VINNOVA Dnr: 2009-00260
Project manager: Martin Hiller, Volvo Technology

DEDICATE
Dependability and Diagnostics Concept Assessment and Test

Automotive systems see increasing amounts of electrical and electronic systems with increased integration and interaction. This leads to increased complexity which, if not handled appropriately, decreases safety, quality and uptime by producing higher overall failure rates and more complex maintenance needs. This increases the overall cost of transports of goods.

DEDICATE develops and demonstrates new and improved concepts for increasing uptime, quality and safety by i) decreasing failure rate with better in-vehicle solutions for automatic detection, diagnosis and management of faults, and ii) facilitating repairs with better service solutions for diagnosis and maintenance, remotely and in workshops. DEDICATE has in this endeavour produced the following results in its first year:

- **Fault type information. We have collected information on which faults are the most common ones in operational vehicles, based on interviews of people working with diagnostics, aftermarket and maintenance, and by studying relevant databases containing fault information. This has provided us with a comprehensive view on which the most problematic fault types are, how they are handled today and what could be improved. This fault type information then forms the basis for our work on in-vehicle fault management systems and maintenance service concepts**
- **In-vehicle fault handling. Building on our fault type information, we have selected a set of fault types for which we defined new and/or improved mechanisms for fault handling (including detection and recovery) targeting electrical faults, from conductor/node level up to the system level. The defined concepts and prototypes have been empirically evaluated to assess their weaknesses and strengths.**
- **DEDICATE Framework. In order to assess the in-vehicle fault management solutions defined in the project, we have put together an assessment and testing framework based on a test target in the form of an embedded distributed system resembling the technologies present in current and next generation automotive products from the Volvo Group, together with prototypes of the defined fault handling mechanisms. This framework also contains the DEDICATE Dashboard for controlling and monitoring the test target, and the DEDICATE Fault injEction and Analysis Tool (D-FEAT) for artificially recreating relevant fault types.**
- **Maintenance service problem analysis. Similar to the fault types study, we have conducted a study on what the perceived problems and bottlenecks are in the maintenance service situation we have today. By means of interviews with people working with or affected by maintenance services, such as workshop personnel, drivers and haulers, we have analysed the current situation and produced a comprehensive view on the current situation and what could be improved.**
- **Maintenance service concepts. Based on the problem analysis of current maintenance service solutions, we used the Service-GDP (an internal Volvo Group process for developing new services) together with co-creation workshops involving haulers and workshop personnel to define the Volvo Non-Stop Concept for improved maintenance services. Using visualisations and other means we then evaluated those concepts.**

Objective

Quality and *Safety* are two of the corporate values of the Volvo Group. There is a very close link between quality and safety in that it is virtually impossible to achieve safety without achieving quality and vice versa. Furthermore, uptime is an increasingly important factor for our customers, and both quality and safety are intimately linked to uptime.

The trend in automotive systems is increasing amounts of electrical and electronic systems with increased integration and interaction. This trend leads to increased complexity which, if not handled properly, works against safety and quality by producing higher overall failure rates. Furthermore, the increased complexity makes diagnosing faulty systems more difficult and thus generates more complex maintenance needs. Altogether, this results in decreased uptime, decreased perceived quality and, in the worst case, decreased safety.

In current product development efforts, these problems are of course being addressed, based on the needs and requirements at hand. However, the trend mentioned above is not showing signs of slowing down, so new needs and requirements are identified continuously. Thus, new ideas and concepts need to constantly be devised and assessed.

In Figure 1 a simplified view of the phases in which a vehicle can be during its lifetime is illustrated. The main three phases are: 1) operational, which is when a vehicle is performing actions necessary to fulfil its mission, 2) out of order, which is when the vehicle no longer can fulfil its mission due to some fault occurring in the system, and 3) in maintenance, which is when the vehicle is being repaired. After successful maintenance, the vehicle is once again in the operational phase.

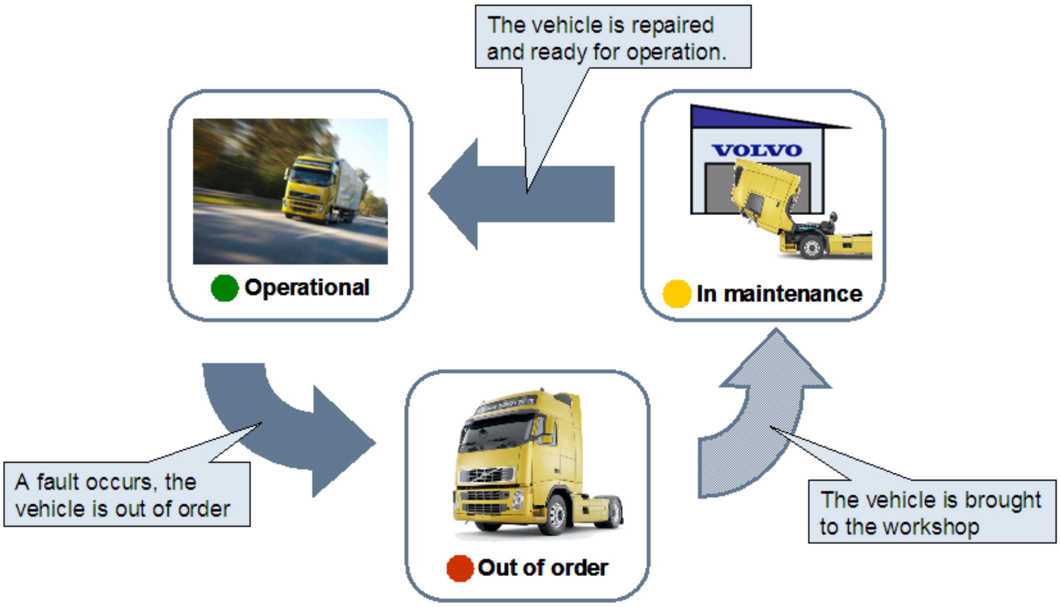


Figure 1. Simplified view of vehicle phases

In DEDICATE we want to develop solutions for increasing uptime, quality and safety by lowering the failure rate and shortening the time required for maintenance. We address this with a two-pronged approach (illustrated in Figure 2): i) new and improved in-vehicle solutions for automatic detection, diagnosis and management of faults, i.e., increasing the time in which the vehicle is in the operational phase, and ii) new and improved service solutions for diagnosis and maintenance, i.e., decreasing the time the vehicle is in the out of order or in maintenance phases.

