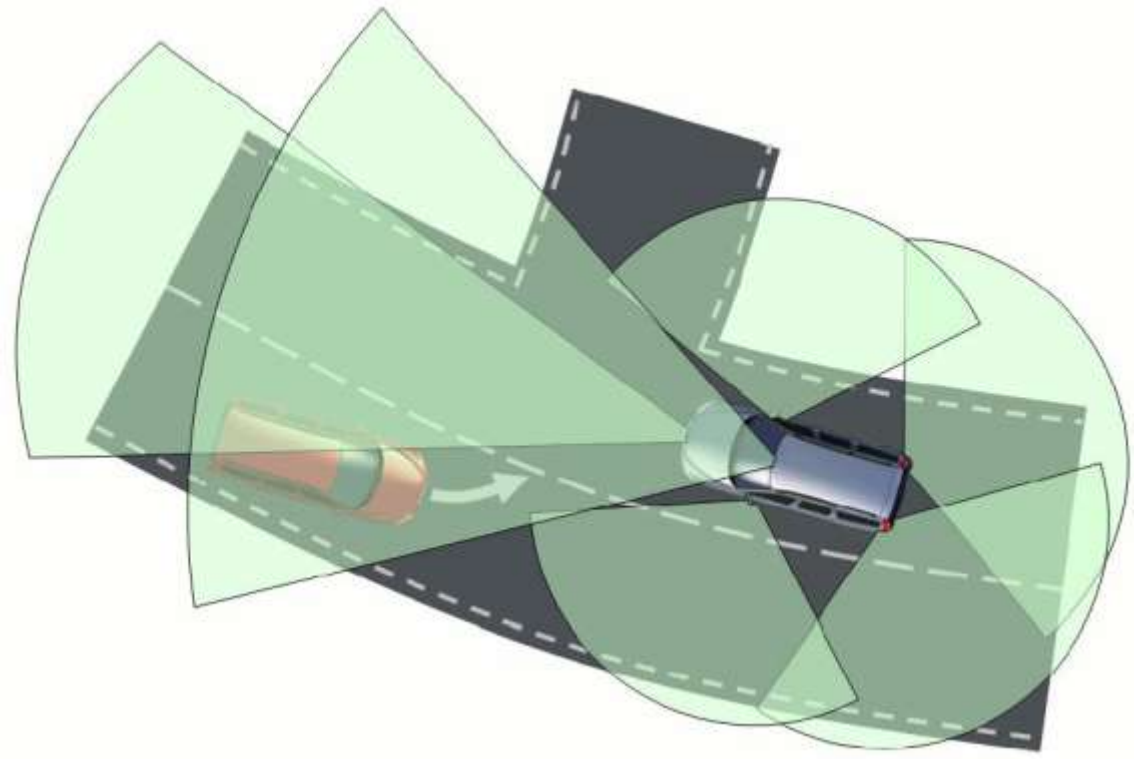
FFI

Final Report Non Hit Car And Truck 2010-2015



Project within Vehicle and Traffic Safety

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FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

