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Glossary

Abbreviation/acronym	**Description**
Continuous parameter	A parameter which is measured by the monitoring system at regular intervals and at all times
DLD	Drive and Locking Devices
EFFBD	Enhanced Functional Flow Block Diagram
FMECA	Failure Mode, Effects, and Criticality Analysis
LCC	Life Cycle Cost
RAMS	Reliability Availability Maintainability Safety
S & C	Switches and Crossings
SP6	Sub Project n°6 from INNOTRACK project: LCC calculation
Throw parameter	A parameter which is measured by the monitoring system only when the switch is being thrown from one position to the other.

1. Executive Summary

The objective of the Innotrack project is to find new technologies for S&C which can contribute to an overall 30% reduction in their life-cycle cost.

Around 50% of the LCC for a S&C system comes from routine maintenance, which is generally organised according to fixed periods which are determined using a conservative estimate of the amount of time it is safe to leave parts of the S&C unmaintained. This means that more money is spent than necessary, in periodic maintenance. Technical staff are also exposed to lineside hazards more than is necessary, because of the extra time they spend on site.

Additionally, these maintenance and inspection periods are not always sufficient to mitigate the risk of right-side failures. Inspection by humans often only has a superficial insight into the operation of a switch.

A more efficient approach to maintenance would be to have accurate automatic condition monitoring systems which can direct maintenance activities more efficiently by only specifying and scheduling tasks which are needed.

The requirements for automatic monitoring systems will be different depending on what equipment is to be monitored and where the system is operating. However, it has been possible to create a generalised set of requirements which can be applied globally and these are presented in section 4.

The functionality and physical architecture of the higher levels of monitoring systems have also been specified in this document. The functional architecture in section 5 shows how the system is expected to interact with its environment, and includes a description of the inputs and outputs. The possible physical architecture is described in section 6.

2. Introduction

2.1 Purpose

This document aims to guide the design of new monitoring systems for switches and crossings. It contains a minimal set of general requirements which should be fulfilled by new S&C monitoring systems. The requirements are supported by diagrams which specify the minimum functionality of a S&C monitoring system.

2.2 Motivation: reducing maintenance costs

Maintenance tasks performed on S&C can be put into one of two categories:

- Safety-critical tasks

Failure to complete these tasks properly can lead to wrong-side failures. S&C components which fail wrong-side have the potential to cause derailments.

- Reliability-critical tasks

Failure to complete these tasks properly can lead to right-side failures which cause disruption to train services, possibly resulting in penalty payments, loss of reputation and reduction in custom for railway stakeholders (such as infrastructure managers, contractors and service operators).

Section 8 contains summaries of the inspections and maintenance tasks carried out on S&C in Germany and Sweden.

Even if failures do not occur, inadequate maintenance can reduce the lifetime of components of S&C and reduce its performance in terms of throw speed, noise emission, power consumption, and leakage of power transmission media (in hydraulic- and pneumatic-actuated systems). This may, in turn, lead to reduced component lifetimes or increased maintenance needs, both of which increase the LCC.

S&C systems demand a large amount of periodic maintenance, most of which consists of visual inspections and measurements. These observations are needed in order to gain the most accurate understanding possible of the switch’s condition and thereby to mitigate the risk of failure.

Typical switch locking systems alone require around 60[1] maintenance tasks including observations, adjustments (where necessary) and lubrication. These tasks are performed every 6 months to 3 years, depending on the criticality of the task and the number of throws the switch performs.

Periodic maintenance accounts for a significant portion of the life-cycle cost of a switch-and-crossing system. Since manual condition monitoring (inspection and measurement by technical staff) forms a large part of this cost, there is clearly a large potential to reduce the LCC of S&C by performing some of the previously manual condition monitoring tasks with new automatic systems. The maintenance costs for DLD components have been studied on two examples in two countries. The result is documented in deliverable D 3.2.1

2.3 Content

Section 3 sets out the general requirements for S&C condition monitoring. Each requirement has been written with the intention of being as clear as possible. Where a requirement is not a single, testable

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[1] Source: Deutsche Bahn maintenance schedule for Klinkenverschluss (pin locking mechanism)

statement, it has been refined by creating child requirements which refer to the original one and each cover a small part of the scope of the original requirement.

Mandatory requirements are marked with the letter '*M*'; if this letter is not present next to a requirement, then it is a preference (optional) requirement.

The term "the switch" refers to any switch monitored by the system.

Section 5 describes the functional context in which the monitoring system is expected to operate. This representation can be used as a starting point for system design.

This document represents some of the early work needed to develop new monitoring systems. The internationally-recognised 'V' model for system development is shown in Figure 1 along with section references for this document, to give some reference for what part of the design process is addressed in each section.

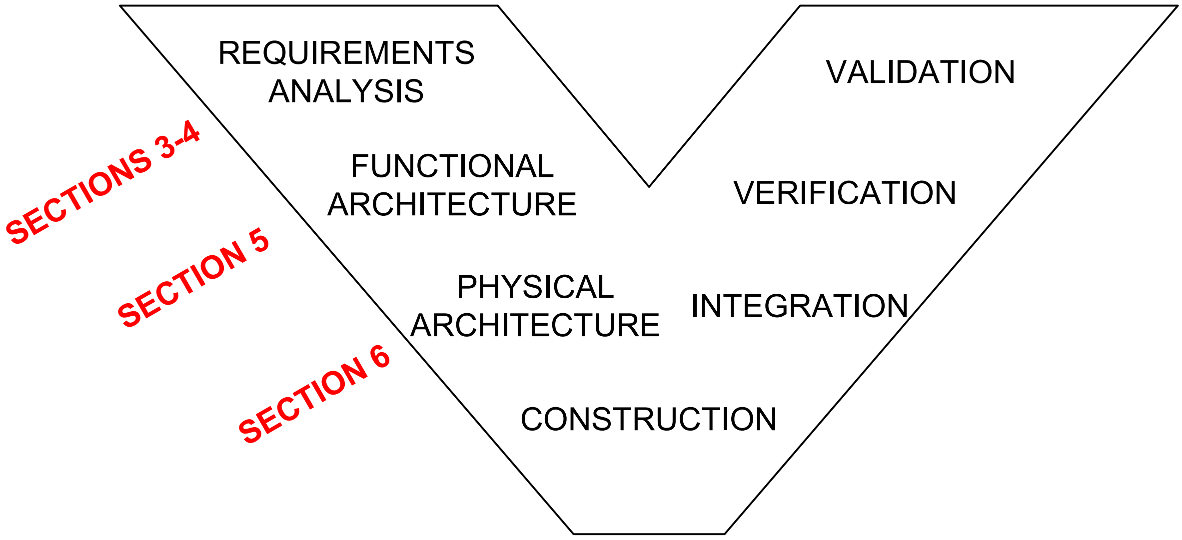

Figure 1 - 'V' model for systems engineering design process

3. Focus on LCC in S&C monitoring systems

It is important to quantify the reduction of LCC which can be achieved by introducing monitoring systems for S&C.