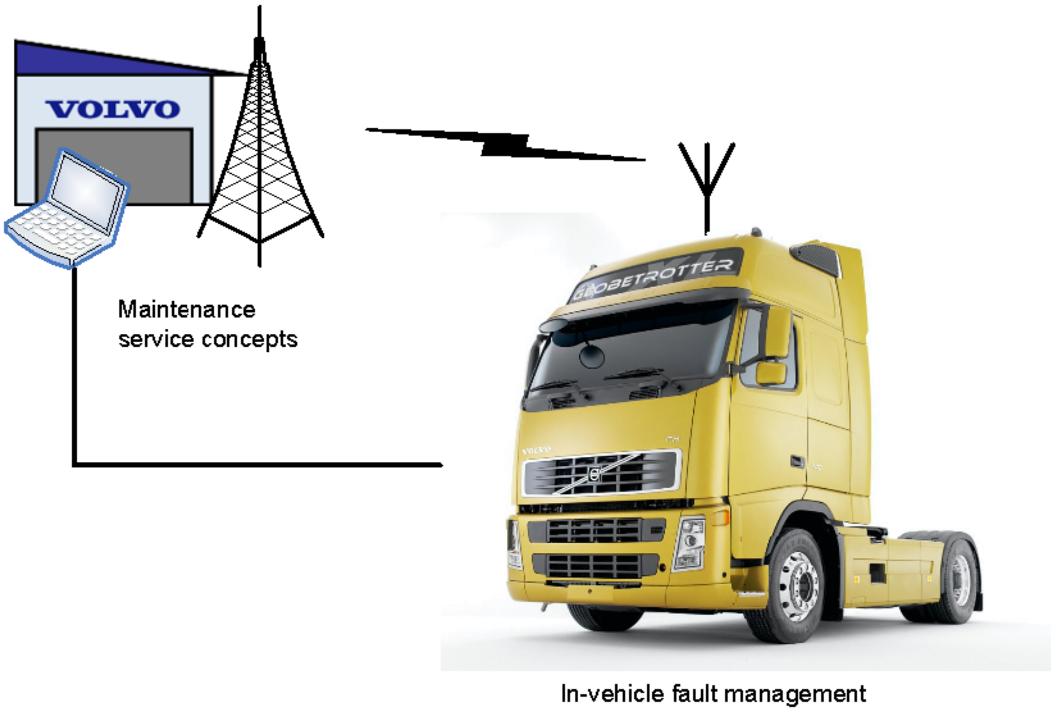


Figure 2. DEDICATE covers in-vehicle solutions for fault management as well as external maintenance services.

DEDICATE will in this pursuit address the following questions:

- Which faults happen in electronic and electrical automotive embedded systems? What is the probability of these faults and the potential damage they may cause?
- How can we detect and handle the faults that occur, using in-vehicle solutions as well as workshop/Back Office based solutions?
- How efficient are the solutions we identify? From a technical as well as cost perspective? And how shall they be applied for optimal efficiency?
- How can the solutions be combined to create a complete fault management chain providing the most efficient fault management approach?

The new and improved in-vehicle solutions will equip the vehicle with the improved ability to automatically detect abnormal situations, i.e. the existence of a fault which prevents the vehicle from operating normally, and subsequently handle these faults such that the mission can still be safely completed, as well as store information pertinent for the improved maintenance services.

Improved service solutions for diagnosis and maintenance are important, as the perceived quality of a vehicle not only based on the capabilities of the vehicle, but also (and maybe even increasingly) on external services, e.g., extended diagnostic abilities in some central Back Office (and proper support for this from in-vehicle systems), as well as easy and swift maintenance locally at the workshops.

Some solutions for fault management, both regarding in-vehicle fault management and maintenance services, have been identified in earlier projects. These solutions and technologies address the aspects and phases of the capabilities and services mentioned above, but do not solve all issues. Furthermore, the impact of these new solutions and technologies has yet to be analysed, especially when combining the results into a complete fault management chain: starting with the detection of faults, going via the handling of faults in the vehicle, to the maintenance services and subsequent removal of faults in workshops. That is, the holistic view on how to provide a complete fault management chain has yet to be taken.

One of the basic building bricks provided by DEDICATE is a compilation of extensive information on relevant fault types which need to be addressed by in-vehicle systems for dependability and diagnostics as well as external services for diagnostics and maintenance. These fault types will be used to identify fault management approaches, both for incorporation into the vehicles electronic systems and for external services. Without this knowledge, efforts aiming at fault management run a risk of being inefficient or maybe even worthless (worst case scenario where efforts are spent on faults which do not occur during operation).

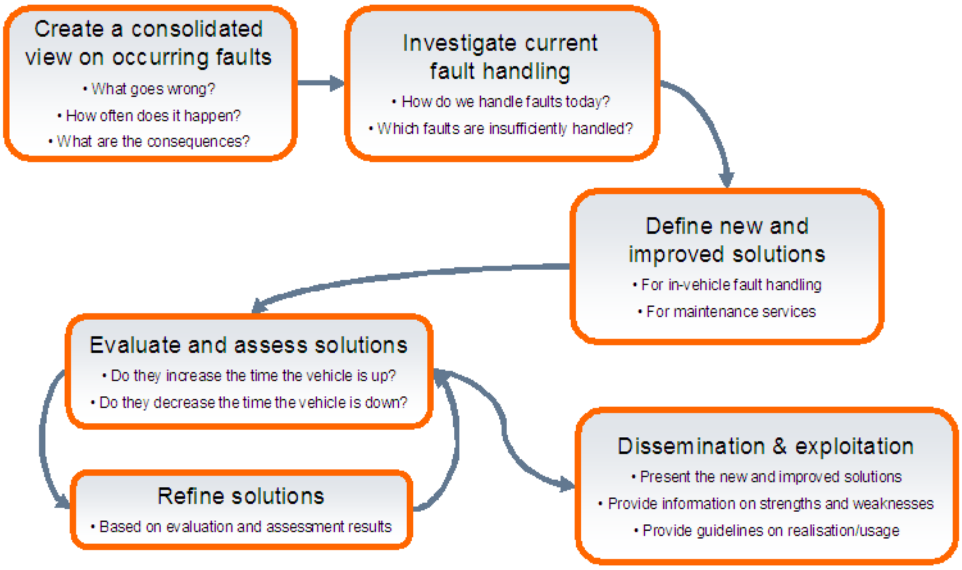


Figure 3. Overall workflow in DEDICATE

The overall work flow in the DEDICATE project is illustrated in Figure 3. Based on a consolidated view of occurring faults and investigation of current fault management approaches, new solutions for in-vehicle fault management and maintenance services will be defined, and subsequently evaluated and possibly refined based on the evaluation results. The outcome of the project will be disseminated in different ways, such as demonstrations and visualizations, and guidelines.