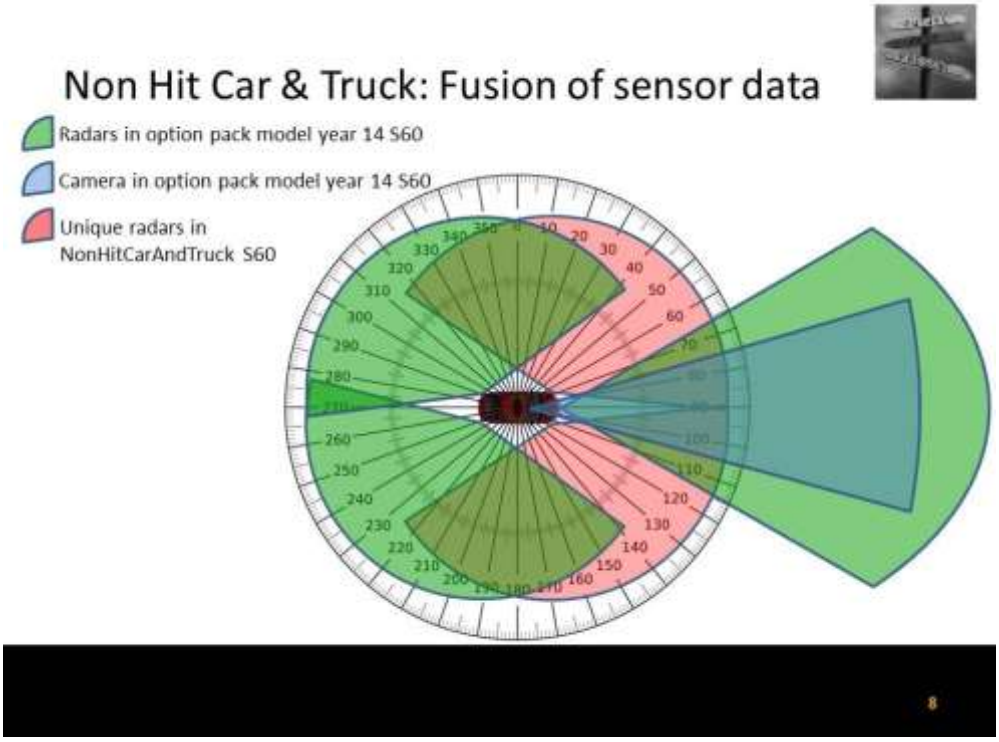
The Non-hit Car and Truck project aims to support Volvo Cars' 2020 safety vision, which states that by 2020 no one should be killed or seriously injured in a Volvo car as well as the Volvo Group vision of zero accidents with Volvo products.

The project has focused on developing safety functions that address the accident types that are not fully covered by today's safety systems

This functionality expansion creates increased needs for perception. New sensors are added to support new functions, but these sensors also provide additional information to existing functions and may also enable extended functionality. One of the most important challenges of today is therefore securing the ability to effectively combine and share the information from the growing number of available sensors in the vehicle, e.g. camera, radar, lidar, GPS etc. The co-operative approach increases the potentials to reach the overall objectives.

Result Non Hit Car And Truck:

1. Sensor Fusion framework that support current existing sensors technology
2. 360 degree view of the environment
3. New function independent threat assessment called" Maneuver Generator" that creates collision-free escape paths for complex traffic scenarios
4. Demonstrator vehicle with the technologies/findings deployed/visualized



Picture1: Sensor Fusion framework and 360 degree view of the environment

Picture2: New function independent threat assessment called" Maneuver Generator" that creates collision-free escape paths for complex traffic scenarios

Volvo Cars is the responsible project coordinator. Joining parties are: AB Volvo (Volvo Group, represented by Volvo 3P and Volvo Group Trucks Technology (CCT)), Chalmers University of Technology, HiQ, ÅF and Mecel. The collaboration with industrial and academic partners is of great importance since building competence within the safety domain in Sweden.

The project period is from Q3 2010 to Q2 2015. Total project cost is 79775340 SEK. This summary covers the years 2010 through 2013 due to that the project is administratively divided into two projects (Non Hit Car & Truck, Official Records No. 2010-01148 and Non Hit Car & Truck 2014-2015, Official Records No. 2012-03680).

2. Background

Non Hit Car And Truck project is an extension of "Non Hit Car project proposal" previously defined by Volvo Cars in 2008-2009. The project has focus on jointly developing technologies to reduce accident risks for both passenger cars and commercial vehicles and particularly address the situations at which today’s active safety systems are not yet sufficient.

To reach the goals brand new and improved safety functions with real-life benefits need to be invented across the whole safety domain, ranging from strategic drive to in-crash activities.

