anthropometric data sets. Simple reach envelopes can be constructed to estimate the suitability of controls based on grip and finger tip reach.
Step 3 – CAD evaluations

The combined requirements from the standards and guidelines, along with the additional requirements can then be used to inform and test early design concepts.

At the project infancy, it is sometimes easier to start with 2D projection as they can be faster to update.
3D Assessments

As the design develops, 3D assessments provide a greater level of confidence.
Initial layout philosophy

The development of structural panels and the control layout need to happen together to ensure that they are compatible. The reach envelope forms the basis for the panel location and size.
Initial layout philosophy

1. Key info central in primary zone

2. Left hand often on combined power brake controller

3. Controls to be actuated on right side, displays on the left

4. Functional Grouping of controls

In this case, the control layout was dominated by a number of core philosophies, the key one being that all pertinent information and controls are presented in the primary zone directly in front of the driver.

The next philosophy derives from the fact that the user is required to operate the combined power brake controller with their left hand. Accordingly, controls that require actuation are biased to the right, whereas display only features such as CCTV screen and indicator lamps have been placed to the left. The final philosophy is to cluster controls by their function for example all engine controls together in one place.
This concept of functional grouping is shown here. All the electric controls are in one place, as are the diesel ones and the doors.
Consistent conventions are also followed for example up above down, not next to it or below it. And start always above stop. To us, of course, all of this all sounds like incredible basic stuff, but it’s staggering to see how many trains are out on our network that don’t follow even these basic heuristics.

Once we completed an initial layout we created some basic 2D drawings like the one shown here for each panel and sent them to the key stakeholders for comments. As expected, we received lots of comments back, some with very strong opinions to the contrary. Many of the drivers involved had expectations set by other trains and wanted to see these replicated on this train. Despite the logic for the CCTV on the left as there was no need to touch it, drivers wanted it on the right because that is where it was on their train.

Of course expectations are something to take very seriously, the trouble is of course that there is very limited commonality between trains, particularly as this train is for two different networks.
Step 4 – Low fidelity rig assessment

To get a more accurate assessment of the cab layout we created a simple scale mock up out of foamboard. We printed off each of the controls on paper and used bluetack to position them.
As a result it was very quick and easy to re-position the controls, this proved very useful for engaging the drivers in the task.
Having the engineers on hand was great as we were able to keep the design grounded to what was technically feasible behind the panels.
Excellent mechanism for group discussion

And it proved great for group discussion that involved a diverse range of stakeholders. Much of the debate came from the two train operating companies. Each had different expectations based on legacy vehicles and slightly different task distributions with guards.
This then formed the basis for the final control layout. The approach was incredibly useful as it made sure that each stakeholder had a voice, and perhaps more importantly understood why the final configuration was the way it was. We were able to challenge initial concerns by asking drivers to play out common tasks. Within a few hours we were able to reach a happy consensus.
Step 5. Ergonomic mock up

The next stage of the development process was to up the fidelity of the mock up by building something a little more representative out of wood. The aim here was to get something that was spatially accurate but lacked the detail and finish of the final train. Controls at this stage were limited to print outs.
We mounted the mock up at rail height as this allowed us to start to consider ingress and egress. We also started to explore driver postures in more detail.
The other key advantage of mounting at rail height was that it allowed us to evaluate external visibility.
There are prescribed ways of assessing external visibility based on drawings; however, this was considered to be the base level of acceptability and we used subjective assessment to optimise the design around this.
Step 6. Full mock up

After a few iterations of the wooden mock up we moved on to develop a cab that was intended to very closely represent the final cab. We used production seats switch gear and controls, while the main structure was wood painted to give a representative finish.
Control based static assessment

We used a structured approach looking at each of the 87 cab controls in turn assessing it for its visibility, reach, suitability, and risk of inadvertent operation.

