Acquiring a custom-made sensor-system for S&Cs – experiences, recommendations and perspectives

Presented for the INTELLISWITCH Symposium 28th-30th of August 2017 by Tom E. Thøgersen, Banedanmark, Technical Division, Track East, Track Systems & Development

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Background

The task in WP1:

- Acquire a measurement system for the INTELLISWITCH project that could…
  - Be physically implemented in an S&C of type UIC60 (60E2) 1:14 R500 with concrete sleepers and (primarily) manganese crossing
  - Continuously capture data of the right type, format and quality in designated measurement points in the S&C – to be used for the verification of S&C wear models and works in the other WPs
  - Help to identify changes over time in the superstructure and substructure of the S&C
  - Be acquired within an initial budget of some DKK 500,000 (~ EUR 68,000)
- In the end, it had to be aqcuired in a tender process to meet internal legal requirements and requirements from the funding entity ”Innovationsfonden”

Program

1. Approach in the tender and acquisition of the S&C measurement system

2. Considerations, challenges and important aspects of our requirements

3. Experiences with the outcome of the tender and the S&C measurement system so far

4. Recommendations on dos and don’ts in such an acquisition process to lower your risks

5. Future perspective of the S&C measurement system

1. Approach in the tender and acquisition of the S&C measurement system

- Looking to the market, it quickly became clear that it would end up being a customized system
- The initial budget of DKK 500,000 (~ EUR 68,000) was too low – we therefore agreed to raise it a little, but the goal was still to come as close to the initial budget as possible
- Time was of the essence since other WPs needed the measurement data to start up/continue their work
- So:
  - Very little insight into what could meet our needs
  - Too small a budget for a ”Rolls Royce” of a system
  - No time for a proof of concept fase

1. Approach in the tender and acquisition of the S&C measurement system

- ”Market dialogue” with a supplier to get insight into possibilities

- Due to the estimated lower costs of the system, it could be acquired through a limited tender process where a smaller amount of tenderers were invited to give their offer

2. Considerations, challenges and important aspects of our requirements

Overall considerations and challenges:

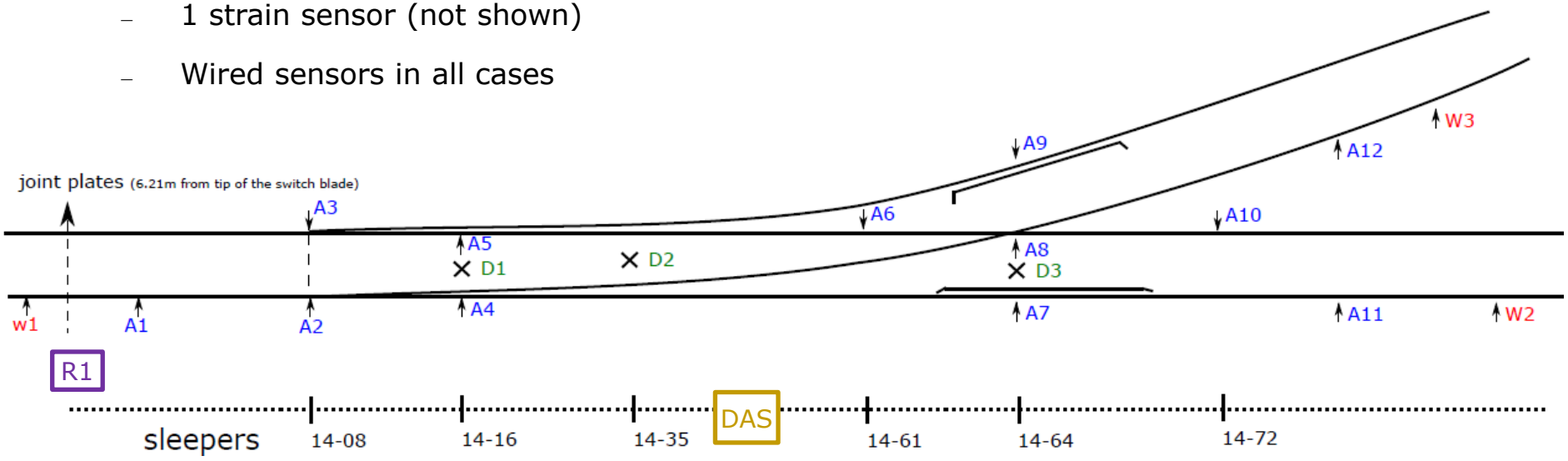
- How to get sophisticated measurement equipment on a low budget?