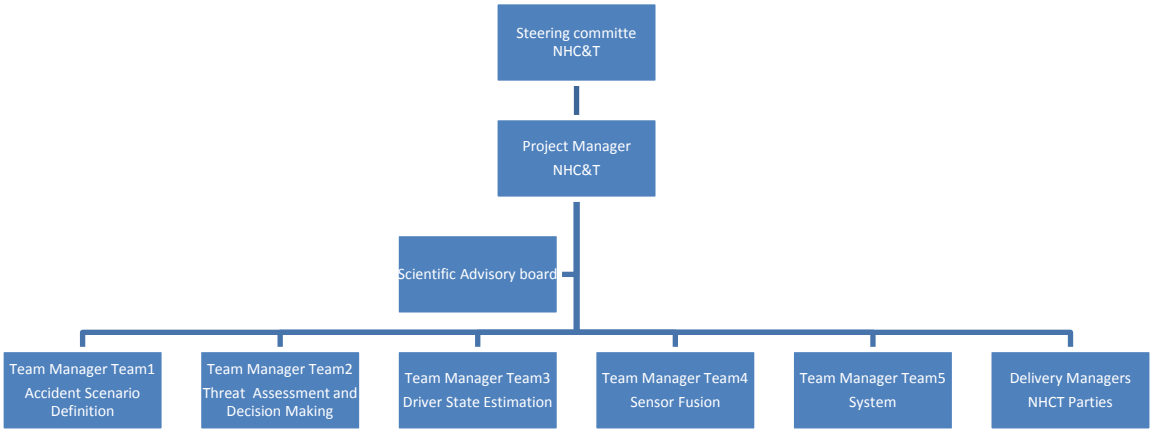
3. Objective

The Non-hit Car and Truck project aims to support:

- Volvo Cars' 2020 safety vision, which states that by 2020 no one should be killed or seriously injured in a Volvo Car
- The Volvo Group vision of zero accidents with Volvo products.

4. Project realization

The project has been carried out using the following organization



Picture3: Organization Non Hit Car And Truck

Initially, the project had four main work packages (WP, Work Packages):

1. Project Management
2. Threat Assessment and Decision making
3. Perception
4. System Design

The contents of the four work packages were refined initially in the project and were divided between the various teams as follows:

Team1 = Accident scenario definition			
Team2 = Threat Assessment and Decision Making			
Team3 = Driver state estimation			
Team4 = Sensor Fusion			
Team5 = System			

WP 1 – Project management			
Task	**Task description**	**Contributor**	
Task 1: PM	Project Management	VCC	

WP 2 – Threat Assessment and Decision Making			
Task	**Task description**	**Contributor**	**Team**
Task 1: Adaptive Driver Models	Deliver an adaptive real-time driver model that predicts driver behavior for situation assessment in all accident scenarios.	Chalmers, VCC, Volvo Group	3
Task 3: Situation assessment and decision making	Deliver an adaptive real-time situation assessment model that predicts situation assessment in all accident scenarios. Deliver an adaptive real-time decision model that decides specific motion requests in all accident scenarios.	Chalmers, VCC, Volvo Group	2
Task 4: Warning and actuation	Deliver a real-time path module that includes path predictions for all accidents scenarios	VCC, HiQ, **ÅF**, Volvo Group	2
Task 6: Accident scenario definition	Deliver a common Scenario definition document/database that will be used throughout the project (incoming requirements from partners based on statistical accident facts, markets demands and research level needs)	Chalmers, VCC, Volvo Group, **HiQ, ÅF**	1
Task 7: Passive Safety System	Consider Passive Safety system sensors when making an adaptive real-time situation assessment model that predicts situation assessment in all accident scenarios.	VCC	2
Task 8: Test Equipment	Create test equipment setup that covers all scenarios defined (HIL, SIL, CAE, …).	VCC, Volvo Group, HiQ, ÅF, Mecel	5
Task 9: Test Methods	Create test methods that covers all scenarios defined (HIL, SIL, CAE, Simulink, Matlab …).	VCC, Volvo Group, HiQ, ÅF, Mecel	5
Task 10: Testing	Perform test in different environmental (HIL, SIL, CAE, Simulink, Matlab, vehicle …).	VCC, Volvo Group, HiQ, ÅF, Mecel	5

