An executive summary

Certification roadmap for the hyperloop

This study is part of the Hyperloop Development Program (HDP).

The HDP is a public-private partnership between the ministry of Infrastructure & Water management, Ministry of Economic Affairs and Climate, Province of Groningen, and more than 15 private partners.

More information:
https://hyperloopdevelopmentprogram.com/

hyperloop development program

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Precisely Right.

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Summary

TÜV Rheinland, specialist in international product certification, recently created a 'Certification Roadmap' for the Hyperloop Development Program.

The certification road map defines the necessary steps required for the final safety acceptance of the hyperloop by the approval authority. This road map provides guidance on the methodology on system safety documentation and the engineering approach to the safety architecture. In addition it identifies the relevant generic standards that could be used in this process and provides recommendation for speeding the approval process. Finally the road map is concluded with an approach to approval in order to achieve final acceptance of hyperloop from the relevant authorities differentiating between testing in a public area and commercial deployment.

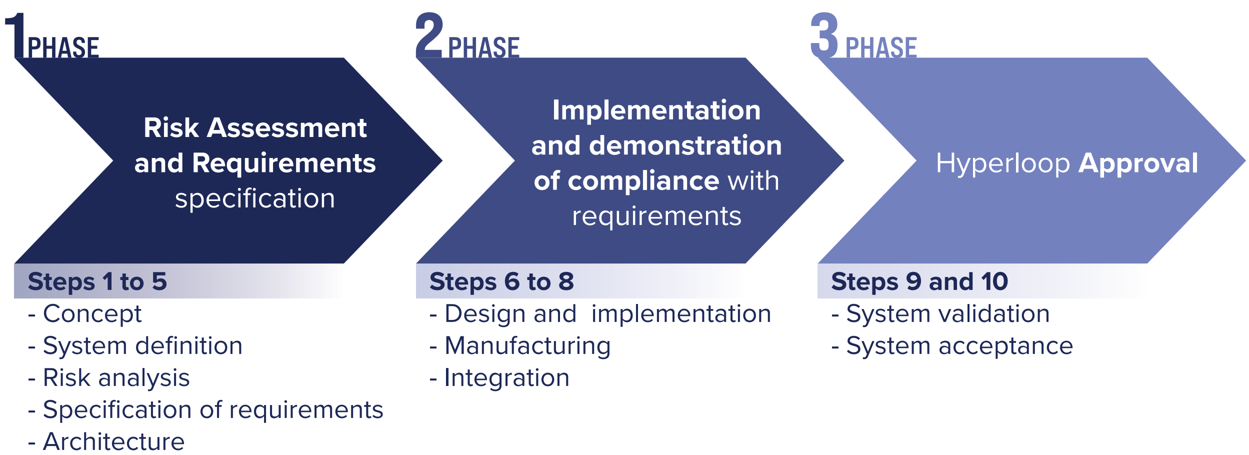
Steps to **hyperloop approval**

The road map utilizes the well-known and broadly used life cycle approach depicted in the European Standard EN50126-1.

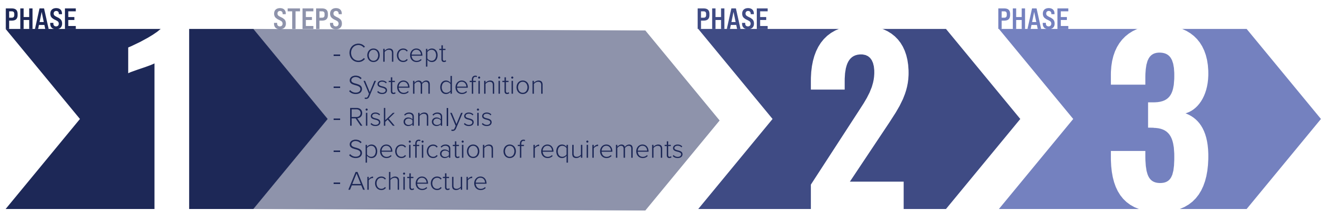
There are three main phases in the life cycle relevant for the generic system safety documentation that can be applied for hyperloop certification, hyperloop approval for commercial deployment. These three phases are depicted below:

— Risk assessment and requirements specification.
— Implementation and demonstration of compliance with requirements.
— Hyperloop approval

The first two phases are in particular of importance for the hyperloop approval. Each of the phases has its own relevant steps, see figure below:



It must be noted that only the steps relevant for the hyperloop approval are depicted in this summary. The operations and maintenance activities are omitted in this description.