A spreadsheet-based tool was developed in SP6 to assist in determining the possible reductions in LCC. A cost structure was defined with 4 topics: procurement, services, maintenance and availability. The tool focuses on some costs related to the monitoring system and these costs are classified by the cost structure.

The reference system is a turnout without a monitoring system and the optimized system is a turnout with monitoring system.

The data set used in the tool is an average view of the European infrastructure. The goal of this work was not to make the LCC calculation but rather to define the requirements of a monitoring system in terms of LCC reduction.

The LCC calculation will be done achieved in SP6 with data from throughout Europe.

3.1 Variables to optimise LCC reduction

Two key factors influence life-cycle cost, from a maintenance point of view. These are the cost of time spent in maintenance, and the indirect costs incurred as a result of delays caused by failures.

Another aspect is the cost of large components and raw material. This cost may be significantly reduced by using a monitoring system and avoiding or preventing the deterioration of components such as the switch blade. Accurate condition monitoring can reduce the amount of components which are exchanged unnecessarily in attempts to correct faults which have been incorrectly diagnosed.

3.1.1 Maintenance time

Monitoring systems must be supervised by humans, for the foreseeable future, and this requires the time of trained technicians. However, much time can be saved in avoiding inspections, manual diagnosis and unnecessary periodic maintenance if an accurate condition monitoring system is introduced. The time saved by the system must be many times larger than the time technicians must spend learning the operation of the monitoring system, and supervising it when it is operating.

3.1.2 Failure rate

The failure of S&C installations can cause large-scale disruption to train services. In a deregulated environment this leads to the payment of penalties, which are usually calculated on the basis of delay minutes. Each delay minute represents a single train being delayed for one minute – on a busy route a single disruptive incident may delay many trains and therefore incur a high cost in delay minutes. By identifying faults early, failures can be avoided, not only reducing delay minutes but also the extra cost of finding technical staff to make repairs at short notice.

3.2 How monitoring can reduce the impact of the key cost drivers

3.2.1 Reduction of inspections

Currently, most inspections are carried out at the switch site by experienced maintainers, using mechanical tools. The potential for reducing time spent by maintainers on these tasks depends on the technology available, that is, what variables can be remotely monitored, and what can be inferred from them about the state of the switch. This leads to a potential reduction in the number of inspections required.

By using modern remote access technology, the cost of the time spent is also reduced (since on-site inspection, with its safety arrangements and transport, is much more expensive than off-site supervision of monitoring).

3.2.2 Reduction of the corrective maintenance

An optimal maintenance regime would focus on preventive maintenance and objective (i.e. automated) condition monitoring, replacing some of the unavoidably subjective inspections by human maintainers. Corrective maintenance must often be arranged in a hurry, to correct a failure which is causing a delay. This adds to the cost because resources must be obtained at premium cost. Rushed repairs may also need to be revisited later for further work. Since the state of health of a switch is worse when it has eventually failed than it is when a fault is slowly developing, the cost of repairs is likely to be higher as well.

3.2.3 Increasing switch lifetime

Maintenance is likely to be more efficient with a monitoring system. Components like the switch, the frog and the DLD will be kept in a better condition, providing the opportunity to increase the life of the components of the turnout. The benefit is an increase in the residual value of the asset. There is little evidence currently available to support this idea, but it is intuitively true and it seems likely that future experience with condition monitoring systems will show that switches can be kept in service longer if they are more efficiently maintained.

3.2.4 Reduction of the failure rate

The primary purpose of monitoring systems is to reduce the failure rate by sending alarms before the failure occurs. The capabilities of monitoring systems should be adjusted for the failure modes which cause the most delays, in order to reap the maximum benefit. The parameters to monitor and the analysis capabilities used should be tailored for each switch installation according to what failure modes are prevalent at that location.

3.3 Investment in condition monitoring

Monitoring systems can be configured with varying levels of capability, with corresponding variation in the cost of installation. The capability of the monitoring system should therefore be matched closely to the potential savings in maintenance and reliability. For example, relatively low levels of monitoring capability can bring large benefits when installed on heavily-used switches or those with known reliability problems. On the other hand, it brings little benefit to install high levels of monitoring capability on rarely-used or exceptionally reliable switches. However, it is also desirable to make expansion as easy as possible, should the circumstances change at a particular site.

4. General requirements for S&C monitoring systems

R1	***M***	***Communications interface***
Description		The system shall have a standard communications interface.
Rationale		This will promote interoperability between systems installed by different manufacturers or at different times.
R1.1	*M*	*Communications interface – physical and data link layers*
Description		The system shall have an Industrial Ethernet communications interface.
Rationale		Industrial Ethernet enables the exchange of safety and non safety-critical messages and commands on one physical data line. Telecommunications and signalling are likely to include this technology in the near future. Industrial Ethernet can reduce cabling costs and improve access to data. More details on this are given in D 3.2.3.
R1.2	*M*	*Communications interface – message formats*
Description		The system shall send and receive messages on the standard interface in an agreed standard file format.
Rationale		This will allow monitoring systems to be made up from components made by different manufacturers.
R1.3	*M*	*Communications interface – communication with external systems*
Description		The monitoring system shall communicate with external systems using an agreed standard XML file format.
Rationale		This will allow other infrastructure systems to have access to the data collected by the S&C monitoring system, reducing the duplication of effort and components. For example, if the ambient temperature at a switch location can be used as an accurate ambient temperature for another monitoring system, it makes sense for that data to be made available to other systems, rather than for another temperature sensor to be installed. XML is a format which is already a well defined standard in widespread use and is readily compatible with Web-based applications, making it a suitable standard choice for this application.
R2	***M***	***Condition evaluation***
Description		The system shall continuously evaluate the condition of the switch, using data measured from sensors at switch sites.
Rationale		This will help maintenance staff to predict failures, or to respond more effectively when failures occur.
R2.1	*M*	*Custom monitoring rules*
Description		The system shall allow custom fault detection rules to be created by users.
Rationale		Countries and network companies have different capabilities and staff to perform data analysis. They also have different varieties of equipment for the same functions. This means that an adaptable approach to fault detection and diagnosis is required.
R2.2	*M*	*Detection of increased driving force*
Description		The system shall display an indication to the user when the driving force for a switch throw shows an increasing trend.
Rationale		The driving force is a key indicator of incipient faults in a DLD component or the switch itself. The detection of such a trend enables preventative