- Cut down on certain requirements that would otherwise cost money:
  - A pure equipment purchase – Banedanmark/DTU to install and operate the system on its own and process the sensor outputs
  - Focus on sensors providing vertical and lateral accelerations of the rail or sleeper and vertical track deflection
  - A good amount of optional requirements, including RFID-readers and optional sensors
  - No FAT/SAT
  - Limited sensor fixation methods (gluing, magnets and clamping devices)
  - Durability/service life of system limited to the project life (5 years)
  - IP-ratings not to the high side (IP64 instead of IP66/67)
  - Limited storage in the Data Acquisition System (DAS)
  - Lowering the requirements for documentation to a certain degree

2. Considerations, challenges and important aspects of our requirements

This is what we asked for:

- 12 2-axis accelerometers, vertical and lateral accelerations (A1…A12)
- 3 vertical displacement sensors (D1…D3)
- 3 wheel sensors (W1…W3)
- 1 RFID-reader (R1 - optional)
- 1 Data Acquisition System (DAS) with wireless data transfer
- 1 strain sensor (not shown)
- Wired sensors in all cases



2. Considerations, challenges and important aspects of our requirements

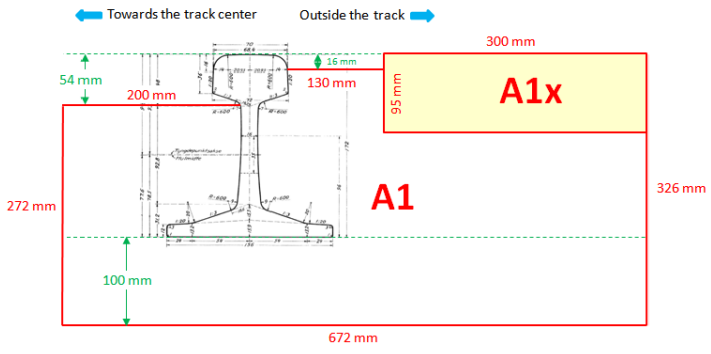
Layout requirements

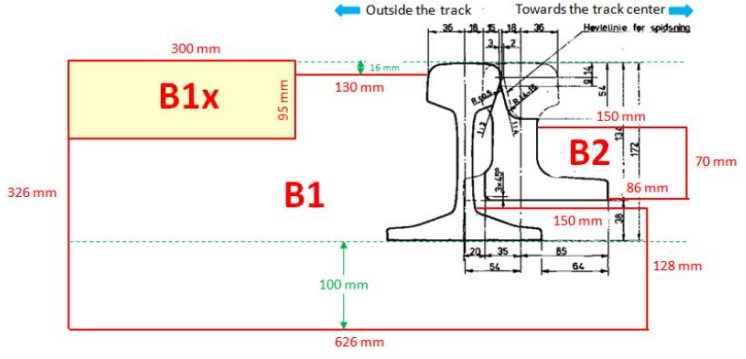
- No modification of existing track components – this also eases the safety paperwork significantly!
- Maximum installation time and de-installation time: 3.5 hours (fitted to our normal track possession possibilities during nighttime)
- Maximum weight of each component of 25 kg (even the DAS)
  - To allow us to carry equipment by hand, transport it in a minivan, and thus avoiding the high costs of big trucks or railway trolleys
- 80 m cable lenght as standard for each sensor
  - This is a lot of cable, but needed to ensure flexible repositioning of sensors during measurement campaigns
  - Existing power sources can be positioned a long way from the cabinet, so a power cable lenght of 150 m was required (cheaper than establishing a new power source)

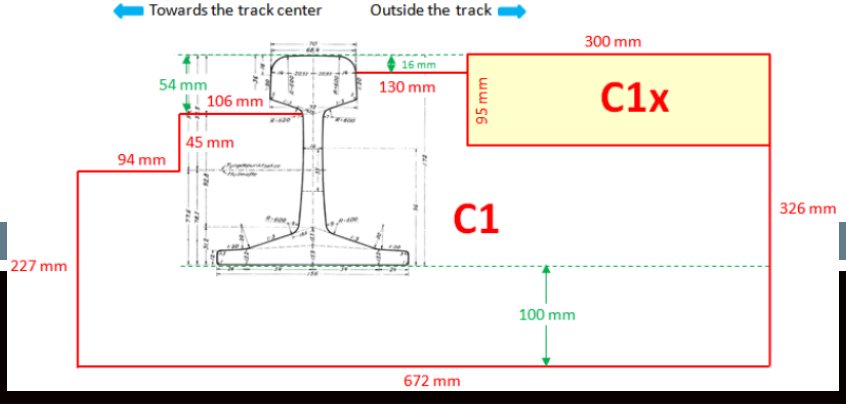
2. Considerations, challenges and important aspects of our requirements