DEDICATE will focus on solutions for the 2020 timeframe where we envision all vehicles being fitted with telematic systems to meet the connected truck vision. This will be a requirement for the services for diagnostics and maintenance to be developed in DEDICATE.

One step in ensuring the efficiency (both from a technical point of view and a cost ditto) is to assess capabilities of solutions in a setting as close to reality as possible. For this, DEDICATE aims at developing a concept assessment and test framework related to dependability, diagnostics and maintenance, such that new solutions and technologies can be demonstrated and visualized and their feasibility and effectiveness assessed.

Using the DEDICATE framework will enable assessment and validation of new concepts for improved dependability, diagnostics and maintenance for incorporation into TEA2+ and the generations beyond. A proven and validated concept will be easier to incorporate into products as we will know how to incorporate it efficiently and we know what the benefits are. This will lead to *increased cost-efficiency for dependability and diagnostics solutions*.

Improved dependability and diagnostics capabilities, both in terms of in-vehicle systems and external services, will lead to *safer vehicles and longer uptime* and thus *better perceived quality and safety* of Volvo Group products.

Furthermore, extensive diagnostic and maintenance information will provide Volvo with valuable information from the field which can be used to improve aftermarket services and routines, and enable an assessment of specific Key Performance Indices (KPIs) with regard to their relevancy in the field.

From a closed-loop-perspective, feedback from aftermarket to vehicle development will promote sustainable quality improvements and enables *more accurate and cost-efficient maintenance services* to our customers.

Results and deliverables

Overview

The project has produced the following overall results:

- **Fault type information.** We have collected information on which faults are the most common ones in operational vehicles, based on interviews of people working with diagnostics, aftermarket and maintenance, and by studying relevant databases containing fault information. This has provided us with a comprehensive view on which the most problematic fault types are, how they are handled today and what could be improved. This fault type information then forms the basis for our work on in-vehicle fault management systems and maintenance service concepts
- **In-vehicle fault handling.** Building on our fault type information, we have selected a set of fault types for which we defined new and/or improved mechanisms for fault handling (including detection and recovery) targeting electrical faults, from conductor/node level up to the system level. The defined concepts and prototypes have been empirically evaluated to assess their weaknesses and strengths.
- **DEDICATE Framework.** In order to assess the in-vehicle fault management solutions defined in the project, we have put together an assessment and testing framework based on a test target in the form of an embedded distributed system resembling the technologies present in current and next generation automotive products from the Volvo Group, together with prototypes of the defined fault handling mechanisms. This framework also contains the DEDICATE Dashboard for controlling and monitoring the test target, and the DEDICATE Fault injEction and Analysis Tool (D-FEAT) for artificially recreating relevant fault types.
- **Maintenance service problem analysis.** Similar to the fault types study, we have conducted a study on what the perceived problems and bottlenecks are in the maintenance service situation we have today. By means of interviews with people working with or affected by maintenance services, such as workshop personnel, drivers and haulers, we have analysed the current situation and produced a comprehensive view on the current situation and what could be improved.
- **Maintenance service concepts.** Based on the problem analysis of current maintenance service solutions, we used the Service-GDP (an internal Volvo Group process for developing new services) together with co-creation workshops involving haulers and workshop personnel to define the Volvo Non-Stop Concept for improved maintenance services. Using visualisations and other means we then evaluated those concepts.

The subsequent sections will describe the results in more detail.

Fault type information

The fault type information is used to form a comprehensive picture of the faults pertaining to electric and electronic subsystems of Volvo products. This comprehensive picture is useful in several aspects: a) it provides quantifiable justification for the need to handle common faults and thus guidelines for research on new and improved fault handling mechanisms; b); b) it provides input to assessment of fault handling mechanisms; and c) serves as an "eye-opener" to engineers and researchers within the field.

The method used is two-folded. First an interview study is performed, where engineers from several Volvo Group companies and departments are questioned regarding the most common and problematic faults, from their perspective. The second part is a database study where existing databases containing fault information are studied and compiled. Up until now focus has been on the interview study although several candidate databases have been identified in the process.

So far eight interviews with twelve engineers have been conducted. The interviews were planned ahead, with a set of questions that should be asked. Additionally the interviewees received introduction material prior to the interview containing questions to be answered before the actual interview took place. During the interviews notes were taken which were later cleaned up, summarized and approved by the interviewee. The main results from the interview are summarized in deliverable D3.1.

Overall three main failures where identified as the most common and problematic today: sensors, cables and connectors. That failures were identified (and not faults) was expected, since most diagnostics is focused on replacement of parts (i.e., failed components) rather than the faults causing the failures.

The study revealed certain differences among the companies, where companies working with safety-critical systems experience fewer issues. This is natural since more focus (and money) has been put on developing these systems, but also shows a great potential for improvement overall.

This part of the project will now continue with a few more interviews and a study of the databases identified. The database study will enable quantifiable data (such as fault frequencies) to be gathered.

In-vehicle fault handling

In this part of the DEDICATE project, we been looking at two different approaches for handling the identified most common failures: i) a concept we have named the Proactive and Accurate Diagnostic System (PADS) and ii) a measuring technique called Time Domain Reflectometry (TDR). The two different approaches are described in the following sections.

Proactive and Accurate Diagnostic System (PADS) concept

PADS overview

The diagnostic system, PADS - Proactive and Accurate Diagnostic System, is a concept developed internally within Volvo and consists of one (or more) PADS units and a PADS Controller, see schematics in Figure 4.