maintenance tasks to be applied before the system fails and downtime occurs. This requirement helps to improve reliability and reduce the operational cost.

Infrastructure operators commonly apply thresholds for the maximum force in the drive when they install switches. Alarms raised on the increase of the maximum force are therefore very relevant to maintainers and can indicate a serious problem.

R2.3 *M* *Detection of incipient faults*

Description The system shall detect incipient faults in the switch.

Rationale Incipient faults develop slowly but can cause failures. If the system can detect them in the early stages of development, maintenance can be scheduled before a failure occurs, which avoids delays to train services. Knowledge of the type of incipient failure enables the accurate planning of maintenance action.

R2.4 *M* *Isolation of incipient faults*

Description The system shall determine which component in the switch is faulty when an incipient fault is detected.

Rationale The switch contains many mechanical components that may be damaged or at least need to be adjusted. The required replacement parts can be obtained in advance, and the downtime for the repair can be estimated.

R2.5 *Determination of maintenance intervals*

Description The system shall be able to determine the required dates for maintenance tasks to be carried out.

Rationale If the condition monitoring system is reliable, the service intervals can be extended and the service tasks synchronised with safety critical maintenance tasks. For instance a fixed safety inspection can be carried out at the same time as the replacement of a faulty unit or maintenance of the component, reducing the amount of time maintainers need to spend on site.

R2.6 *M* *Reporting of operations since last inspection*

Description The system shall be capable of reporting the number of throws a switch has performed since its last inspection.

Rationale The frequency of the switch use corresponds with the wear and tear of parts. This capability gives the infrastructure manager greater visibility of the use of assets on the network.

R2.7 *M* *Reporting of parameters*

Description The system shall be capable of creating a custom report to display the user's choice of parameters for any switch operations (including single operations or ranges of operations, to be specified by the user) in the data record.

Rationale The flexibility of the report gives the users the opportunity to quickly familiarise themselves with a switch's individual performance, to diagnose faults using their own knowledge of certain parameters, and to gain a deeper understanding of the switch's operation.

This can aid staff installing the switch as well, as a custom report could be created to compare measured parameters with a reference data set, to check a switch has been installed correctly.

R2.7 *M* *Reporting of condition monitoring results*

Description The system shall be capable of creating a custom report to display the user's choice of condition monitoring results for any switch operations (including single operations or ranges of operations, to be specified by the user) in the data record.

Rationale A flexible reporting system allows users to match condition monitoring results to the parameters measured at any one time. This promotes better understanding among users and allows them to create new rules for diagnosis.

This capability can also help staff in the validation and commissioning of switches.

R3 M Monitoring of key parameters

Description The system shall monitor the key parameters which affect the switch's performance.

Rationale The key parameters are those which show the largest effects when faults are present and therefore give the system the best chance of accurate diagnosis.

R3.1 M Monitoring of heater activity

Description If a heater is installed at a switch, the system shall monitor whether the heater operates correctly when required.

Rationale Temperature and the heater function have influence on the driving force. Non-operation of the heater is a major cause of switch failure. This is often caused by manual setting of the heater.

R3.2 M Monitoring of narrowest flangeway

Description The system shall monitor the narrowest flangeway distance.

Rationale This feature improves switch safety by raising alarms if the minimum flangeway is detected to be less than the safe minimum.

R3.3 M Monitoring of drive force

Description The system shall monitor the force in the drive during each switch movement.

Rationale This is required in order to analyse long-term trends and detect incipient faults.

R3.4 M Monitoring of fluid pressure

Description If hydraulic or pneumatic actuators are used to throw a switch, the pressure in the actuators shall be monitored during each switch movement.

Rationale Changes in the individual drive point pressure can indicate an incipient problem.

R3.5 M Monitoring of motor current

Description If a switch actuator uses an electric motor, the current in the motor shall be monitored during each switch movement.

Rationale Current in the motor was determined as a key parameter in D3.3.1. It is relevant to all types of switch actuator with electric motors. In the case of AC machines, the r.m.s. current should be measured.

R3.6 M Monitoring of displacement

Description The system shall monitor the horizontal displacement of the drive rod.

Rationale The displacement bears more information than the throw time measurement alone. A force-displacement curve indicates incipient problems that may be related to DLD components (e.g. locking device).

The measurement of the displacement of the drive rod provides information about the adjustment at the point. The best indicator of the adjustment of the drive rod is given by this measurement.

R3.7 *M* *Monitoring of end position*

Description The system shall continuously monitor the state of each end position detector.

Rationale By monitoring each detector separately, detector faults can be isolated quickly, reducing the time maintainers need to correct them.

R3.8 *M* *Monitoring of acceleration levels*

Description The system shall continuously monitor acceleration levels at a suitable location on the switch.

Rationale The effects of vibration are not completely understood, but it is likely to be a key factor in the failure of switches. When more data have been gathered, it will become possible to draw useful conclusions on how vibration affects the operation of a switch.

R3.9 *M* *Monitoring of the switch blade temperature*

Description The system shall continuously monitor the temperature of the switch blade on the switch.

Rationale The temperature around the switch has a large effect on the operation of the switch. Monitoring of the temperature will help users tell the difference between mechanical faults on the switch and poor performance due to extreme temperatures.