Risk Assessment and Requirements specification

Implementation and demonstration of compliance with requirements

Hyperloop **Approval**

PHASE 1

Risk Assessment and Requirements specification

Step 1 of 10

Concept

Description	**The certification road map recommends as the first step the preparation of the following aspects:**
Sub-activities	a) the scope, context and purpose of the hyperloop system; b) the environment of the hyperloop system, including: system interface, environment and legislative / economic issues c) Reliability, Availability, Maintenance and Safety (RAMS) requirements and past RAMS performance of similar and/or related systems (Aviation and Rail); e) safety legislation: functional safety standard to be used, institution responsible for final approval of the system f) identification of the requirements and standards that are required by the approval authority (including upcoming JTC20 European Standards on Hyperloop systems).
Actors involved	**Development team, Approval Authority, Assessor (Recommended)**

Step 2 of 10

System definition

Description	**In this phase, a safety plan, describing the methodology to come to a safe system should be prepared. The following steps are necessary:**
Sub-activities	— Define the system and its mission profile, — Define the boundary of the system, — Establish the operational requirements influencing the characteristics of the system, — Define the scope of system risk analysis, — Establish the initial Reliability Availability Maintenance (RAM) plan for the system, — Establish the initial Safety plan for the System, — Define the functions to be provided by the system, — Define the organization for RAM and safety management of the system.
Actors involved	**Development team, Assessor (Recommended)**

Step 3 of 10

Risk analysis

Description	**In this phase the following steps shall be completed:** **1. A systematic identification and analysis of all internal, external and functional hazards has to be carried out.** **2. Establishment of the hazard log to enable tracing the risk reduction measures that are defined per hazard in the hazard analysis.** **3. Risk analysis to determine safety integrity levels (SIL) for the safety functions.**
Sub-activities	At the end of this phase, safety requirements will be generated for the system, part of them relates to safety functions, for which also a safety integrity level will be defined. The safety requirements will also contain references to specific technical standards. These standards will be specified in the course of the hazard analysis. **If a specific technical design standard is applied and it covers the hazard completely, the risk can be assumed as being acceptable without further analysis.** It must be noted that for the hazard and risk analysis, transport of persons or cargo needs to be distinguished. At least the consequences of accidents will be different, when cargo is transported. This would lead to weaker safety integrity levels (SILs) for certain functions, when only cargo transport is considered.
Actors involved	**Development team, Assessor(Recommended)**

Step 4 of 10

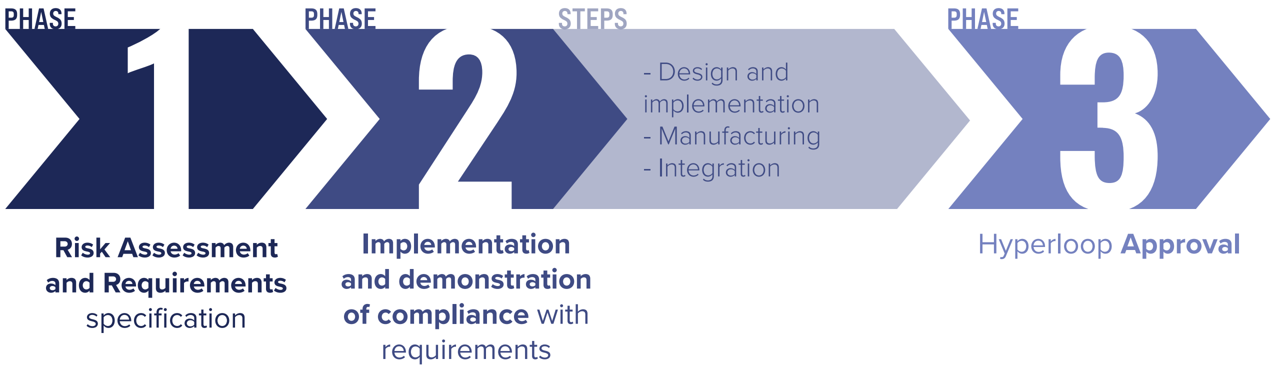
Specification of the requirements

Description	**In this phase, the requirements of the system are defined. This includes safety requirements, which need to be marked as safety-relevant.**
Sub-activities	Safety requirements need to be clearly marked.
Actors involved	**Development team, Sub-suppliers, Assessor(Recommended)**

Step 5 of 10

Architecture

Description	**In this phase, the elements of the architecture are defined and the requirements are assigned to the elements of the architecture.**
Sub-activities	The following aspects need to be covered: a) system architecture (structure of decomposition into subsystems etc.) including interface specifications and system hazard analysis (architecture and hazard analysis of subsystem and components); b) allocation of RAMS requirement specification to subsystems and/or components; c) acceptance criteria and demonstration and acceptance processes and procedures. Furthermore, planning documents and other documents as the hazard log need to be updated. In addition, a first version of the safety case should be established and an FMEA should be carried out on system level to identify possible problems.
Actors involved	**Development team, Sub-suppliers, Assessor(Recommended)**