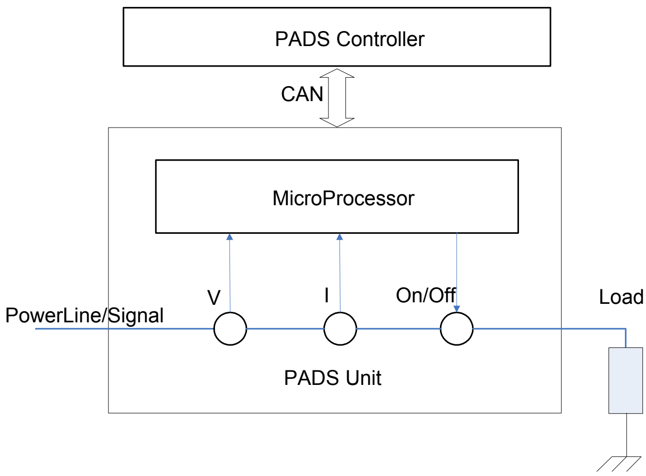


Figure 4. Schematics of PADS

The basic idea with PADS is to place the PADS unit at strategic places within the Electronic and Electrical (EE) system where they monitor and report voltage and current levels to the controller. The PADS units also have the feature to work as an active fuse (disconnecting the delivery of current) in order to protect parts of the EE-system. Using many different PADS units located at different places in the EE-system it is possible to detect also more complex fault scenarios drawing conclusions based on monitored levels from several PADS units. The PADS concept is described more in detail in the following:

- **The PADS units.** The PADS units basically measuring devices for continuously monitor voltage and current and report. The readings are transmitted to the PADS Controller via serial communication (for example via CAN). The sampling speed is set to a level where it should be possible to detect intermittent faults such as micro breaks. Access to multiple distributed measurements of current and voltage, it The PADS units are distributed in the EE-system in order to detect which type of fault that has occurred and also to enable better localisation of the fault using the PADS Controller.

A feature of the PADS units is that they can stop delivering current (working as an active fuse) if suddenly too large current is detected (or demanded by the PADS Controller).

- **The PADS Controller.** The PADS Controller is the brain in the PADS concept. It interprets voltage and current readings received from PADS units and draws conclusions based on variations in the readings. The PADS Controller also interprets other signal information sent on serial data links (for example CAN) in order to have as much knowledge of the EE-system as possible. By doing this, the implementation of the PADS controller is application specific, and a change in an application may require a change in the PADS controller implementation.
  If a fault is detected by the PADS Controller, it sends a diagnostic message on a data link. The PADS controller can also order (by sending a command on CAN) a PADS unit to disconnect the load/signal in order to protect electrical circuits.
  The PADS controller can store voltage and current readings over a period of time long enough to detect long term degrading trends in components or cable harnesses.
  It is important to note that the PADS controller does not need a dedicated hardware of its own. Thus the functionality can be implemented in any ECU.

PADS Fault Diagnostics

The PADS concept has a number of ways in which faults can be diagnosed and handled, utilizing a strategy involving decentralized local approaches in the PADS units, and centralized system-wide approaches in the PADS Controller.

The PADS units distributed in the electrical system continuously monitoring and reporting voltage and current (detecting fast scenarios, milliseconds or faster). If a fault occurs it is possible to draw conclusions on what type of fault it is and where it is located. They are can be calibrated with allowed ranges for current and voltages, and will act automatically if a measurement is outside this range. There is also the possibility for PADS units to work as an embedded measuring device reporting voltage and current readings that helps tracing faults at a workshop.

The PADS Controller records voltage and current measurements from the various PADS units in order to get view of the actual status of the system, and combines this information with applications signals from the ECUs to get a view of what the status should be. This combined information enables the PADS controller to draw conclusions on more complex scenarios, where faults can be present even though individual measurements are within allowed ranges. By recording current and voltage measurements over longer periods of time, the PADS Controller is able to detect for example long-term degrading trends in components or cable harnesses.

PADS Fault Handling

As mentioned above, the PADS concept utilizes a strategy involving decentralized local approaches in the PADS units, and centralized system-wide approaches in the PADS Controller. The following handling approaches are available for the moment:

The PADS units can open whichever line they are set to monitor. Depending on the placement of the PADS unit, this can be used for different purposes, e.g., a PADS unit can shut down parts of the electrical system, working as an active fuse, enabling better power management and the possibility to divide the electrical system in different electrical domains. The PADS unit prototype can disconnect the load within approximately 0,5ms from detection.

The PADS Controller can send orders to PADS units, based on the diagnosis performed at system level. The PADS Controller can also warn and reports to other ECUs after detecting an error.

PADS Prototype

In order to evaluate and assess the principles behind PADS we have developed PADS unit prototypes (shown in Figure 5). The PADS unit prototypes have been used within the DEDICATE framework described later in this document.

Each PADS unit prototype has two channels (i.e. the possibility to simultaneously monitor voltage and current for two different power/signal lines).

We have also developed software for both the PADS units and the PADS Controller.

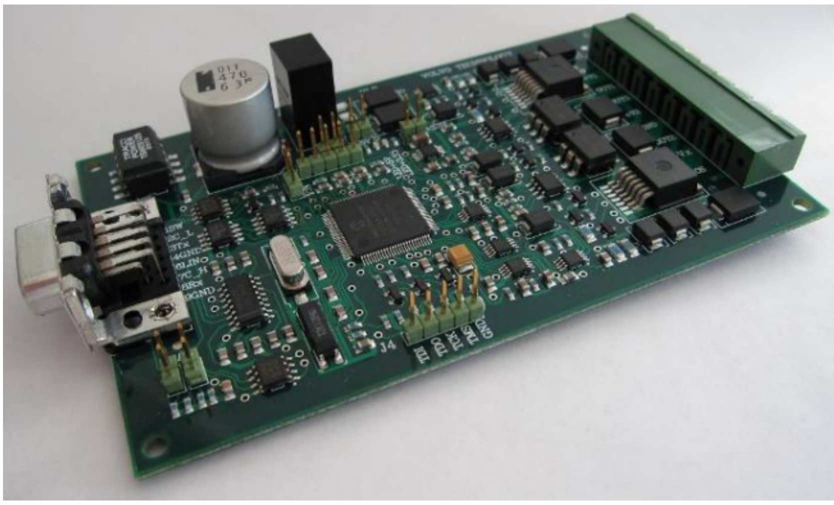


Figure 5. PADS unit prototype hardware

Time Domain Reflectometry (TDR)