<table>
<thead>
<tr>
<th>Control</th>
<th>Location</th>
<th>Frequency</th>
<th>Dynamic</th>
<th>Risk</th>
<th>Visibility</th>
<th>Reach</th>
<th>Suitability</th>
<th>Risk of inadvertent operation</th>
<th>Posture</th>
<th>General</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncouple button</td>
<td>Centre panel</td>
<td>Low</td>
<td>Static</td>
<td>Min</td>
<td>Fine to see</td>
<td>Leaning in to get to it - should be two hand operation</td>
<td>No risk due to cover</td>
<td>Infrequent no more than 4 times in a shift</td>
<td>Look at functional operation of button is inadvertent operation with other coupling a problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanding button</td>
<td>Centre panel</td>
<td>Medium</td>
<td>Dynamic</td>
<td>Medium</td>
<td>Clear</td>
<td>Could be slightly closer push and hold</td>
<td>Might confuse with trainwash at low speed</td>
<td>Look at bringing the sanding button down the panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snow brake</td>
<td>Centre panel</td>
<td>Low</td>
<td>Dynamic</td>
<td>Medium</td>
<td>Can’t read in a braking, fine normally</td>
<td>Easy to read</td>
<td>Good</td>
<td>Low, nothing nearby, nothing to catch</td>
<td>No issues</td>
<td>Should be blue</td>
<td></td>
</tr>
<tr>
<td>Acknowledge (AWS)</td>
<td>Centre panel</td>
<td>High</td>
<td>Dynamic</td>
<td>Medium</td>
<td>In primary line can’t miss it</td>
<td>Fine - good relationship with PBC</td>
<td>Good</td>
<td>No consequence</td>
<td>No issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acknowledge (ETCS)</td>
<td>Centre panel</td>
<td>Low</td>
<td>Dynamic</td>
<td>Medium</td>
<td>Fine clear of AWS unique colour</td>
<td>Clear of other controls</td>
<td>Might not AVS but that’s fine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AWS sunfillower</td>
<td>Centre panel</td>
<td>High</td>
<td>Dynamic</td>
<td></td>
<td>Glare from AWS - shiny surface - seems rather small</td>
<td>Clear of other controls</td>
<td>Might not AVS but that’s line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency brake (driver)</td>
<td>Centre panel</td>
<td>Low</td>
<td>Dynamic</td>
<td>Medium</td>
<td>Primary related to controller</td>
<td>Lean in slightly to reach it</td>
<td>Clear what it is</td>
<td>Well clear of other controls</td>
<td>Not facing driver</td>
<td>Look at recessing</td>
<td></td>
</tr>
</tbody>
</table>

EHF2015.ppt
We recruited a range of drivers from both train lines to help.
Detailed HTA development
Alongside the static assessment we wanted to explore how the cab layout met the requirements of the driving task. The first stage of this was to develop a task model. Rather surprisingly, we struggled to find anything in the public domain that described the driving task. As a result we had to create a Hierarchal Task Analysis of our own based on training materials and discussions with train drivers. The resultant model contained:

- 551 Nodes
- 387 Child

- Start up
- Routine driving tasks
  - Departure
  - Transit
  - Stop train
  - Arrive at station
  - Departure from a station
  - Drive from standing position
- Manage communications
- Unit disposal
- Emergency situations
## Task-based sequenced assessment

The HTA then informed the task-based assessment. Each task was read out in turn and the driver performed it, after each activity they were asked to report any comments, good or bad.

