



Safety for Autonomous Ships

Lessons learned from other domains

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Safety can be defined as freedom from unacceptable risk of harm to humans, property or the environment.

Safety can be achieved by using barriers:

Physical barriers, work processes, training and education, control systems, emergency response, ...

Autonomy is traditionally defined related to the technical capabilities of a system.

SAE¹ Levels of Autonomy

Level 0 No Automation	Level 1 Driver Assistance	Level 2 Partial Automation	Level 3 Conditional Automation	Level 4 High Automation	Level 5 Full Automation
The driver performs all tasks.	Some driver assist features may be present. The vehicle is controlled by the driver.	The vehicle has combined automated functions. The driver must be engaged and monitor the environment at all times.	The driver is necessary but does not need to monitor the environment. The driver must be ready to take control at all times with notice.	The vehicle performs all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle can perform all driving functions under all conditions. The driver may have the option to control the vehicle.

¹ Society of Automotive Engineers

Autonomous cars are currently in testing on public roads.

On 18 March 2018, a pedestrian was killed by an Uber car testing self-driving technology in Tempe, Arizona.

The car made no attempt to brake prior to the accident.

The accident report concluded that emergency braking was not enabled while the vehicle was under computer control.

The driver was relied on to take action, but the system was not designed to alert the driver when intervention was needed.

Uber avoided a potential lawsuit from the family of the deceased by settling shortly after the accident.

In March 2019, Yavapai county attorneys concluded that the Uber corporation is **not criminally liable** for the accident

The driver of the vehicle may still face criminal prosecution.

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SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features			These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none">• automatic emergency braking• blind spot warning• lane departure warning	<ul style="list-style-type: none">• lane centering OR• adaptive cruise control	<ul style="list-style-type: none">• lane centering AND• adaptive cruise control at the same time	<ul style="list-style-type: none">• traffic jam chauffeur	<ul style="list-style-type: none">• local driverless taxi• pedals/steering wheel may or may not be installed	<ul style="list-style-type: none">• same as level 4, but feature can drive everywhere in all conditions

With the introduction automated and self-driving technologies, **electronic systems** are gradually replacing **human operators**.

Autonomy definition revisited:

A system is considered autonomous if it can legally accept accountability for an operation.

NFAS Levels of Autonomy

Level 1 Decision Support	Level 2 Automatic	Level 3 Constrained Autonomous	Level 4 Fully Autonomous
	The operation follows a pre-programmed sequence.	The ship can operate fully automatic in most situations.	The ship handles all situations by itself.
The crew is in command of ship operation and supervises all operations.	Humans must intervene from bridge or shore control center (SCC) upon request.	SCC or bridge personnel must take immediate control when requested by the system.	SCC or bridge personnel is not required.

Summary

Defining autonomy as a **technical capability** introduces uncertainties regarding division of responsibilities between humans and machines.

A general definition of autonomy should be based on **legal accountability** – not technical function.

Unresolved challenges

The practical and formal implications of transferring accountability between humans and computer systems.

The shape and form of the **safety regimes** necessary for handling approval and certification of autonomous systems.

The spilt of accountability between system designers, operators, authorities and certification agencies.



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