The second technology for in-vehicle fault handling studied in DEDICATE so far is Time Domain Reflectometry (TDR). The basic principle of this technique is to send a known signal along the wire you wish to monitor, and analyze any reflections of that signal which return. This is very much like how radar works. The characteristics of the reflection, as well as the timing of the reflection, can be used to identify faults, such as open circuits and other impedance changing anomalies, and also pinpoint the location with good accuracy. One advantage of this technique is that it can also be used on live wires, i.e., the measurement signal and the reflections go on top of the ordinary load (either power or signal). An example of how a measured signal/reflection may look is shown in

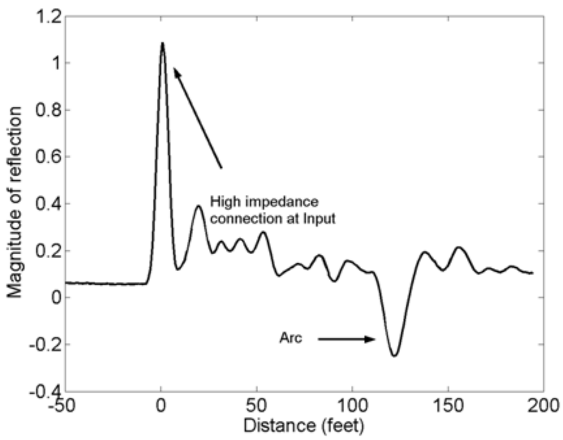


Figure 6. Example of TDR signal (source http://livewiretest.com)

The potential of the TDR technology has been studied and deemed as a possible fault detection technique. As TDR as a principle has been around for quite some time, and the principle has been investigated in a number of other research projects within the Volvo Group, we wanted to go one step further and investigate whether there are any commercial solutions available, and if so if these could be useful for Volvo Group products. In our search for commercial solutions based on TDR, we found that the company LiveWire (http://livewiretest.com, based in Salt Lake City, USA) has a commercial product that is used in for example in the aerospace industry.

In cooperation with LiveWire, a demonstration and short test of their solution has been performed. This test showed the viability of using their solution in a Volvo Group cable harness and encouraged us to plan a second test using a complete live vehicle. This second test is planned for the second part of the DEDICATE project.

DEDICATE Framework

The DEDICATE Framework is our setup for testing and assessing the concepts we develop for fault management. It consists of the following parts:

- Embedded hardware, containing a number of ECUs connected to each other in a network. This embedded hardware is designed to be representative of the technologies used in automotive products form the Volvo Group.
- Embedded applications, running on the embedded hardware. This software exists to exercise the various fault management solutions that are to be tested and assessed.
- Fault management prototypes, implementing the concepts and principles defined for improved in-vehicle fault handling.
- Fault injection capabilities, in order to artificially recreate the faulty situations which the added fault management prototypes are designed to handle.
- A dashboard for monitoring and controlling the framework.

The current DEDICATE framework is the first step towards the final framework, at the end of the entire DEDICATE projects. That is, the parts described here will be refined and further developed over the coming two years.

The first application that has been developed for the framework is functionality for simply activating a brake light when a brake pedal is pressed. This application is used as test case during the assessment of the fault handling mechanisms, that have been developed and implemented in DEDICATE.

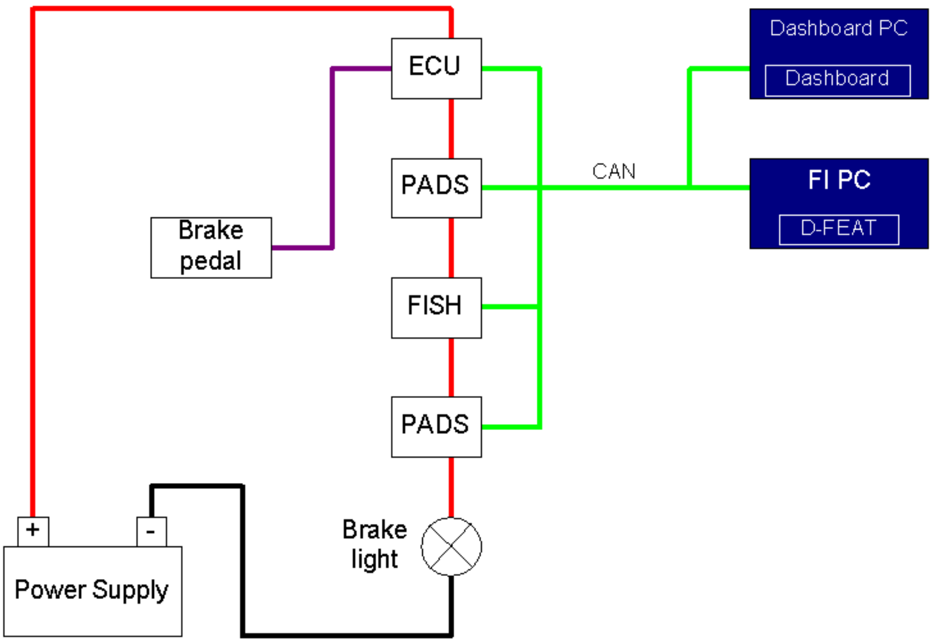


Figure 7. DEDICATE Framework - overview

The DEDICATE framework consists of one ECU with application software that controls a FET (Field Effect Transistor) so that power can be supplied to the brake light.

Two PADS (Proactive and Accurate Diagnostic System) units monitors the voltage and current to the brake light continuously and sends the values via CAN to the PADS controller that is located in the ECU. If the voltage or current to the brake light deviates largely from the nominal value the PADS controller informs the application software about the situation.

If the deviations persist over a longer period of time the application software can deactivate the FET, thus turning of the brake light, and set a fault code.

The PADS controller performs the analysis of the monitored voltages and currents that are gathered from one or more PADS units. However the PADS units can act as an active fuse and stop the delivery of current to the brake light immediately if there is a serious error, such as short circuit, that needs to be isolated in a matter of milliseconds.