<table>
<thead>
<tr>
<th>Rank/number</th>
<th>Description</th>
<th>Level (auto)</th>
<th>Parent or child (auto)</th>
<th>Plan</th>
<th>Sequenced assessment</th>
<th>Comments assessment 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Driving task</td>
<td>1</td>
<td>Parent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Start-up</td>
<td>2</td>
<td>1</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1</td>
<td>Boarding</td>
<td>3</td>
<td>Parent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1.1</td>
<td>Locate cab</td>
<td>4</td>
<td>1.1</td>
<td>Child</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.1.2</td>
<td>Enter cab</td>
<td>4</td>
<td>1.12</td>
<td>Parent</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.1.3.1</td>
<td>Unload to unlock train cabin door</td>
<td>6</td>
<td>1.12.1</td>
<td>Child</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.1.3.2</td>
<td>Open train cabin door</td>
<td>6</td>
<td>1.12.1</td>
<td>Child</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.1.3.3</td>
<td>Enter train cabin</td>
<td>6</td>
<td>1.12.1</td>
<td>Child</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.1.3.4</td>
<td>Enter from bulkhead height</td>
<td>5</td>
<td>1.12</td>
<td>Parent</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.1.3.5</td>
<td>Unload to unlock train cabin door</td>
<td>6</td>
<td>1.12.2</td>
<td>Child</td>
<td>Yes</td>
<td>Handle seems a little far into the middle of the door</td>
</tr>
<tr>
<td>1.1.1.3.6</td>
<td>Open train cabin door</td>
<td>6</td>
<td>1.12.2</td>
<td>Child</td>
<td>Yes</td>
<td>Handle to find light switch</td>
</tr>
<tr>
<td>1.1.1.3.7</td>
<td>Discard gear</td>
<td>6</td>
<td>1.12.2</td>
<td>Child</td>
<td>Yes</td>
<td>With time good hand</td>
</tr>
<tr>
<td>1.1.1.4</td>
<td>Store luggage</td>
<td>4</td>
<td>1.1</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1.4.3</td>
<td>Store box</td>
<td>5</td>
<td>1.13</td>
<td>Child</td>
<td>Yes</td>
<td>On near coat hook to make clear of switches</td>
</tr>
<tr>
<td>1.1.1.4.2</td>
<td>Store bag</td>
<td>5</td>
<td>1.13</td>
<td>Child</td>
<td>Yes</td>
<td>Bbr</td>
</tr>
<tr>
<td>1.1.2</td>
<td>Aux start up</td>
<td>3</td>
<td>1.1</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.2.1</td>
<td>Turn on Aux power</td>
<td>4</td>
<td>1.12</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.2.2</td>
<td>Press the Aux On button for 10 seconds (back wall)</td>
<td>5</td>
<td>1.12.1</td>
<td>Child</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.1.2.3</td>
<td>Ensure the TMS begins its cycle</td>
<td>5</td>
<td>1.12.1</td>
<td>Child</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.1.2.4</td>
<td>Check the main reservoir is 7 bar or rising</td>
<td>4</td>
<td>1.12</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.2.5</td>
<td>If the when the main reservoir pressure has reached 7 bar ensure the driver’s seat has been set and fully operational</td>
<td>5</td>
<td>1.12.2</td>
<td>Child</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>1.1.3</td>
<td>Perform post-seated checks</td>
<td>3</td>
<td>1.1</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.3.1</td>
<td>Check switches on back wall</td>
<td>4</td>
<td>1.13</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.3.2</td>
<td>Safety System switches are in the normal position</td>
<td>5</td>
<td>1.13.1</td>
<td>Child</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.1.3.3</td>
<td>Check all Cab MCP’s are set BR-ATP or ETOCS mode locked and on cab back</td>
<td>4</td>
<td>1.13</td>
<td>Child</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.1.3.4</td>
<td>Continue in BR-ATP or ETOCS mode (located on cab back wall)</td>
<td>4</td>
<td>1.13</td>
<td>Child</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1.1.3.5</td>
<td>Check auxiliary equipment</td>
<td>4</td>
<td>1.13</td>
<td>Parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.3.6.1</td>
<td>Check all Emergency Equipment is present and secured as appropriate</td>
<td>5</td>
<td>1.13.4</td>
<td>Child</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
Assessments with representative users
Evacuation assessments
The task of building the task model was relatively time consuming; however once created, it proved to be a very efficient way of assessing the cab and ensuring that a suitable range of tasks had been considered.

We also found the task based assessments gave us some interesting insights that we missed on the static assessment.

If anyone is interested in more detail we published a description of the approach in the Journal of Rail and Rapid Transport
Glare assessment
We were a little surprised that no standard approach to assessment was available. So we spent a little extra time developing one.