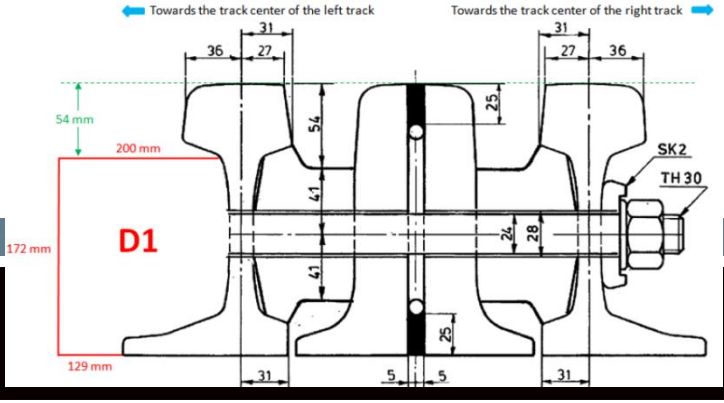
Layout requirements (continued)

- We allowed sensors to be installed either at/in sleeper drilling zones or on rail pieces
  - An S&C is regarded as a safety component, and rules regarding the free profile gauge around rail pieces are strict
  - It was therefore highly relevant to specifiy, for each relevant measuring point in the S&C, where sensors could be positioned









2. Considerations, challenges and important aspects of our requirements

Layout requirements (continued)

- Wireless data transfer to avoid a side-project with Banedanmark's IT-department (which would have been very time-consuming and costly!)
- Training course in the system configuration, installation etc.

Requirements on mechanical properties of sensors

- Sensors to withstand high impacts and mechanical loads of the railway environment
  - Wheel impacts on rails of 650 kN static + peak dynamic force is not at all unusual, and this can be even up to 1000 kN in some rare cases
- Sensors to be protected with suitably robust enclosures, for instance due to hanging/dragging chains from trains

2. Considerations, challenges and important aspects of our requirements

Functional requirements of the sensors and the system:

- Specifying the range of characteristics of passing trains:
  - Speed 5 – 180 km/h
  - Train lenghts from 20 – 1,000 meters
  - Wheel diameters between 300 – 1,300 mm
  - Headway times of minimum 2 minutes
  - Etc.

- Important to also understand the characteristics of each passing train producing the sensor signal outputs:
  - RFID-readings to provide information about the train type, and from this the wheel diameters and axle distances
  - WILD-system nearby to provide information about vertical static and peak dynamic forces of each passing wheel
  - Time stamps from entering wheel sensor and exiting wheel sensor allow the calculation of the speed of the passing train (therefore a high resolution of 0.001 seconds or better was required)

2. Considerations, challenges and important aspects of our requirements

Functional requirements of the sensors and the system (continued)

- Wheel sensors also to be used for either arming the sensor system for a train passage, or for limiting signal outputs and data sets to the relevant ones coming from a train passage

- Accelerometer measurement range: +/- 500g or +/- 5000g?
  - Ended up requiring +/- 500g, a bandwith of 10 kHz and a measured lower frequency of 10 Hz

- Displacement sensor measurement range: ≥ 20 mm with respect to the rest position, 0.1 mm resolution or better

3. Experiences with the outcome of the tender and the S&C measurement system so far

What is the goal of tendering? – many will say:

"To produce a whole **Too simplified – good luck!** *the end will give me a solution with the bes* *est quality and/or the best price"*

The "true" goal of tendering is more often something like this:

- Minimize the risks of both you and the supplier through carefully considering and thoroughly specifying your needs in an understandable manner – this will increase the chances that you are actually delivered what you requested
- Minimize your risks by making sure that the chosen supplier has actually understood the requirements and what he shall deliver
- Establish a good relationship with the supplier

And even then, you are not at all ensured that everything goes according to plan

3. Experiences with the outcome of the tender and the S&C measurement system so far

This is what we got:

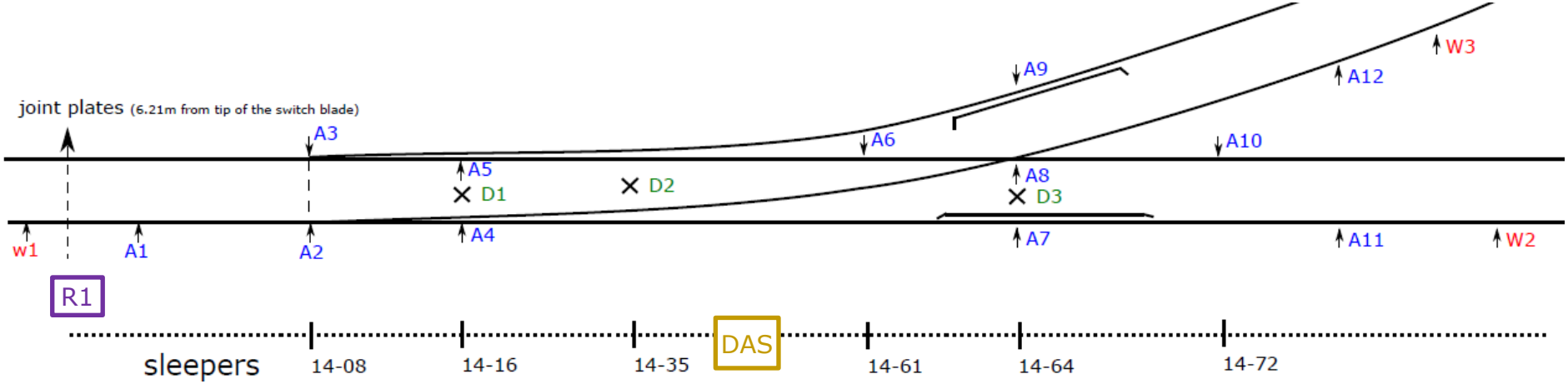
DAS

Wheel sensors

RFID-reader and -antennas

Accelerometers

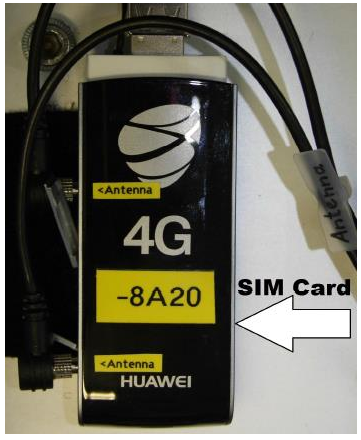
Displacement sensors



3. Experiences with the outcome of the tender and the S&C measurement system so far

After testing all sensors , we went into operation on a ”trial and error” basis

A lot of ”children’s deseases” were rather quickly erradicated, but some were, and some are still more troublesome to overcome:



1. Unstable Internet connection

- Internet connection often disconnected and had to be re-connected manually in the DAS
- No possibilities of altering the software of the LTE-stick provider
- Solved with a script re-booting the PC when internet connection is lost

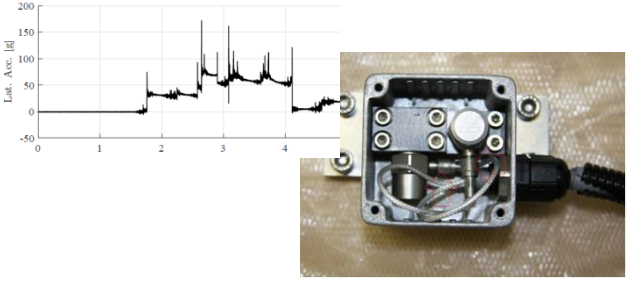
2. The ”science” of RFID-systems

- Loss of time- and data-synchronisation with the DAS, reading RFID-tags from the neighboring track, understanding and translating the RFID-tag code read into RFID-numbers

3. Experiences with the outcome of the tender and the S&C measurement system so far

3. Different problems with accelerometers

- Neodymium magnets not strong enough to hold the weight of the sensor and to keep it from rotating around itself



- Accelerometers need strong fixation within their casings to keep them from producing signal offsets in the data
- Shrink tubing seems to have done the trick

- Gluing sensors to rail pieces is troublesome!
- A yet to solve problem for manganese crossings that are not magnetic
- Difficult to get enough hardening time of the glue when installing it in short track possessions

3. Experiences with the outcome of the tender and the S&C measurement system so far

4. Problems with the tough environment

- Plexiglass is apparently not strong enough for the railway environment!

- There can be high amounts of (rain) water out there - or perhaps too good conditions for moisture condensation?

- The right IP-ratings are highly relevant

4. Recommendations on dos and don'ts in such an acquisition process to lower your risks

Pre-acquisition phase:

Recommendation #1

- Ensure enough time and money to…
  - investigate potential sensors, systems and technologies in the market
  - perform proof of concept tests
  - request a FAT, and even more important a SAT – something that works on a factory floor might not work the same way in its actual environment
  - prepare your tendering material

Recommendation #2

- Most important to get well-functioning sensors from the beginning
  - It is less troublesome these days to get the data aquisition and data processing parts of the system to work properly

4. Recommendations on dos and don'ts in such an acquisition process to lower your risks

Pre-acquisition phase (continued):

Recommendation #3

- Carefully consider the sensor fixation methods that you allow
  - Gluing is a pain unless it will have enough time to dry and harden
  - Neodymium magnets are good, but need to be strong for the sensor not to move
  - Must be substantially fixed at its position due to the very high impacts

- Sturdy and well-protecting enclosures for sensors are definitely needed

- Wired vs. wireless sensors:
  - A lot of cable to manage, but this is manageable
  - Wireless sensors may introduce other problems such as loss of connections and replacement of batteries every second month or so

4. Recommendations on dos and don’ts in such an acquisition process to lower your risks

Pre-acquisition phase (continued):

Recommendation #4

- Consider carefully how robust you want the system to be in its interface to track maintenance activities, to passing trains etc.
  - If you can live with de-installing the system every time the rails are grinded and the S&C is tamped, for instance, you can probably save a lot of money on lower robustness.
  - These days the casings, fixation devices and cables constitute a big part of the combined sensor price