A fault injector called FISH (Fault Injection in Software and Hardware) has been developed in order to inject several different faults types. In this first version of the framework the FISH can inject open circuit and short circuit to ground in the wire harness.

Faults injection campaigns are configured and injected by the fault injection tool D-FEAT (DEDICATE – fault injection and analysis tool).

There are two PCs (Personal Computers) in the framework, one running the D-FEAT tool and one running a tool called Dashboard, used for monitoring, controlling and configuring the DEDICATE framework.

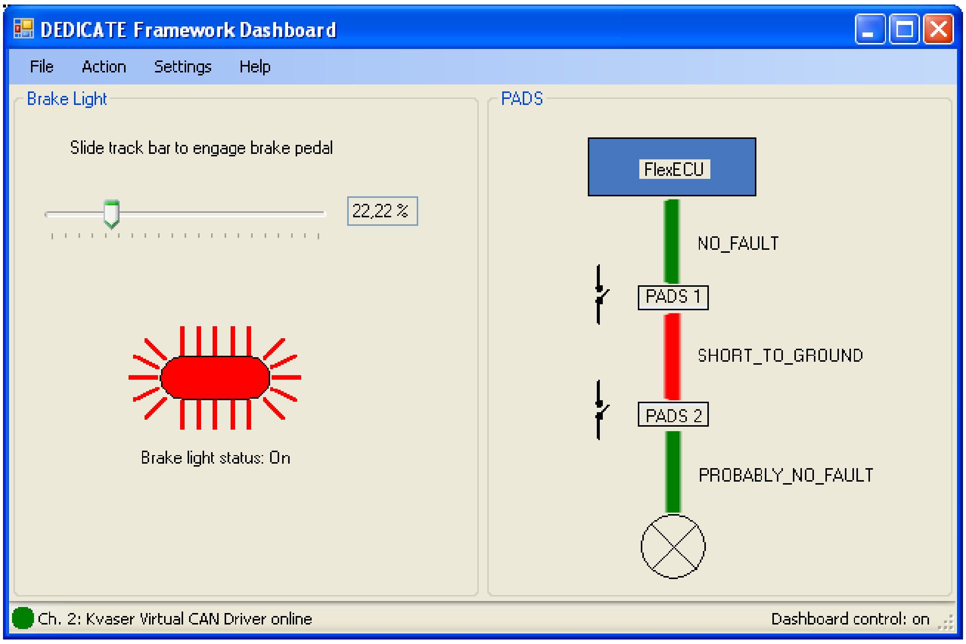


Figure 8. Screenshot of the DEDICATE Framework Dashboard

By a graphical user interface the user can set if the ECU in the framework uses the Dashboard or the brake pedal as actuator for the brake light. The dashboard can also display the status of the output from the ECU and the status of the wire to the brake light.

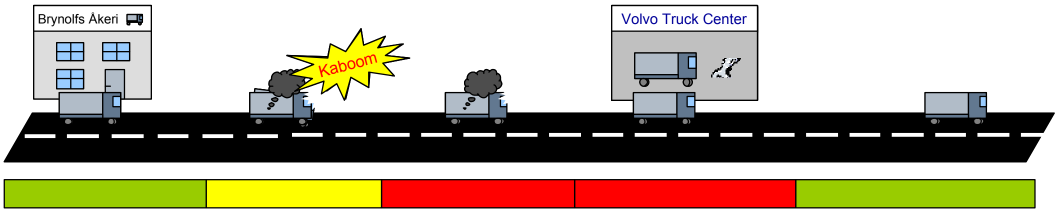
The units in the framework and the PC's communicate via CAN (Controller Area Network).

Maintenance service problem analysis

The maintenance and service problem analysis consists of three parts that describe how uptime can be defined, the current service and maintenance situation, and the results of co-creation workshops.

Uptime is a widely used concept and to be able to use, communicate and apply it the concept was defined based on Avizienis et al, 2004[1]. The definition as used in DEDICATE is shown in Figure 9 below:

[1] Avizienis et al (2004), Basic Concepts and Taxonomy of Dependable and Secure Computing, IEEE Computer Society



Green = Time with full functionality, Yellow = Time with unknown functionality, Red = Time with limited functionality

"A system in our taxonomy is a truck that interacts with other systems, including hardware, software, humans and the physical world. These other systems are the environment of the given system. The system boundary is the common frontier between the system and its environment. A service failure is an event that occurs when the service delivery from the truck deviates from the correct service. An error is part of the system's total state that may lead to a service failure. A fault is the root cause of the service failure. Failure severities describes the different consequences a service failure can have upon the system."

Figure 9. Definition of "uptime" as used in DEDICATE

The current service and maintenance situation was captured in a power point presentation illustrating the customers' service experience and the suppliers' service delivery process and trade offs. Five different perspectives were shown; hauler back office, truck driver, workshop manager, mechanics and customer receiver. All issues, problems and challenges highlighted in the presentation of the current situation were condensed into three main problems areas:

1. Planning, uncertainty and efficiency
2. Information transfer
3. Customer service

In co-creation workshops with haulers, workshop personnel and Volvo Trucks representative, a comprehensive list of current problems were developed and agreed upon by the participants. Examples of problems:

- "Fault-tracing, difficult to estimate the time needed and plan"
- "People dependant – it is important to get the correct information from the driver (very different technical competence driver to driver, 50 % can not even read fault codes in the vehicle). Some may not be able to communicate language wise (e.g. Polish drivers in Sweden who do not speak English)."
- "Workshop personnel/customer receiver shall be able to ask the right questions to the driver"
- "Get good information from driver regarding faults"
- "Driver knowledge – the drivers of today have not enough competence"
- "Available knowledge at workshop – that a mechanic with the right competence is available"

Another important take-away from the problem analysis was how much the haulers appreciate the good relations they have with the workshops. They call the good relations "Volvo's fourth core value".

Maintenance service concepts

In the co-creation workshops, we then used the problems as foundation and generated 19 distinctive ideas from which two concepts were developed on how the uptime can be increased and the downtime decreased referring to the yellow and red parts in our uptime definition. Since, being very similar, these concepts were merged and further enhanced by the project team into the Volvo Non-Stop Concept, which aims to improve the service delivery process to reduce downtime and improve uptime. It describes in detail the future service delivery process and supporting systems. The concept is illustrated in Figure 10 below.

