



Extending Life Time of Railway Systems

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Extending the Life-Time of Railway Systems

The Challenges.

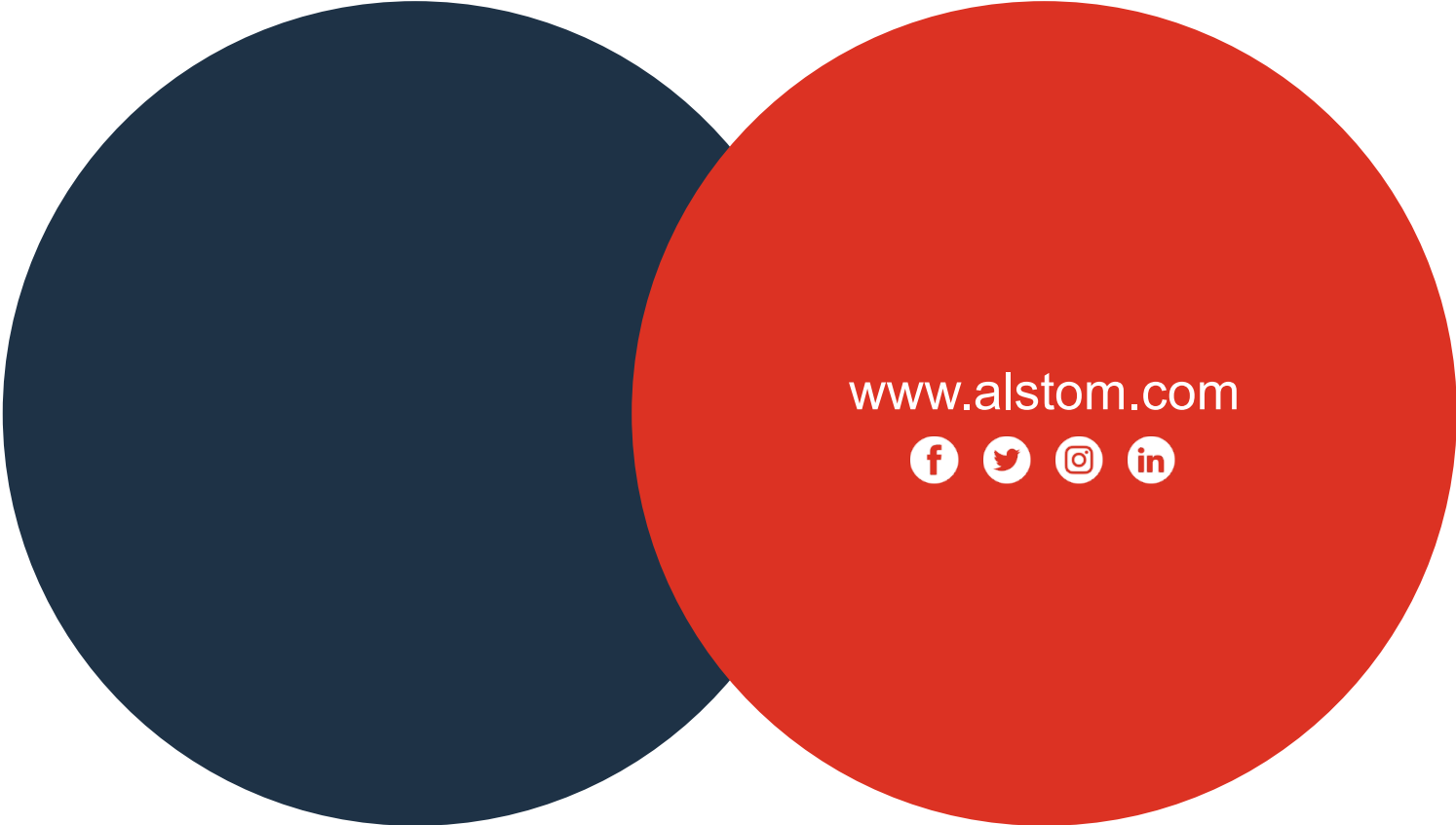
- **Railway Systems** today are **cyber-physical Systems**
 - Hardware which usually degrades with time
 - But also software, which becomes obsolescent, has its own 'degradation' patterns **and interacts with hardware**
- ... which interface other systems (such energy generation and communication) to form a systems of systems
- and are subject (in the medium-long term) to hard-to-predict changes in use conditions and regulations
 - Example : 5 years ago, who would have predicted the distancing rules (COVID) ,or the repeated floodings (Germany, Belgium, China) due to climate change ?
- ...and vulnerable to evolving threats (e.g. cyber-terrorism)



Not just a ' simple' reliability and maintenance question

Some Directions for Research

- **Deep understanding of (hardware) degradation mechanisms at system level (data-enhanced physics-based models)**
- **Fleet level preventive/ predictive maintenance → avoid simultaneous failures of all elements**
- **Sustainable Resilience**
 - Absorptive (withstand 'shocks') → throughout life cycle (design/ redesign , maintenance policy evolution)
 - Adaptive (graceful degradation)
 - Quickly recovering
- **Digital Twins as a tool for Life-Cycle management and Lifetime Extension**
 - simulation of degradation patterns but also enhancements of physical system to dynamically adapt to evolving conditions
 - Some functions implemented in cyberspace and thus hardware independent
- **PHM for Software : predicting/ avoiding 'software crashes' and other soft failures**
- **Maintenance efficiency as a life extender**
- **In-depth study of Safety impact of PHM → essential condition for adoption for key subsystems**



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