Recommendation #5

- The right IP-rating is very important – you should ask for IP67 and maybe even IP68

4. Recommendations on dos and don’ts in such an acquisition process to lower your risks

Post-acquisition phase:

Recommendation #6

- Establish a productive and good relationship with the supplier – especially when acquiring a custom-made sensor system
- Language barriers in the co-operation phase can be time-consuming and difficult to overcome – establish a plan for this in advance should the problem arise

Recommendation #7

- Besides checking the functionality of the system, you should inspect components upon delivery to ensure that they meet requirements on sturdiness, IP-rating etc.
  - Do not expect that these requirements have been met
  - Otherwise you risk spending a lot of time on repair works etc. which kills measurement time in the S&C

4. Recommendations on dos and don’ts in such an acquisition process to lower your risks

Post-acquisition phase (continued):

Recommendation #8

- Calibration of sensors is important
  - Allow some time to investigate the true signal output of the sensors and perform the necessary calibration activities before you put the system to work
  - Do not expect that sensors of the same type and manufacture will produce the same signal outputs

Calibration of the 12 2-axis accelerometers recently performed with the use of a calibrated reference accelerometer, a shaker and a metallic ruler to find the scaling factor for each used accelerometer

Recommendation #9

- Ensure enough time for a trial period – vital when dealing with a custom-made system that nobody actually knows if will work

4. Recommendations on dos and don'ts in such an acquisition process to lower your risks

Benchmarking of Banedanmark sensor system acquisitions:

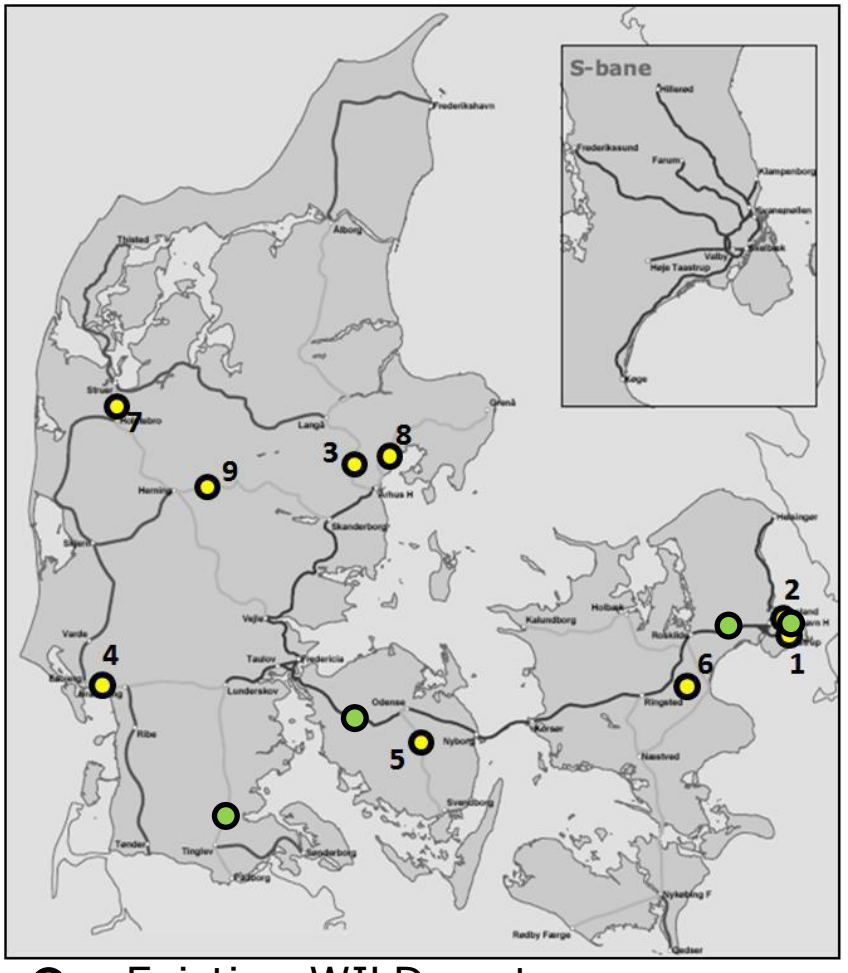
	The S&C measurement system	WILD-system
Technology	Accelerometers, vertical displacement sensors, RFID-system	Fiber-optic sensors, RFID-system
Are they proven sensors in the market?	No	Yes
Were sensors causing problems?	Yes – it has taken 1+ year to achieve valid measurements after 1st installation	No problems with sensors – valid measurements could be obtained right after SAT
Duration of tender process (from writing of tender material began to the acquisition was made)	Approx. 6 months	Approx. 14 months
Proof of concept phase / trial before operation	No	Yes
FAT required	No	No
SAT required	No	Yes