The measurement of the rail temperature helps the maintenance team to know the length variation of the blade. In some infrastructures a high temperature implies that adjustment of the components of the turnout (e.g. locking devices) is needed.

R3.10 *Monitoring of air temperature*

Description The system shall continuously monitor the air temperature in the vicinity of the switch.

Rationale The measurement of air temperature and humidity is important to adjust the signal processing. For example the throwing force is linked to these values.

R3.11 *Monitoring of shocks at crossing nose*

Description The system shall continuously monitor, in all three axes, the acceleration at the crossing nose.

Rationale Measurement near the crossing nose may be useful to estimate replacement time.

The measurement of the shocks on the frog may aid in the assessment of the condition of the check gauge (distance between the check rail and the frog of the crossing). This safety value is usually measured on site several times a year and the check rail is a component which needs to be replaced. The replacement of the check rail is related to the train traffic and in some infrastructures it is replaced every year.

R4 ***M*** ***Data measurement and storage***

Description The system shall create secure permanent records of all parameters monitored and make them available to users.

Rationale Historical data can be of use in creating new rules for automatic fault diagnosis and can aid users’ understanding of the switch’s operation.

R4.1 *M* *Remote data access*

Description The system shall allow remote access to data records.

Rationale		This eliminates the need for users to be in the same physical location as the database server.
R4.2		*Remote notification*
Description		The system shall automatically notify nominated users when significant changes in switch conditions are detected.
Rationale		This adds flexibility and means the staff with responsibility for organising maintenance can attend to their duties in many locations and still be informed when faults occur.
R4.3	*M*	*Data export format*
Description		The system shall be capable of exporting measured data and condition monitoring results to a standard file format.
Rationale		A standard file format allows data to be operated on by programs from different developers and for diverse purposes.
R4.4	*M*	*Data export configurability*
Description		The system's output interface shall be configurable to allow exports to other file formats.
Rationale		This allows the data to be exported for use in existing programs, increasing the usability of the data. For example, data could be exported to databases such as MS Access or business management systems such as SAP. Existing IT systems may not always be compatible with the standard output of the monitoring system, so tailor-made output is desirable.
R4.5	*M*	*Calibration of sensors*
Description		The system shall allow recalibration of sensors by maintainers at the switch site, using portable electronic devices.
Rationale		Replacement of defective sensors makes the new calibration or at least the test mandatory. This requirement ensures that the monitoring system supports this function.
R4.6	*M*	*Expandability*
Description		The system shall be capable of handling additional sensors without degradation in performance.
Rationale		Other sensors may be available in the future (e.g. image processing sensors)
R5	***M***	***Construction of hardware and wiring***
Description		All system components installed on or near the railway shall conform to the requirements of EN 50125-3 (Railway applications. Environmental conditions for equipment. Equipment for signalling and telecommunications).
Rationale		The requirements in this standard will ensure that the system can withstand the railway environment.

5. Functional description of monitoring systems

5.1 Functional representation of systems

5.1.1 The functional context

Before trying to understand the functions of the monitoring system, it is important to understand the **functional context** of the monitoring system.

The functional context is the functional representation of the world in which the monitoring system exists. This consists of the function of the system as a whole, and the functions of anything which is expected to interact with the system. This includes users, any external systems to interact with the system under consideration, and also any environmental factors (for example, any equipment on the railway will be subject to the rigours of the railway environment, which may include shock, vibration, electromagnetic interference, audio noise, water, dust and vandalism).

5.1.2 Functional flow block diagrams

The system can be drawn in its functional context using an Enhanced Functional Flow Block Diagram (EFFBD). Functions from different external sources are shown on separate lines, labelled with the name of the system they represent.

Inputs and outputs of the system under consideration are represented in EFFBDs as **items**. Items are high-level views of inputs and outputs, and they will be decomposed in section 0 to show individual inputs and outputs of interest.

The flow of the system is the sequence in which functions operate. The direction of the flow in these diagrams is from **left** to **right**. Parallel branches indicate functions which are performed at the same time.

5.2 The functional context for S&C condition monitoring

Figure 2 shows the functional context of a generalised S&C condition monitoring system. The external streams considered are **users**, the **switch**, and the **rest of the railway**. This represents the fact that we expect the monitoring system to function correctly when subject to all types of railway environmental interference that can be experienced under normal conditions.

The **user** is shown performing two main functions: observing the normal output of the monitoring system i.e. alerts for faults and required maintenance (**EXF1.1**), and requesting reports of data stored in the monitoring system (**EXF1.2**). An example of a report requested in this way might be the user asking for the force waveforms measured during the last five switch throws.

The **switch** is modelled with two functions: waiting for throw commands (i.e. the steady state, where the monitoring system is expected to continuously monitor parameters such as temperature, humidity, vibration from passing trains and detection signals) and throwing the switch (where, in addition to the continuous parameters, we expect the monitoring system to record throw parameters in the actuator, such as current and force).