PHASE 2

Implementation and demonstration of compliance with requirements

Step 6 of 10

Design and Implementation

Description	**The tasks of this phase consist of:** **- create subsystems and components conforming to RAMS requirements;** **- demonstrate that subsystems and components are conform to RAMS requirements.**
Actors involved	**Development team, Sub-suppliers, Approval Authority, Assessor(Recommended)**

Step 7 of 10

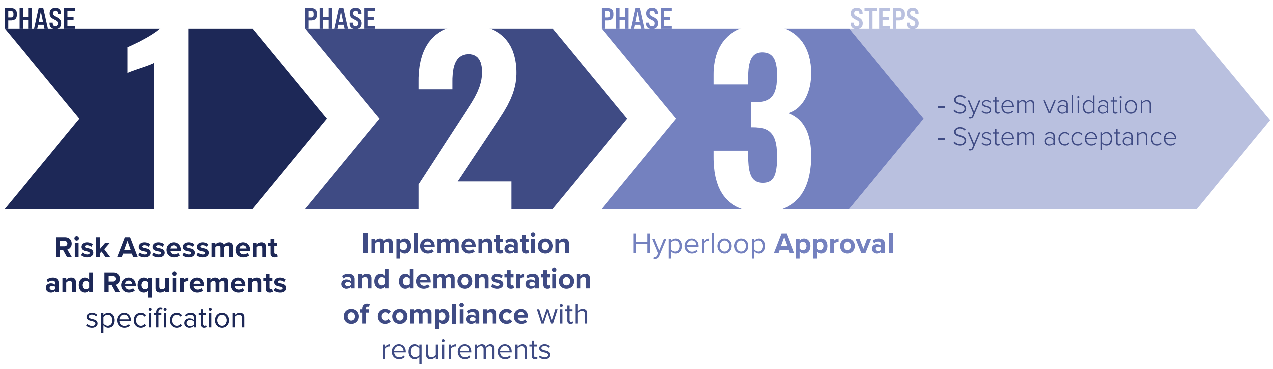
Manufacturing

Description	**The manufacturing phase will implement the technical design. Manufacturing is carried out according to the specifications generated in the previous phase. It needs a quality system to be present and qualified sub-suppliers to be sure that the necessary evidence (as test protocols etc.) is generated. It is important to choose for proven manufacturers and suppliers.**
Sub-activities	Test reports need to include environmental tests as well as EMC tests for relevant components. Note that EMC proofs normally need to be done on system level.
Actors involved	**Development team, Sub-suppliers, Assessor(Recommended)**

Step 8 of 10

Integration

Description	**In this phase the sub-systems are integrated and integration tests are carried out. It is important to do this stepwise, first testing levitation, guidance, propulsion / braking with low speed, then with evacuated tubs and high speeds.**
Sub-activities	Also, EMC tests have to be carried out in this phase to show that the integrated system satisfies the emission as well as the susceptibility of the systems.
Actors involved	**Development team, Sub-suppliers, Assessor(Recommended)**



PHASE 3

Hyperloop **Approval**

Step 9 of 10

System Validation

Description	**In this phase the validation tests are carried out. The results need to show that the top level requirements (for headway, speed, etc.) are fulfilled.**
Sub-activities	As a result, the validation report is elaborated. It shows that all planned verification activities have been carried out and that all requirements have been implemented and tested. For this sake, a traceability matrix is used. Possible deviations from the planned validation activities must be listed and analysed. The final version of the safety case has to be prepared.
Actors involved	**Development team, Sub-suppliers, Approval Authority, Assessor(Mandatory)**

Step 10 of 10

System Acceptance

Description	**Acceptance for the system is gained by the relevant authority.** **The approval authority is responsible for public safety and as such sets the requirements for a documentation set with typically the safety case as the top level document.**
Sub-activities	The safety case provides the documented evidence on safety and can be supposed that the safety case has to be accompanied by a safety assessment report of an independent organization, underlying documents as the plans, verification reports, test reports, validation report, etc. The detailed content of the dossier needs to be agreed with the approval authority. It must be noted that there is a difference between the: a) Approval for a Hyperloop system for testing in a public area b) Approval of a Hyperloop system for commercial operation In case of testing in a public area the not all risk reduction measures need to be in place and other compensating measures can be implemented while for a system for commercial operation all risk reduction measures need to be fully implemented.
Actors involved	**Development team, Sub-suppliers, Approval Authority, Assessor(Mandatory)**