WP 3 – Perception			
Task	**Task description**	**Contributor**	**Team**
Task 1: Next generation sensor set	Sensor research ensures a X (360) degree view of the vehicle surroundings including utilization of map data, Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication needed for supporting defined scenarios.	VCC, ÅF, Mecel, Volvo Group	4
Task 2: Sensor Fusion – Object Fusion	The main deliverable is to create a X (360) degree tracking system, capable of positioning objects on the local map. The proposed work will help the interpretation of the situation and the risk judgement, which in turn guides the decision of warnings or o	Chalmers, VCC, Mecel, Volvo Group	4

WP 3 – Perception			
Task	**Task description**	**Contributor**	**Team**
Task 3: Sensor Fusion – Static Environment Fusion	The main deliverable is an implementation of Static Environment Fusion i.e. a sub function of the Sensor Fusion block that fuses information from map data with data cameras and radars to provide a X (360) degree local map around the ego vehicle.	Chalmers, VCC, HiQ, Mecel, Volvo Group	
Task 4: Test Equipment	Create test equipment setup that covers all scenarios defined (HIL, SIL, CAE, …).	VCC, Volvo Group, HiQ, ÅF, Mecel	5
Task 5: Test Methods	Create test methods that covers all scenarios defined (HIL, SIL, CAE, Simulink, Matlab …).	VCC, Volvo Group, HiQ, ÅF, Mecel	5
Task 6: Testing	Perform test in different environmental (HIL, SIL, CAE, Simulink, Matlab, vehicle …).	VCC, Volvo Group, HiQ, ÅF, Mecel	5

WP 4 – System			
Task	**Task description**	**Contributor**	
System (Task1..3)	System management and define prerequisites and requirements on future architectures. Development of novel system verification methods.	VCC, HiQ, ÅF, Mecel, Volvo Group	5
Task 1: System Design	The System designer is responsible for managing the Functional architecture in Simulink. The System Designer shall manage the function requirement cascading process and allocation of requirements according to the defined functional system architecture.	VCC, HiQ, ÅF, Mecel, Volvo Group	5
Task 2: System Verification	The system tester is responsible for the development of Design Validation Methods and tools. The System requirements derived during the project will act as a base for the Design Validation methods. The system tester is also responsible of managing the Sys	VCC, HiQ, ÅF, Mecel, Volvo Group	5
Task 3: Vehicle Build	The main topics of this task are to integrate the chosen sensor set and the development system in the demonstration vehicle. The demonstrator will be continuously updated during the project in order to support the overall objectives.	VCC, HiQ, ÅF, Mecel, Volvo Group	5

The project has delivered in accordance with defined tasks and work packages. In order to solve the tasks has a project office been arranged for Team4 = Sensor Fusion (ÅF's office Lindholmen) and Team2 = Threat Assessment and Decision Making and Team3 = Driver state estimation has frequently used Safers conference room Haddon at Lindholmen. Without these two venues had not the project been able to deliver results in the extent that it has done. It is simply a requirement to have access to common meeting places and office spaces in order to generate results in a project of this magnitude.

5. Results and deliverables

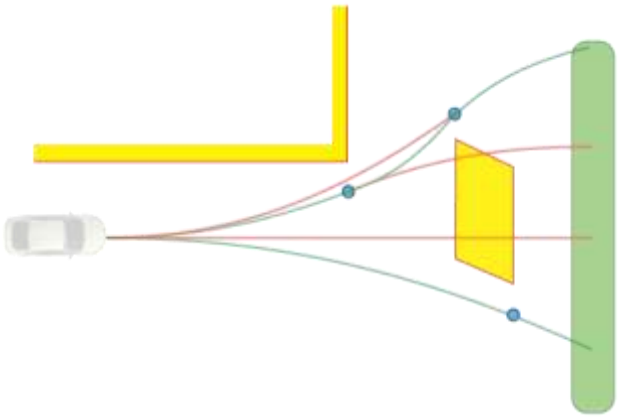
5.1 Delivery to FFI-goals

The project has contributed in that we have been innovative within sensor fusion and further developed the existing threats and decision algorithms in collaboration with academia, institutes and industry with some element of international cooperation. Competitiveness in specific subject areas such as sensor fusion and function development has been strengthened in that way that all parties have had the opportunity to educate and thus increase the amount of persons with knowledge of the subject. In the short term, we actively provide some newly graduated engineers a very interesting and developing work. Many of them have chosen to work within NHCT for several years and can now be considered experienced and can choose to work on alternative help spread the skills to other stakeholders in the automotive cluster in Western Sweden. Both AB Volvo and Volvo Cars have several ongoing projects there the Non Hit Car And Truck knowledge can be applied and used directly to help strengthen the research and innovation capacity. The international connection will probably be greater after the project in future European cooperation projects.