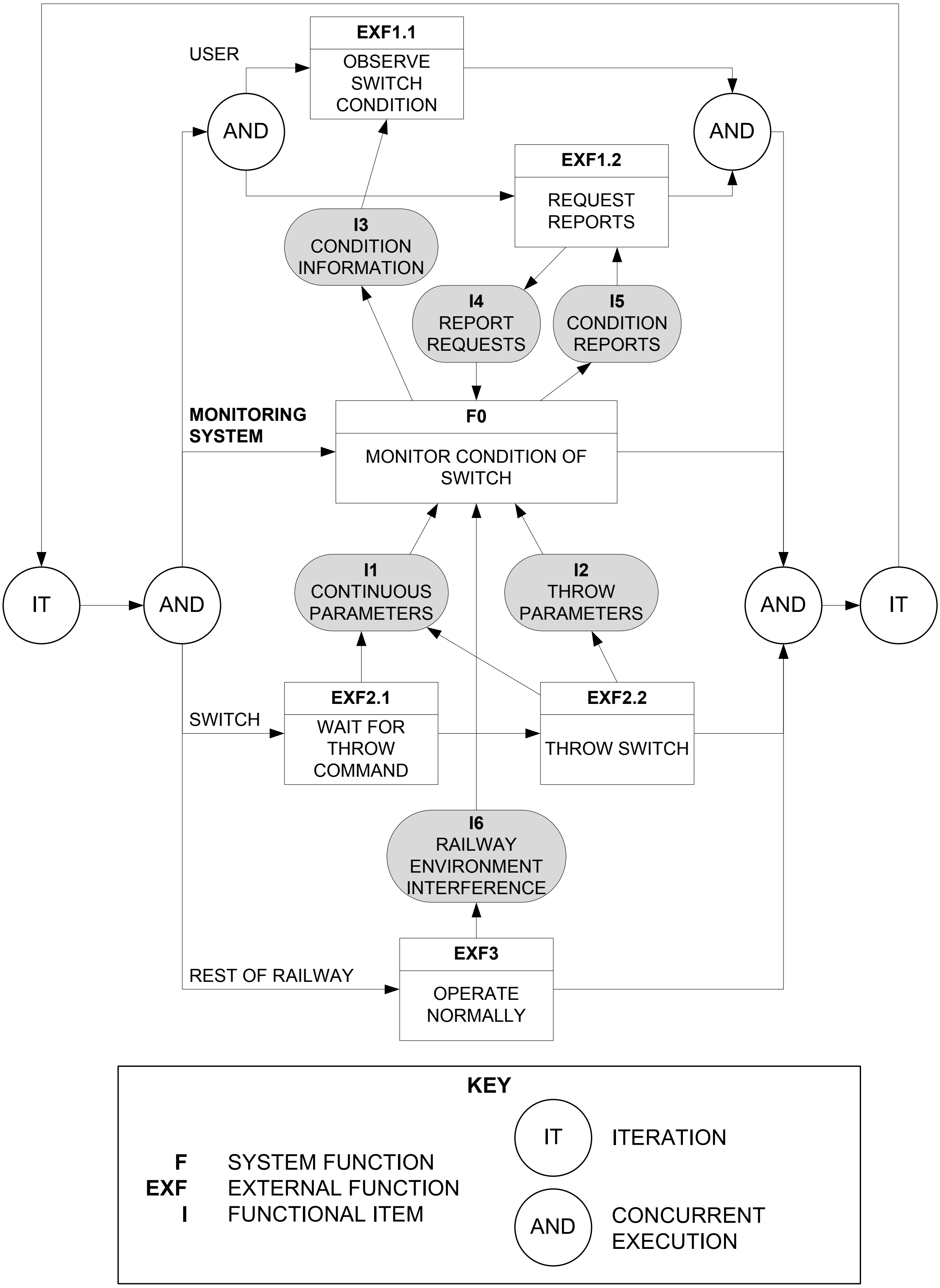

Figure 2 - Functional context for a generalised S&C monitoring system

Item ID	Description
I1	**Continuous parameters**
I1.1	End position detection lines
I1.2	Heater operation
I1.3	Vibration levels
I1.4	Narrowest flangeway
I1.5	Acceleration at crossing nose
I1.6	Temperature
I1.7	Humidity
I2	**Throw parameters**
I2.1	Drive force
I2.2	Displacement
I2.3	Motor current
I2.4	Drive fluid pressure
I3	**Condition information**
I3.1	Increased drive force alert
I3.2	Incipient fault alert
I3.3	Switch condition
I3.4	Maintenance dates
I4	**Report requests**
I4.1	Request number of operations since last inspection
I4.2	Request custom parameters report
I4.3	Request custom condition report
I5	**Reports**
I5.1	Number of operations since last inspection
I5.2	Custom parameters report
I5.3	Custom condition report
I6	**Railway environment interference**
I6.1	Shock
I6.2	Vibration
I6.3	Electromagnetic radiation
I6.4	Water
I6.5	Dust
I6.6	Vandalism
I6.7	Maintenance actions

Table 1 - Level 1 decomposition of functional items in the system context Functional item decomposition

Using our knowledge of the requirements and the environment, the items in Figure 2 can be decomposed into more meaningful inputs and outputs. Each item in Table 1 has been decomposed from level 1 to level 2 and the result is a more useful representation of all the signals and parameters that we have specified for measurement.

It is clear from an initial examination of these items that they can be decomposed further. However, this is a task for the system designer and is not necessary in this document.

5.3 First-level decomposition of the monitoring system

The requirements and our understanding of the functional context should provide us with enough information to construct a first-level decomposition of the function of the system.

This should aid the system designer's understanding of how the system works because in order to draw the EFFBD for a decomposed function, the engineer must fully understand how that function works. Therefore, it forces questions to be asked which might otherwise go unanswered – and important issues may not come to light before it is too late to make changes.

Figure 3 is an EFFBD of the level 1 decomposition of the system's functionality. It is essentially a close-up of the inside of the **F0** box from Figure 2. Here we can see the different types of monitoring carried out, and the data storage. Note also that there are now three new functional items which are contained within the function of the system – measurements of the parameters, and the stored data, which is used when constructing reports.

This diagram can be used as a starting point for discussions about the structure of a system and can be refined by further decomposition during the system design process.