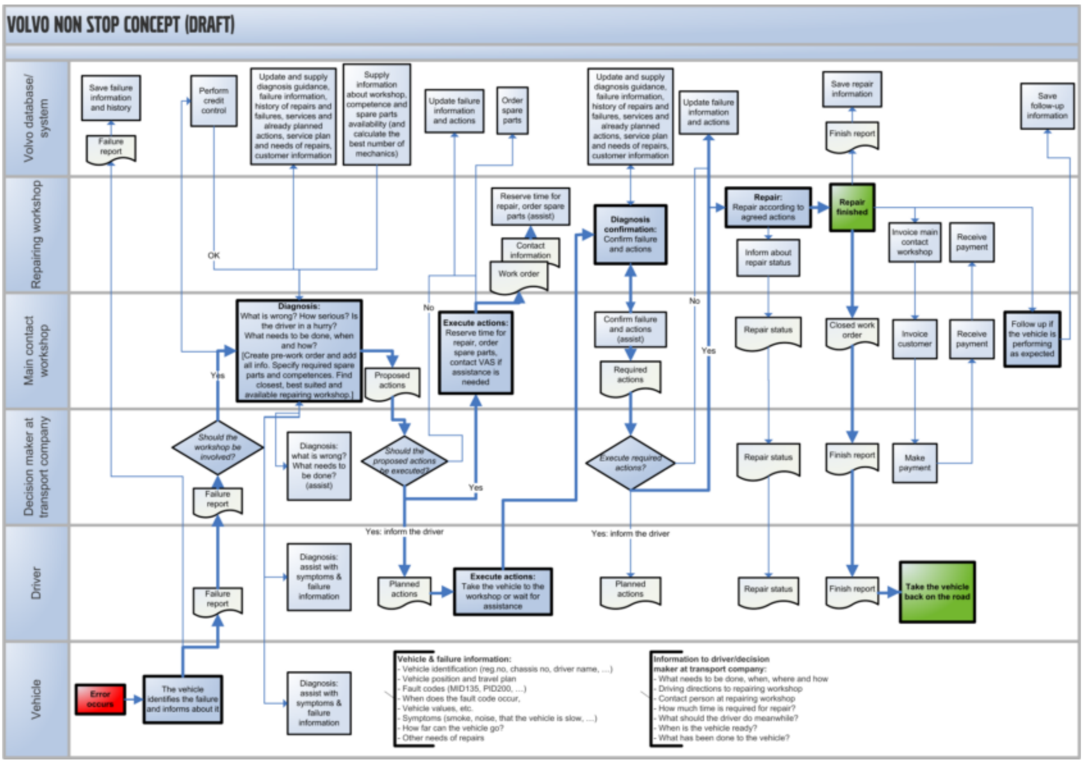


Figure 10. The Volvo Non Stop Concept

In the concept we have prioritised the personal relations already established today, which the customers so highly appreciate. Also, we have assumed an ability to send information from the vehicle to the workshop and hauler/transport company. Then, failure information can be accessed by the workshop personnel early in the process to diagnose the vehicle and decide upon actions which minimises the time required for the vehicle standing at the workshop when the workshop personnel is trying to figure out what is wrong and what needs to be done. Also, this eases the pressure on the driver and makes the diagnosis not so dependant on the driver's skills and competences.

- When some failure occurs on the road, information is sent to the transport company and the workshop that starts to diagnose and specify required actions. All information needed is gathered in one common centralized Volvo system/database. The customer receiver at the workshop immediately creates a pre-work order where all information is gathered.
- Early information to the workshop facilitates customer adapted measures to be taken. If the driver is in a hurry, the failure could be repaired temporarily and later repaired properly at a planned workshop visit. Planned workshop visits imply the right mechanic with the right competence, which was one common problem for unplanned visits.
- Continuous feedback to the driver/decision maker at transport company is important, e.g. to the driver in the vehicle display or via instant messaging/sms. The transport company needs to know if another vehicle should take over the goods delivery and the driver needs to know what to do (e.g. wait at the workshop for the vehicle to be repaired, take the time off and wait at a nearby hotel, or go back to the transport company's back-office).
- The service needs to be adapted to each customer's preferences. Should the failure report from the vehicle go directly to the workshop or via the transport company? Who at the transport company should be involved in vehicle repair decisions? Should the driver, transport company or workshop initiate the first contact? Preliminary target customer is long haul transport companies.

A quick assessment of the concept at the seminar gave valuable feedback which we will consider in the follow-up project (2009-04159 DEDICATE). We have also specified high-level technical requirements and formulated an implementation proposal for the concept. Existing systems, databases, and tools which already is used by the workshops should be used as starting point and further development of them are recommended to support the technical requirements.

Deliverables

The results described in the previous sections have been documented in a number of deliverables, in addition to other project relevant information:

- D1.1 Project plan (V1.0 and V1.1)
- D2.1 DEDICATE Framework (DRAFT 1)
- D2.2 DEDICATE Framework documentation (DRAFT 1)
- D3.1 Fault model (DRAFT 1)
- D3.2 Fault injection tool (DRAFT 1)
- D3.3 Fault injection tool documentation (DRAFT 1)
- D4.2 FHM prototypes – electrical level (DRAFT 1) (This is the PADS prototypes)
- D4.3 FHM documentation – electrical level (DRAFT 1)
- D5.1 Maintenance service concept – problem analysis (DRAFT 1)
- D5.2 Maintenance service concept – specification (DRAFT 1)
- D5.3 Maintenance service concept – realisation prerequisites (DRAFT 1)
- D6.1 Visualisations (DRAFT 1)
- D7.1 DEDICATE Seminar 1

The deliverables are in general not available for public access. Please contact us for further questions about the project results.

Project realization

The overall method employed in this project is described in the section Objective above and illustrated in Figure 3. The realizations are described based on the two parts of the project indicated in earlier descriptions:

1. In-vehicle fault management, and
2. Maintenance service concepts.

In-vehicle fault management

Several different methods have been employed in the in-vehicle part of the project. The investigation on current fault types is conducted as a field study, where interviews and data analysis (from existing databases) are used. An interview template is used to ensure consistency across interviews. The same interviews are also used to gather information regarding current use of fault handling mechanisms, forming the basis for the fault handling gap analysis.