6. Dissemination and publications

6.1 Knowledge and results dissemination

Which Drivers for Change in the project's external environment can speed up the dissemination of the project results? Links with other internal / external projects that can accelerate the introduction or give greater impact?



Picture4: Collision-free escape path, a maneuver that is constantly ongoing

That there are other technical groups at parties (mostly at Volvo Cars and AB Volvo) showing interest in what the maneuver generator can do to develop their functions further

and perhaps even more closely integrated with security functions, thus driving development further toward fewer injured in traffic.

One example may be that the braking system of the vehicle elects to be control by a generated collision free maneuver and not only after prior well known state from the current brake sensor system.

Volvo Cars is working with integration of the results from the project directly to an industrial project with the name Argus. This project contains the next generation of Volvo Cars scalable safety system and its features. The dissemination of information is secured and now (2015) also introduction into production.

Knowledge and results have also been distributed to all involved parties at two internal demonstration sessions at the test facility Hällered.

Final Demo at AstaZero 2014-09-26

Public events
FFI program Conference - På väg mot målen 2013
http://www.vinnova.se/sv/Aktuellt--publicerat/Kalendarium/2013/131121-FFI-programkonferens/

FFI program conference, November 6, 2014

6.2 Publications

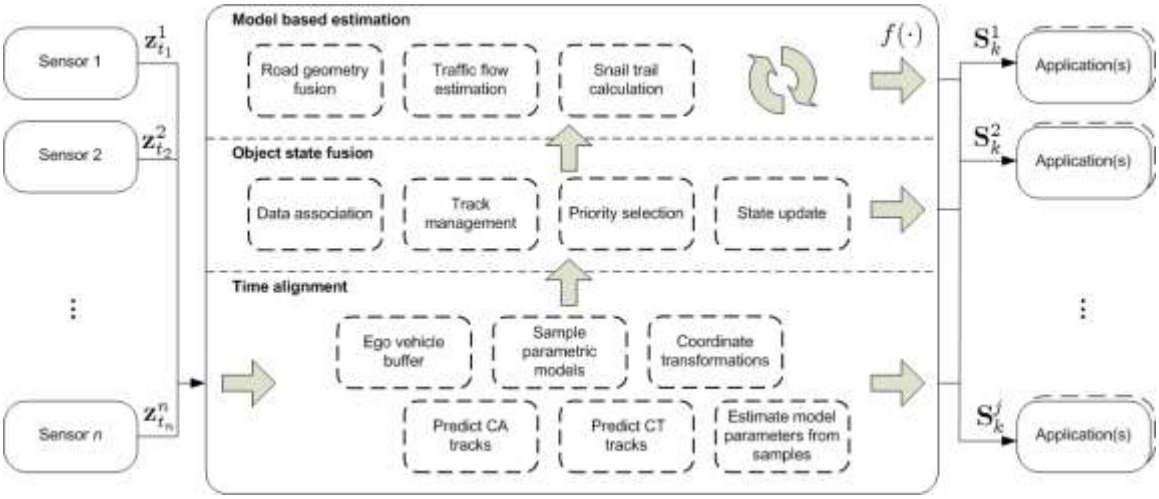
Parties	Title
VCC	Splines for Multi Target
VCC;#AB Volvo;#Chalmers;#Hi Q	Survey of maneuver generation methods for active safety path planning and threat assessment
Chalmers	A Study of MAP Estimation Techniques for Nonlinear Filtering
AB Volvo;#ÅF	Transforming local sensor tracks prior to track-to-track fusion in an automotive safety system
Chalmers	Bayesian road estimation using on-board sensors
Chalmers	Online driver behavior classification using probabilistic ARX models
VCC;#AB Volvo	Sensor data fusion for multiple sensor configurations
Chalmers	Clothoid-Based Road Geometry Estimation Using Moving Objects
Chalmers	Classification of longitudinal driver behavior
Chalmers	Nonlinear Filtering Methods in Road Geometry Estimation
Chalmers	A study of appropriate model complexity for estimation of car-following behavior