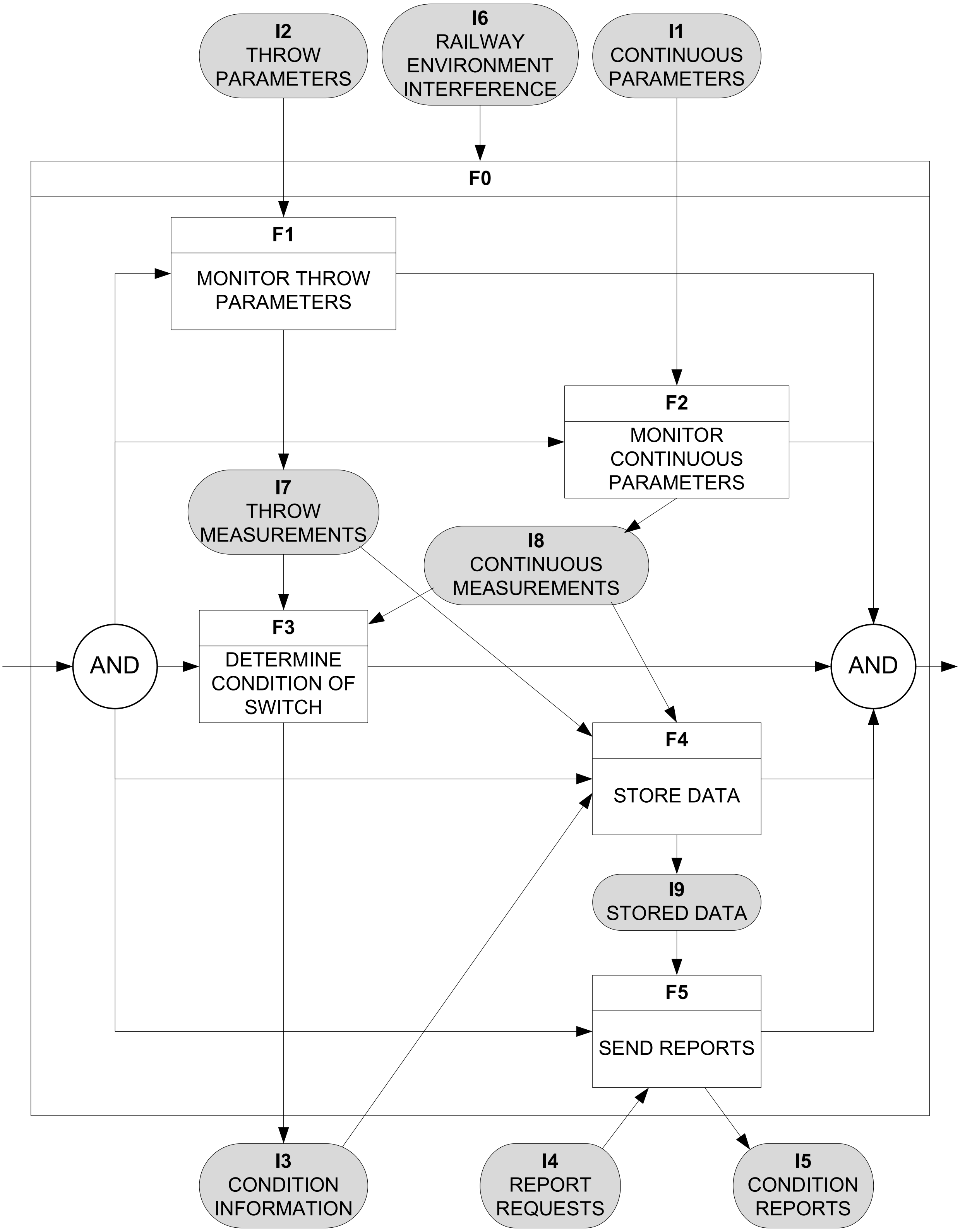

Figure 3 - Level 1 enhanced functional flow block diagram for a general S&C monitoring system

6. Physical context of the monitoring system

Just as the system can be represented in a functional context, so it can also be represented in a physical context. Figure 4 shows the interfaces which can be expected to be present in a monitoring system for S&C. External components are numbered XCy, and components of the monitoring system are numbered Cx and shaded in grey.

This diagram shows how a monitoring system can be included in a signalling system, providing that the network allows for the prioritisation of traffic so that safety-critical messages can take priority over monitoring messages. The Industrial Ethernet interface has this capability and therefore it is specified for monitoring systems in this document.

It is important to note that some sensors must be non-invasive in order to maintain safety integrity. The most obvious example is that detection lines must be monitored without detriment to their function in the signalling system. This must be kept in mind when sensors are specified.

NB: This diagram does not represent a perception of the current structure of signalling systems. It is an indication of one future possible topology and is similar to the structure described in D3.2.4/3.3.5 for the Innotrack switch demonstrator, except that the control of switch throwing functions and monitoring functions has been separated into two components.

Figure 5 gives examples of the sensors which can be incorporated into a S&C monitoring system and their relative locations in the switch.