5. Future perspective of the S&C measurement system

- Highly unlikely that Banedanmark acquires S&C sensor systems for its 3500 S&Cs

- More likely to utilize the already measured data on static and dynamic wheel forces and axle loads from Banedanmark's WILD-systems to say something about the S&C usage over time

- The accumulated WILD-data could become a parameter variable included in the calculation of the Maintenance Performance Indicator for each S&C



= Existing WILD-system
= Possible future WILD-system

5. Future perspective of the S&C measurement system

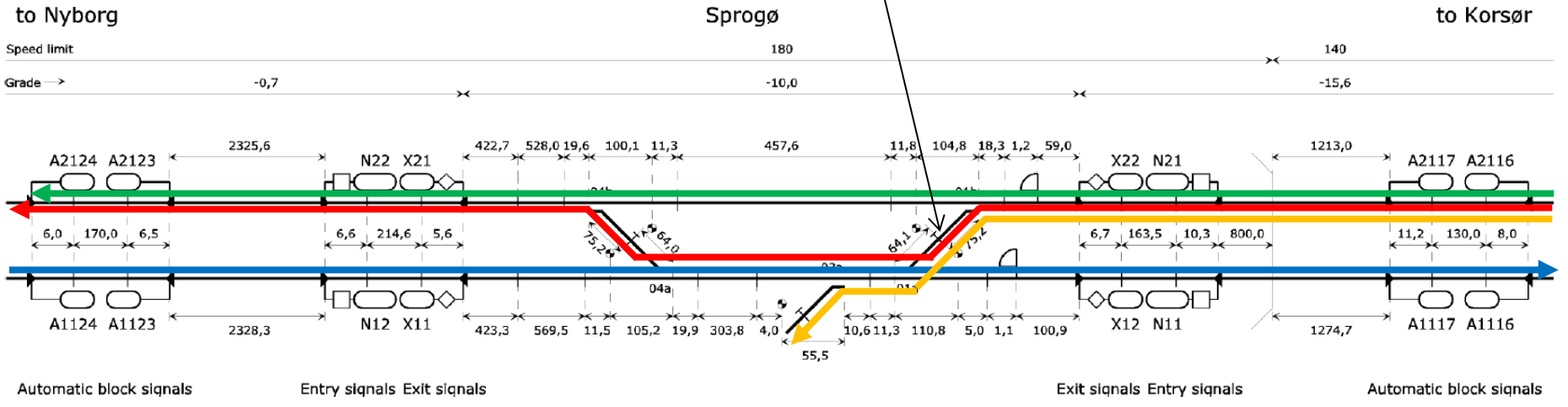
Application/algorithms which combines the detailed train routes from Togstatus / ATNS with the data from Banedanmark's WILD-systems

- To calculate and accumulate the static and dynamic wheel forces (S&C tonnage) through the main and divergent track of each S&C
- The more WILD-systems, the more certainty about S&C tonnages

WILD-system, Od-Tp
Measures static weights and dynamics of trains

Togstatus / ATNS
Keeps track of train routes and if the train has run in the main or divergent track of an S&C

WILD-system, Gl-Htå
Measures static weights and dynamics of trains



Thank you for your kind attention!

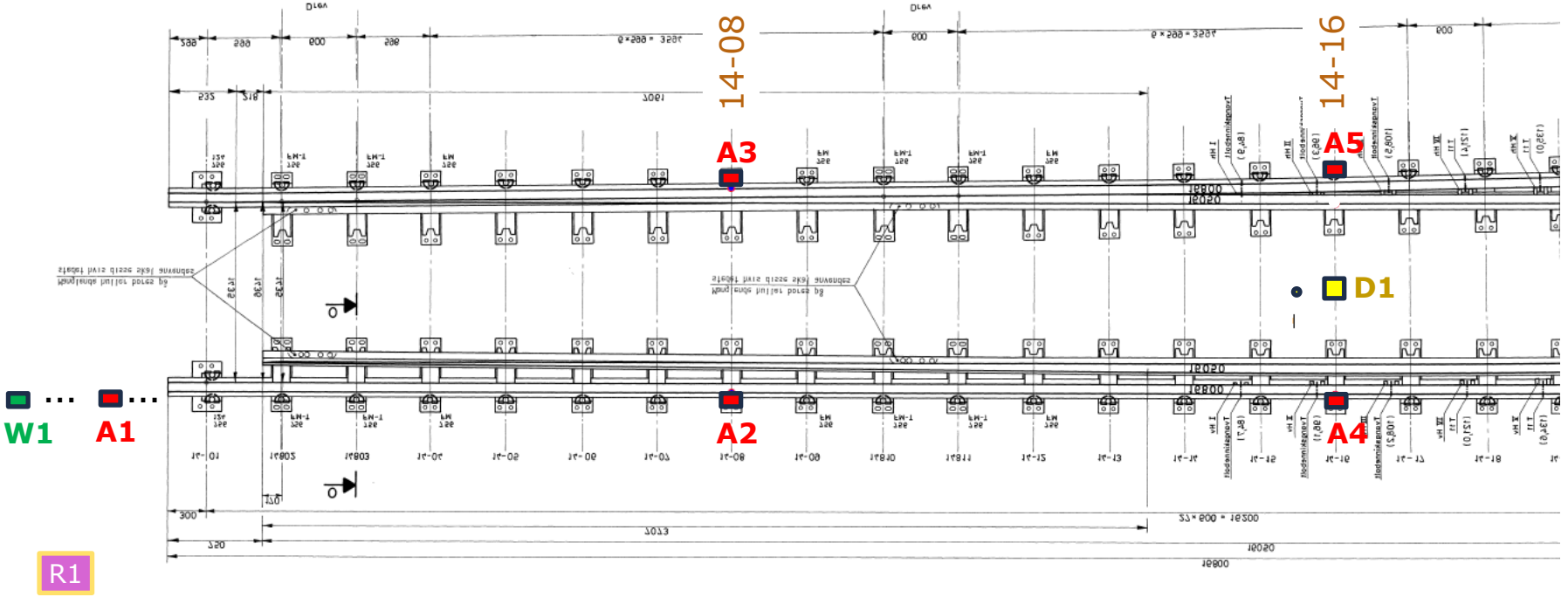
For any questions, you are most welcome to contact me:

Tom Elnar Thøgersen
Project Manager of R&D projects

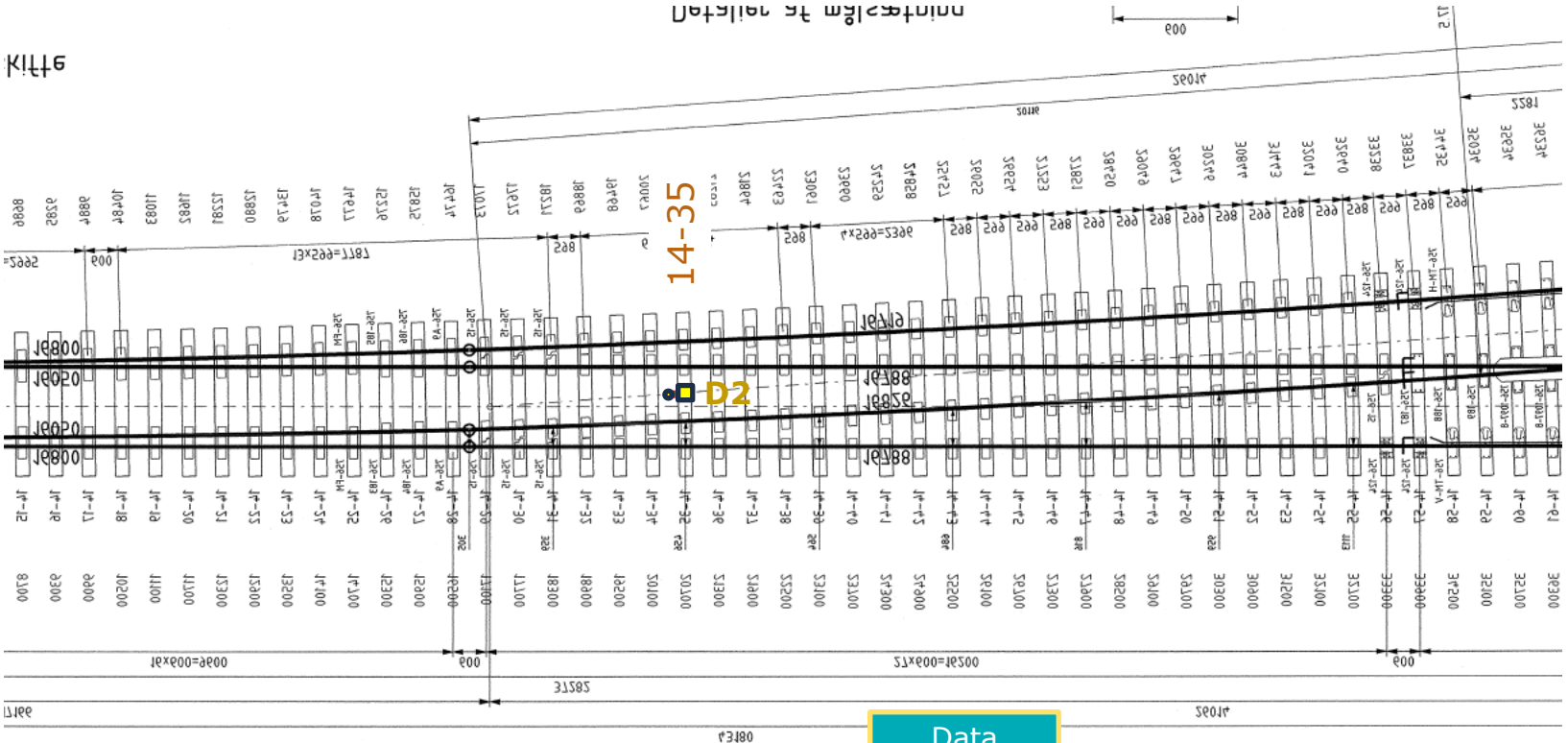
Rail Net Denmark
Technical Division, Track Systems & Development
Vasbygade 10
DK-2450 Copenhagen SV
D: +45 8234 9584 | M: +45 2096 9474
teth@bane.dk
www.banedanmark.dk