7. Conclusions and future research

Team2 - Threat Assessment and Decision Making
We have managed to create a functioning independent threat assessment which describes generic threat scenarios for the environment that sensor fusion describes. Furthermore creates the threat assessment code several lateral escape paths where the host-vehicle longitudinal velocity profile is assumed.
An interesting, and quite natural, next step is to allow the threat assessment code to not only evaluate the lateral threat - but also search for combined lateral / longitudinal escape paths.

Team3 - Driver state estimation
The research that has been conducted in this area has focused on the classification of driver behavior based on historical data set. In particular, the focus has been on the relationship between cornering behavior and the road geometry and the relation between brake and gas behavior and the vehicles ahead. This allows us to use the driver's cornering and acceleration profile to determine if the driver is active or passive. The next step is to analyze the driver's lateral behavior in relation to surrounding objects. This is an important step and particularly relevant in the classification of driver's style since avoiding overtaking is usually an easy way to avoid a collision at high speed. If we manage to determine / estimate the driver's lateral margins and the margins are acceptable by the driver, which will lead us to improve our ability to tune the warnings and interventions in a proper and correct way.

Team4 – Sensor Fusion
We believe that a vehicle manufacturer should if possible avoid using raw measurements in the sensor data fusion system. If the required performance cannot be met using a high-level algorithm (e.g., Track2Track fusion), we propose to use a sensor system employing low-level fusion to start with and treat this as a single sensor. Instead, focus should be on the correct treatment of data and a systematic approach towards verifying and re-using code components and complete functions.
The project fusion system is implemented according picture 5 (below) that comprises three demonstrator vehicles — a truck and two car — with different electrical architectures, equipped with radars, cameras and other sensors from multiple suppliers. Since a single fusion system has been successfully employed on both demonstrator vehicles, sharing all components but sensor specific tuning, our belief that the design is appropriate is strengthened.



Picture5. Non Hit Car And Truck fusions system

The fusion system (picture5) is suitable given the maturity of safety systems today and the technology trend. The assumptions may change — clearly there are no reason to do fusion if a single sensor is good enough —but nevertheless, the time and space alignment is always needed.

Future research will focus on:

- Data Association and state estimation especially for V2V data
- Representation of the stationary object or surface structure using grid representation
- Modeling and handling of uncertainties regarding target reference point, such as extended radar targets in adjacent lanes
- Modeling of sensor uncertainties

Team5 - System

System design
The project developed system design supports the program's specific goals that technology is developed with the potential to support a third of the reduction of the number of dead as a Parliamentary interim targets for 2020 means. Coming research should focus on addressing and developing a system design that is capable to support autonomous vehicles in both private and commercial contexts.

System verification
The project has delivered system verification to the extent required in a research project. To take the next step and industrial verify new functionality is not yet technically feasible due to the lack of working equipment in the vicinity of Gothenburg. Test plant AstaZero is an important part in enabling improved system verification but to realize that, and that the future projects will be able to deliver, equipment must be purchased and research into how it is managed and controlled must be initiated immediately. Research around AstaZero test plant and the opportunities created there.

Test vehicle build
The fact that technology content becomes more advanced in these vehicles requires systems engineers with different skills. The trend is clear and it means that these vehicles should be able to manage an increasingly complex environment and set of requirements than before. They must be able to handle the real environment available on test tracks and on the road but also be able to manage a virtual environment created as needed to manage the increasingly complex scenarios to be verified. Invest in research at AstaZero test plant and prospective test vehicle as they may provide for stakeholders from across the world.

8. Participating parties and contact person

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