

Safety for Autonomous Ships

What can we learn from other modes of transportation?

Ocean Week, Trondheim, May 9, 2018

Stig Petersen, SINTEF Digital

stig.petersen@sintef.no









(2016 - 2019)H2020 ECSEL SafeCOP project Safe collaborative cyber-physical systems using wireless communication

(2017 - 2020)H2020 Galileo H2H project Using EGNOS and Galileo to support autonomous maritime operations

RCN MAROFF Sacomas project Safe communication for autonomous ships



uropean **G**lobal Navigation **S**atellite Systems





(2017 - 2020)





Introduction to safety

Railway safety

Automotive safety

Safety for autonomous ships

















Safety

Safety can be defined as the freedom from unacceptable risk of harm to humans, either directly, or indirectly as a result of damage to property or to the environment.

Safety can be achieved through various barriers: Physical barriers, work processes, training and education, monitoring and control systems, emergency response.

Functional safety are barriers in the shape of electrical and programmable systems. These must operate correctly in order to ensure safe operation.









Functional Safety

Functional safety can be achieved by adhering to international safety standards. Safety requirements for different domains are regulated by authorities.

• IEC 61508	M
• ISO 26262	Αι
• ISO 13849-1	M
• IEC 62061	M
• IEC 60601	M
• IEC 61511 series	Pr
 IEC 60880 and IEC 61513 	N
• DO 178C	A۱
• EN 5012x series	Ra

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- lain (generic) standard for safety
- utomotive
- 1achinery
- lachines
- ledical
- rocess industry
- uclear industry
- vionics
- ailway domain





Functional Safety: Life cycle management

Functional safety requirements governs the entire life cycle of a safety system, from concept and specification, through design and development, to maintenance and decommissioning.

Developing a safety system is much more complex, time consuming and costly than a similar non-safety system.

With functional safety, the perspective is changed from developing technology that works, to developing technology that does not fail.



Railway safety

The railway infrastructure is typically managed by national railway authorities. International collaboration ensures compliance across national borders.

In EU, railway systems must be verified by Notified Bodies prior to deployment.



- Functional safety for railway is addressed by EN 50126, EN 50128, EN 50129 and EN 50159.
- The train operator (UK) / railroad engineer (US) is not responsible for the safe operation of a train.
- The removal of the human component in safety management has led to railway having the most stringent functional safety requirements of all safety domains, including aviation and nuclear.





Railway safety barriers

Railway infrastructure Planning, construction, operation and maintenance of the railway network

Railway traffic management

Train safety

Trains are subject to periodic control and maintenance.





- Planning, construction, operation and maintenance of railway signaling and control systems. Railway signaling and control systems must adhere to functional safety requirements.
- Train control and protection systems that must adhere to functional safety requirements.





Autonomous trains

- A train with modern control systems is not capable of running a red light. A train with modern control systems is not capable of exceeding speed limits.

Fully unmanned trains are already in commercial operation. Many urban metro systems also operate without a driver.



Trains have safety systems capable of overriding the decisions of the train operator:

- A train operator thus has limited degree of freedom and is uncapable of causing accidents.
- An autonomous train will have the same limitations, and will not be able to cause accidents.



Automotive safety

Automotive functional safety is covered by the international standard ISO 26262. Adherence to ISO 26262 must be proven in court after potential accidents.



- Rules and regulations for road transportation safety is handled by national road authorities. International collaboration ensures conform requirements for motor vehicle and road safety.
- The driver is ultimately responsible for the safe operation and handling of a motor vehicle.







Automotive safety barriers

Road infrastructure Planning, construction, operation and maintenance of roads and road marking. **Road traffic management** Planning, construction, operation and maintenance of traffic signs, lights and signaling.

Motor vehicle safety Motor vehicles must adhere to ISO 26262 for relevant safety functions. Mandatory periodic control and approval of the condition of individual motor vehicles.

Driver education and training Driver's licenses give permission to operate one or more types of motor vehicles.





Autonomous cars

Autonomous cars are being tested on public roads in several countries.

On 18 March 2018 a pedestrian crossing a road was killed by a self-driving car tested by Uber in Tempe, Arizona. The car made no attempt to brake prior to the accident.

The Tempe accident was the third fatality related to self-driving cars, and it has put to question the rules and regulations for testing autonomous cars on public roads.

Although the testing continues, authorities, the public and car manufacturers are taking notice of the recent accidents.

There are currently no formal functional safety requirements for the control and navigation of autonomous cars.





Merchant ship safety

safety of merchant ships.



The IMO SOLAS Convention is considered the most important international treaty for the

- Flag States are responsible for ensuring that ships under their flag comply with SOLAS requirements. Compliance to requirements can be validated by classification societies.
- National port and coastal authorities handle the safe management and operation of harbors and coastal waters. This includes navigational aid services and vessel traffic services.
- A ship captain is ultimately responsible of the safe operation of a merchant ship.



Merchant ship safety barriers

Harbors and coastal-near infrastructure

Traffic management Operation and control of ship traffic in and near harbors.

Ship safety

Education and training Certification and Watchkeeping for Seafarers.



- Management and operation of harbors, harbor pilots, shoal and hazard markings, lighthouses.
- Safe control and navigation systems, fire protection systems and other safety functions.
- Licensing of senior positions according to the International Convention on Standards of Training,







Autonomous ships

Activities addressing autonomous ships are also initiated.

responsible for the safe operation of the USV or autonomous ship.

control, navigation and protection systems of USVs or autonomous ships.

they must be at least as safe as conventional vessels in similar service.



- Unmanned surface vehicles (USVs) are being successfully tested in several countries.
- National authorities typically allow testing under the condition that the operator is ultimately
- There is currently no regulations requiring adherence to functional safety standards for the
- However, it is often stated that for autonomous ships to be acceptable for commercial use,







Summary

Autonomous trains and metros are in successful operation with no registered accidents so far. In the railway domain the human train operator is not part of the safety barrier management.

Autonomous cars are in testing in several countries in the world. Regulations for testing and operation are under discussion and renewal following recent fatal accidents.

Autonomous ships are under development, although there are no formal functional safety requirements for the control, navigation and protection systems.





Conclusions and recommendations

• How can a driver's license be issued to a driverless car? • Who is the captain of an unmanned ship?

shipping companies, and various system and technology providers.

- Autonomous ships and cars partly or fully remove the human as a safety barrier, but:
- To ensure future safe operation of autonomous ships it is necessary to enforce relevant regulations for functional safety of signaling, control, navigation and protection systems.
- This requires a close collaboration between authorities, classification societies, ship owners,







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