The approach we adopted was very simple, for the internal assessment, we blacked out the windows and assessed any instances of glare from the internal lights and illuminated controls and displays. For external, it involved taking a very bright light and repositioning it around the cab to represent a range of external light sources

• 25 windscreen locations
• Side windows
• Side door windows
Subjective assessments
- Internal light sources
- External light sources
- Considering potential mitigations (sunblind, cowling changes, eliminating light sources)

Patterned film to the side windows (initially right side only)

Raising the cowling & recessing controls

Recessing the interior lights

1 – Unbearable
2
3 – Disturbing
4
5 – Just Acceptable
6
7 – Satisfactory
8
9 – Unnoticeable
Impact of mitigations

Reduced internal glare
Reduced glare along top of console
Reduced glare from side window with film

Impact of mitigations

<table>
<thead>
<tr>
<th>Light location</th>
<th>Assessment 1</th>
<th>Assessment 2</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen pos 1</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 2</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 3</td>
<td>2</td>
<td>4</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 4</td>
<td>5</td>
<td>7</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 5</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Screen pos 6</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 7</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 8</td>
<td>1</td>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 9</td>
<td>3</td>
<td>5</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 10</td>
<td>6</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td>Screen pos 11</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 12</td>
<td>1</td>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 13</td>
<td>1</td>
<td>2</td>
<td>-1</td>
</tr>
<tr>
<td>Screen pos 14</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Screen pos 15</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 16</td>
<td>2</td>
<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>Screen pos 17</td>
<td>1</td>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 18</td>
<td>1</td>
<td>2</td>
<td>-1</td>
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<tr>
<td>Screen pos 19</td>
<td>3</td>
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<tr>
<td>Screen pos 20</td>
<td>6</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td>Screen pos 21</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Screen pos 22</td>
<td>3</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>Screen pos 23</td>
<td>3</td>
<td>5</td>
<td>-2</td>
</tr>
<tr>
<td>Screen pos 24</td>
<td>6</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td>Screen pos 25</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Left side</td>
<td>2</td>
<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>Left door</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Right side</td>
<td>2</td>
<td>5</td>
<td>-3</td>
</tr>
<tr>
<td>Right door</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>
It is a subjective rating, so there are certainly some limitations to the approach; however, it was found to be a very effective way of identifying issues in a relatively quick time frame.

If you would like to read more about the approach and its limitations, we published this in Applied Ergonomics.
Cab layout informed by…
- Anthropometric requirements of driver population
- External visibility requirements
- Functional grouping
- Compatibility with the driving task
- Careful consideration of environmental factors
The design includes first and standard class seating areas, wheelchair spaces and Universal Access Toilets, and Space Saver Toilets.
Step 1 – Contractual & regulatory requirements

The main requirements for the passenger areas come from a document called the Persons with Reduced Mobility Technical Specification for Interoperability (PRM TSI). Along with the Train Technical Description (TTD), these requirements ensure accessibility and safety for passengers with reduced mobility.
Steps 2&3

As with the cab, we tried to summarise the requirements pictorially wherever possible, we added additional anthropometric data where appropriate to perform CAD assessments.

The great thing about the PRM TSI regulations is that they are, in most cases, measurable and testable, removing much of the subjectivity.
Step 4 – Low fidelity rig assessment

We prioritised the build of the wooden mock up to focus on the areas that posed the most uncertainty.

There is always a conflict between the space inside the universal access toilet and the width of the corridor along the side. By swinging the wall in and out, we were able to optimise the position.
Step 5 – Ergonomic rigs

We then developed a more detailed rig of the toilets
...and the saloons which were evaluated with passenger groups
Including the assessment of things like luggage and pushchairs
Step 6 – Final mock-up
The final design was verified in a detailed mock-up
As with the cab, we used representative controls and components where possible.
We were able to validate the initial usability assessments.
Step 7 – Compliance demonstration

The final stage was to demonstrate compliance, this was largely done against drawings; however, the mock up proved an invaluable part of demonstrating the more subjective aspects of the design.
Force meters were used to ensure forces were within limits.
The same with light levels
We also designed and assessed bike storage
And the compatibility of the trolley with the train
It’s been a really exciting project to be involved with right from the drawings through to the first train being manufactured.

As a team of designers, engineers, model-makers and HF people we have been able to deliver the project.

Early and frequent HF assessments have been a key part of this ensuring that stakeholders were consulted and engaged with the process and that any issues of non-compliance or poor usability were uncovered early in the project.
From a personal perspective, it’s great to be part of a project where true integration of HF can happen.

It’s also great to be able to publish and share the more novel aspects of the project.

And it’s great from a commercial perspective too, the HF aspects of this project were a key part of the decision in making DCA strategic partners with Hitachi and the award of a further train contract which we are now about half way through.
For further information please contact
daniel.jenkins@dca-design.com