For the research on new and improved fault handling mechanisms a more applied method is used, where mechanisms are first conceptually developed and described and then later realized in prototypes which are experimentally assessed. A simplified development process is followed for the prototype development, where requirements, use cases and modelling is performed prior to commencing the actual implementation in hardware and software.

For the evaluation of the prototypes fault injection is used for validation and verification. In fault injection faults are artificially injected into the target system and its behaviour is studied. Based on the expected behaviour the target system is classified as being able to handle the faults or not (there is typically a more fine grained scale for this purpose). In DEDICATE the faults injected are based on the fault types collected from the field (to be realistic) as well as those from standards (such as IEC 61508/ISO 26262). A framework (D-FEAT) has been developed for injecting faults and collecting result data automatically.

Maintenance service concepts

When developing the service concepts, the S-GDP (Volvo internal Service-Global Development Process - draft) has been used. We have performed the first two phases and partly the third and fourth phases. See Figure 11 below for an overview of the S-GDP.

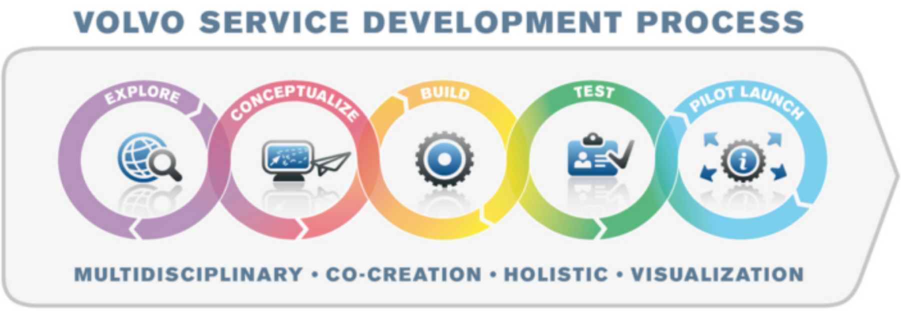


Figure 11. The S-GDP (Service - Global Development Process)

The work has included interviews, observation studies and co-creation workshops aimed to explore customers' (haulers') needs related to maintenance and repairs. Maintenance and repair suppliers (workshop personnel) together with Volvo Trucks were also included in the study to get a holistic picture of the current situation.

As initialisation, interviews with Volvo colleagues were performed to get a first understanding of the problem area, organisation and ongoing work (e.g. the LOCK project). With this as input, observations and interviews were then carried out at workshops to understand the customers' experience of a workshop visit and the repair and maintenance process. Furthermore, two co-creation workshops were held together with haulers, workshop personnel and Volvo Trucks to summarise related problems, generate ideas and develop concepts for future solutions to increase uptime. The methods used are shown in Figure 12.

Interviews

Semi structured interviews were conducted with various people from service suppliers and customers

(Explore phase)

Observations

Observational studies were performed at service suppliers were the customers and workshop personnel were observed rather than questioned

(Explore phase)

Co-creation workshops

Co-creation workshops were set-up based on methods developed within Volvo Technology and methods developed together with Chalmers University of Technology and held together with haulers, workshop personnel and Volvo Trucks

(Explore and Conceptualize phases)

Figure 12. Three methods for service development in the S-GDP used in DEDICATE

In the co-creation workshops the following was produced: a comprehensive list of current problems, 19 distinctive ideas, two concepts on how the future service and maintenance delivery process should look like and evaluation of the concepts. The results from the co-creation workshops were further enhanced by the project team at Volvo Technology into the Volvo Non-Stop Concept *(Build phase)*. In addition, the concept was visualized through Adobe Flash to make it tangible and easy to understand. This was showed at an open Volvo seminar where the concept was evaluated by the audience *(Test phase)*.

Project outcomes

The results of the project are disseminated and available for all within the Volvo Group.

- **Fault type information.** This information is useful not only for defining fault handling mechanisms within the DEDICATE project, but also as input to the definition of future actions for improving diagnostic coverage, maintainability, dependability, etc.
- **In-vehicle fault handling.** The PADS concept and prototype implementations are available internally and ready for use. The PADS unit prototypes can be used by other projects individually or as part of the DEDICATE framework. The hardware and software will be used for refinements of the PADS concept over the remainder of the DEDICATE project. The TDR (Time Domain Reflectometry) principle can be used either as a diagnostic fault location tool in workshops or implemented directly in the EE-system in a vehicle detecting and localising faults while the vehicle is operating.
- **DEDICATE Framework.** The assessment and testing framework is available for other projects to use as a platform for test, demonstration, assessment and evaluation of solutions pertaining to in-vehicle electronic systems. The DEDICATE Fault injEction and Analysis Tool (D-FEAT) for artificially recreating relevant fault types, is developed as a stand-alone tool and can be used for fault injection experiments in other settings as well, for instance for benchmarking of functional safety.
- **Maintenance service problem analysis.** This information gives anyone an insight into haulers and workshops daily business, problems and needs and is useful input to all activities related to increasing the efficiency of maintenance services.
- **Maintenance service concepts.** The Volvo Non-Stop Concept provides a step towards a better maintenance experience for mainly Volvo Group customers but also the workshops in the future. The concept can be used as inspiration and input for several related projects at Volvo.

Participating parties and Contact person

DEDICATE is a so called vertical project in the FFI programme, and thus only involves Volvo Group companies. The main work of the project is performed by Volvo Technology. During the project, we cooperate with personnel from just about all other Volvo Group companies.

Contact person

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Publications and dissemination of results

No publicly available documents have been produced in this project.

On May 26, 2010, we held the first DEDICATE Seminar. This event was open to all Volvo Group employees and to invited guests from Volvo Car Corporation, from Chalmers, and from the haulers we have collaborated with.

A number of internal presentations to related Volvo Group bodies for research and technology strategies (Key Technology Group – Embedded Systems, Key Technology Group – Electrical, Key Technology Council – Future Transport Solutions) have been held. More presentations and events are planned for the follow-up project (2009-04159 DEDICATE).