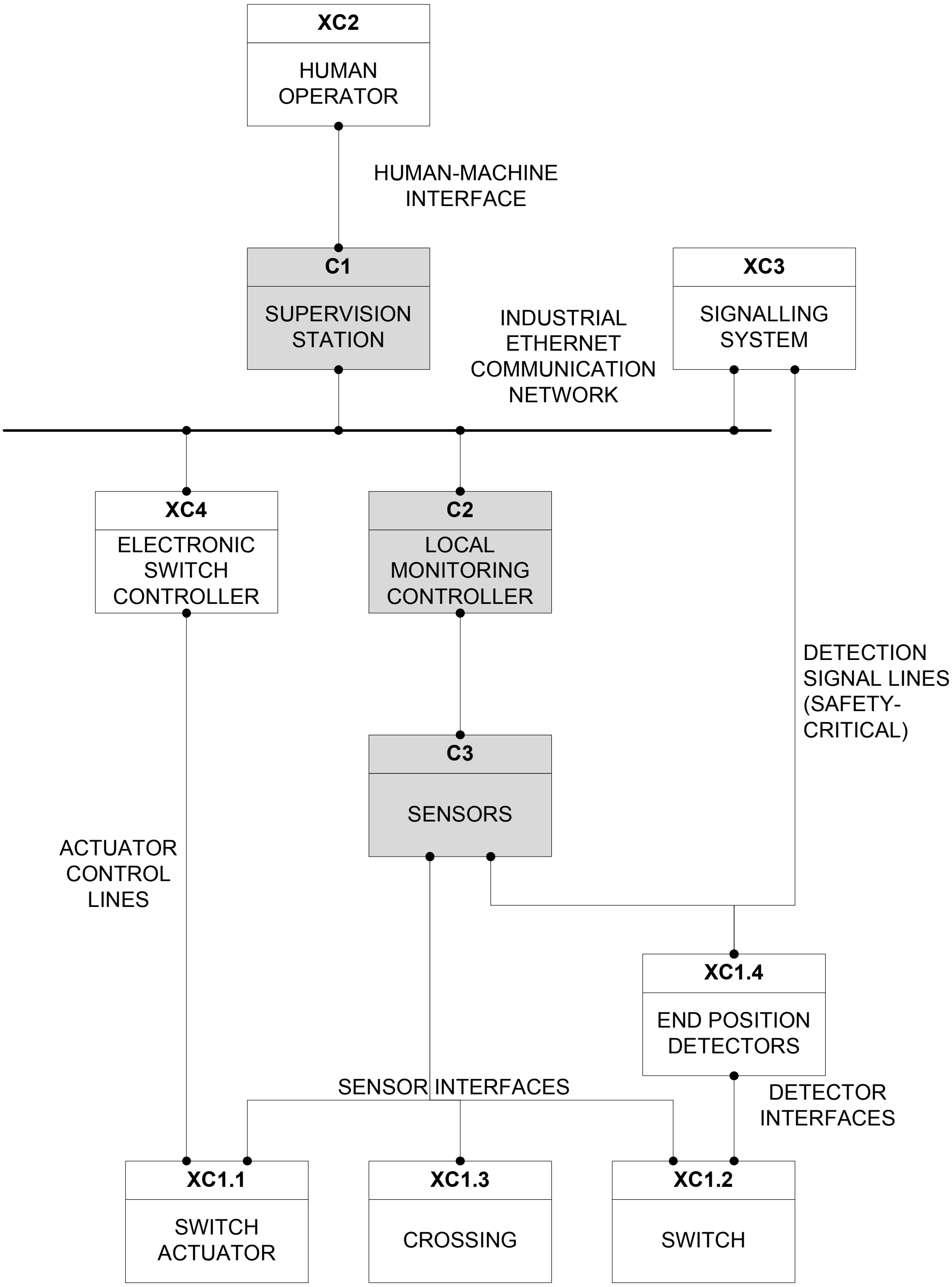

Figure 4 - Physical context of the S&C monitoring system

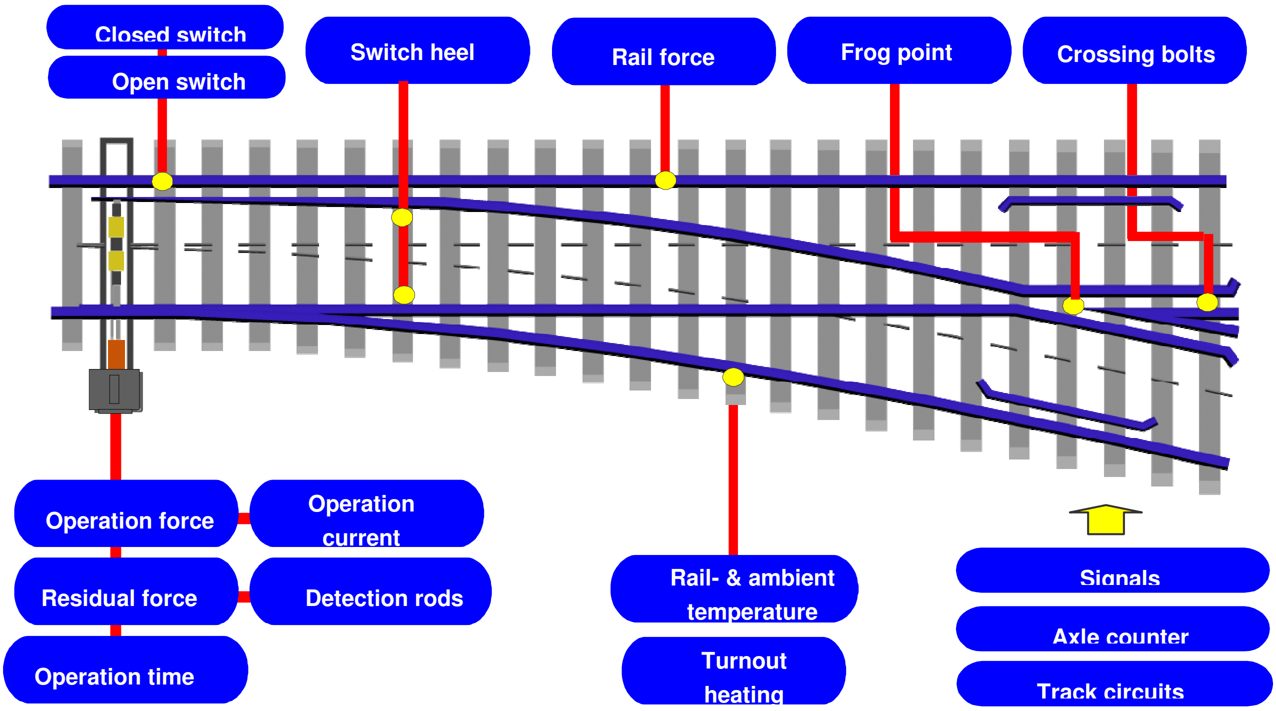

Figure 5 – Detailed S & C sensor configuration (source VAE)

7. Conclusions

In this document, the general requirements and functional structure of future S&C monitoring systems have been presented.

The work done here is intended as a starting point for the standardised design of monitoring systems for S&C.

For further information on systems engineering techniques such as functional analysis, the reader is directed to the book “Systems Engineering and Analysis” by B.S. Blanchard and W.J. Fabrycky, published by Prentice Hall, ISBN 0-13-135047-1.

8. Annex – Maintenance and inspection details for S&C

8.1 DB Safety inspection of Switches and Crossings

Outline

The inspection includes the whole area of the S&C from or until the joints of the normal rail. The following subsystems are checked:

1. Track components:
    a. Track
    b. Rail
    c. Sleeper
    d. Fasteners
    e. Joints
    f. Ballast
    g. Switch blade
    h. Frog
    i. Check rail
2. Signalling components:
    a. Actuation system
    b. Locking device
    c. Point machine
   Switch blade position detector
    d. Sliding chairs / blade rollers
2. Heating components:
    a. Heating device
    b. Track components:

Track inspection

The frequencies of track inspections are related to the line speed and are shown in the following table.. Purpose of the inspection is the observation of deterioration and recognition of damages.

Speed range (km/h)	Inspection period
< 120	6 months
120-160	4 months
160-230	3 months
> 230	2 months

Table 2 - DB track inspection frequencies

Actuation system

The minimum flangeway in switches must be large enough (safety critical).

All pins and safety plates are checked to see that they are well fastened (safety critical).

All screws and screw nuts are tightened (safety critical).

The rods are checked to make sure they are well adjusted, and have no cracks. The bolts are checked for tightness (safety critical).

The detection rods are checked to make sure they are well adjusted and all bolts are correctly tightened (safety critical).