Backup slides

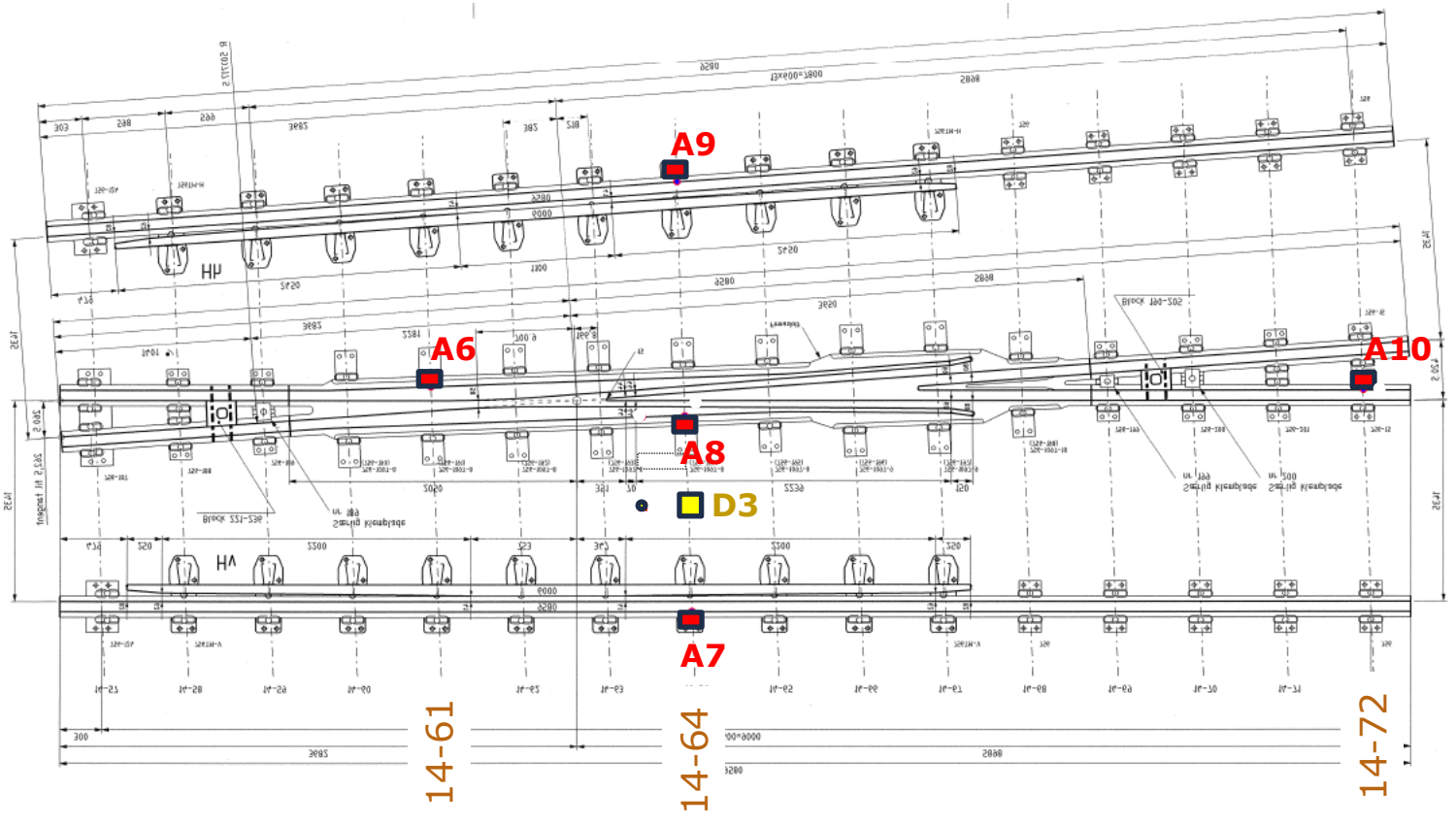
SMS-sensor locations – S&C switch panel



SMS-sensor locations – S&C closure panel



SMS-sensor locations – S&C crossing panel



SMS-sensor locations – S&C rear end