The residual stress in the switch rails must be within limits (safety critical).

The joints of the backdrive rods are checked for adequate lubrication.

The throw resistance is checked to make sure it is within limits.

The fastenings of the actuator foundation(s) are checked to ensure they are secure (safety critical).

Locking device

The locking devices are checked with a 4 mm probe to ensure they are well adjusted (safety critical).

The drive rod displacement and overlap must be within limits (safety critical).

The components of the locking devices have to be ok (safety critical).

All bolts and screws have to be tightened and not loose, all pins well done (safety critical).

Point machine

The fastening on the foundation must be secure (safety critical).

The driving rods are checked to ensure they are well adjusted (safety critical).

No visible cracks on the actuator or the foundation are accepted.

The interior of the actuator is checked for being clean and dry, for wear/damage and cracks on gears and other moveable details. There must be no loose objects inside the actuator.

All screws and screw nuts have to be tightened (safety critical).

The detecting rods are checked to ensure they are

- operative (safety critical)
- well adjusted (safety critical)
- in good condition.

The throwing force must not exceed the limit (safety critical).

The wires inside the point machine are checked to ensure they are in good condition (safety critical).

The electrical contacts and switches are checked to ensure they are in good condition.

All places where there is protection to avoid for water to come in shall be in good condition (in capsulation and so on).

The cover of the point machine is checked to ensure it fits correctly.

The marking of the object and a description of the wiring are checked to ensure they are in place.

The earthing is checked to ensure it is in good condition.

Switch blade position detector

The fastening on the foundation is checked to ensure it is secure (safety critical).

The interior of the detector is checked to ensure it is clean and dry and for wear/damage.

All screws and screw nuts are tightened (safety critical).

The wires inside the position detector are checked to ensure they are in good condition (safety critical).

All seals are checked to ensure they are in good condition.

The detecting rods are checked to ensure they are well adjusted (safety critical).

The electrical contacts and switches are checked to ensure the signalling voltages are adequate (safety critical).

Electrical contacts are tightened and wires checked to make sure they are in good condition.

The earthing is checked to ensure it is in good condition.

The cover of the position detector is checked to ensure it fits correctly.

Slide chairs / blade rollers

Slide chairs are checked to ensure they are clean. Rollers are adjusted so the switch blade is lifted when it is moved. No metal objects that can cause a short circuit should be in this area.

The fastening of the rollers is tightened.

Slide chairs of S&C without rollers are checked to ensure they are clean and well lubricated.

Service/Maintenance

The following are lubricated or cleaned as necessary:

- Actuation system with force transmission rods, bolts
- Joints of the backdrive rods
- Driving rods, components of locking device

Heating components:

The heaters are checked to ensure they are working.

The electronic controls are checked to ensure that heater failure raises the correct alarms.

The earthing is checked to ensure it is in good condition.

8.2 Banverket: Safety inspection of Switches and Crossings

The inspection includes the whole area of the S&C from or until the joints of the normal rail on all three tracks involved (in a simple S&C).

The following subsystems are checked

- Track position
- Rail
- Sleeper
- Fasteners
- Joints
- Ballast
- Switch blade
- Frog
- Check rail
- Snow cover
- Actuator
- Switch blade position detector
- Locking device
- Heating device

Track position

This is partly done by a measurement vehicle. So far measurement by vehicles can not take absolute measurement and therefore S&C is in many of the parameters excluded from the failure lists. Manual measurements are taken at certain points where the distances between the rails are recorded.

Rail

Cracks are inspected by ultrasonic NDT equipment. All rails are tested once or twice per year by a NDT-train. Manual ultrasonic testing is carried out where defects have been detected by the NDT-train or by visual inspection.

Rail is checked by visual inspection to find cracks and follow up the cracks that have been observed previously. All cracks must be classified according to the standards. Rust on the rail is also noted while it will lead to bad electrical contact.

Sleeper

Checks are made for cracks or broken sleepers. The sleepers should be aligned perpendicular to the rail, otherwise the gauge will change.

Fasteners

Checks are made for missing fasteners or springs. No more than 4 missing fasteners on 20 sleepers are acceptable. In the switch blade area there should be no missing fasteners. At no place there should be any missing fasteners on both sides. On the rail foot look for marks that indicates movement in the rail.

Joints

The joints are checked to ensure that there are no cracks in the plate, the bolts are tightened and that the joint is not lower than the rail. For insulated block joints a special check is done that the insulation is OK and that the sleepers are well tamped.

Ballast

Checks are made to ensure that there is enough ballast to stabilize the track, especially sideways. At line speeds higher that 160 km/h, ballast between sleepers should be 3 – 4 cm below the upper sleeper surface.

Switch blade

Manual force is applied to check for possible movements of the switch rails. Slide chairs should be clean and rollers or ball bearings should be adjusted so the switch blade is lifted when it is moved. No metal objects that can cause a short circuit should be in this area.

The wear of the switch blade is checked against fixed patterns. Patterns for side and height wear are used to show if there is any risk for derailment. These are shown in Figure 6.

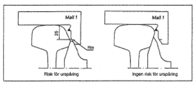

Figure 6 - Wear measurements for switches. The left and right figures show cases with risk, and no risk of derailment, respectively.

Frog

The frog is checked to ensure no nuts or bolts are missing. No visible cracks or damages should be spotted. The bolts for the crossing should be correctly in place. The groove between wing rail and frog should not be blocked by obstacles and the check rail should be mounted correctly.

Check rail

The check rail must be securely bolted. The groove between check rail and support rail must be free from obstacles.Snow cover

The snow cover must be securely fastened. Drainage must work to avoid water staying on the covers.

Actuator

No visible cracks on the actuator or the foundation are acceptable. The rods are checked so there are no cracks, and all bolts are tightened.

The earthing is checked to ensure it is in good condition.

The interior of the actuator is checked for wear and cracks on gears and other movable details. There should be no loose objects inside the actuator. On trailable S&C:s the trailable stop is in order.

Indicator for the position is checked on two places. 3 – 5 mm is the allowable distances in front and 10- 13 mm at the second place of switch position detectors.

Switch blade position detector

The 10-13 mm distance at the second switch position detector is checked. The detector and magnet must not be loose.

Heating device and environmental sealing

As DB section on heating components.