Assurance cases in an era of smart and collaborative cyber-physical systems – pain points and ways forward

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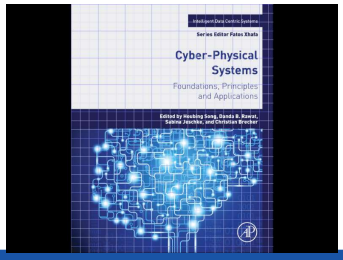
About the lecturer - Dr. Who?

- Prof. at KTH in Embedded Control Systems since 2002
- Architecting and MBSE, Automated vehicle safety,
- KTH and industry competence network - www.ices.kth.se
- Scandinavian System and Software Safety Conference

PLATFORMS 4CPS

CyPhERS



Safety (and assurance) cases

Safety case: "… a structured argument, supported by a body of evidence, that provides a compelling, comprehensible and valid case that a system is safe for a given application in a given operating environment" - NASA System Safety Handbook ver. 1 (2014)

Assurance case: "A documented body of evidence that provides a convincing and valid argument that a specified set of critical claims regarding a system's properties are adequately justified for a given application in a given environment" – MITRE (2005)

Applied in one way or the other in many domains
(safety standards, sometimes directly connected to regulations),

Typical safety case content

Core content

- Environment description (airspace system)
- System description, system change description
- Aircraft capabilities and flight data
- Accident / incident data
- Pilot / crew roles and responsibilities
- Hazard analysis, risk analysis, risk controls, …
- …

Safety risk management plan

- Hazard tracking and treatment
- Safety performance monitoring

FAA (8900.1, FSIMS, vol. 16, UAS), Courtesy of Ewen Denney

Cyber-physical systems (~2006)

Integration of computation, networking and physical processes where CPS range from minuscule (pace makers) to large-scale (e.g. national power-grid).

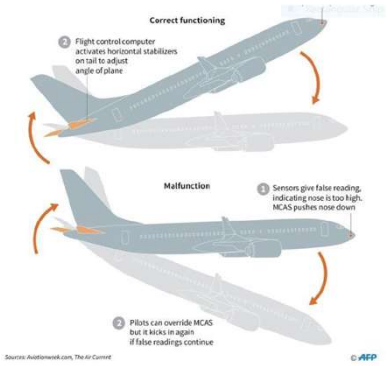
Not new but characterized by

- Live, collaborative, ”smart” and automated
- Integration: Technology, systems, domains, life-cycle
- Business model evolution
- Open society scale deployment

Unprecedented opportunities, societal reliance and risks

CPS trends and melting pot

Boeing 737 MCAS

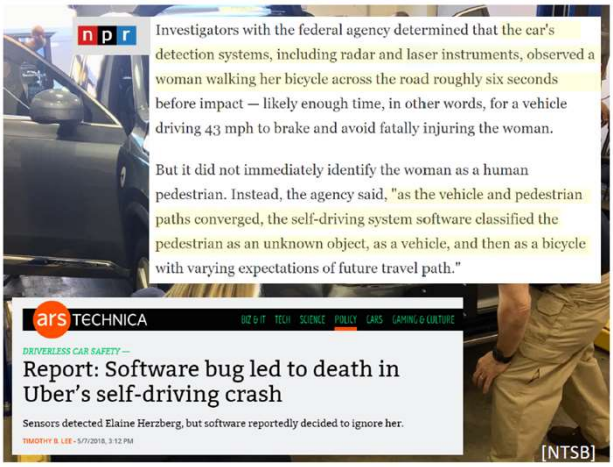


After two flight crashes:

A <u>compelling</u>, <u>comprehensible</u> and <u>valid</u> case?

The Maneuvering Characteristics Augmentation System (**MCAS**) flight control law **was designed and certified** for the 737 MAX **to enhance the pitch stability** of the airplane – so that it feels and flies like other 737s (Source: Boeing).

Uber crash March 2018



A <u>compelling</u>, <u>comprehensible</u> and <u>valid</u> case?

Dealing with inherent dynamic risk

www.youtube.com/watch?v=HjtiiGCe1pE&feature=youtu.be

Reflections

Safety represents a continuous struggle!

- Safety cases are non trivial even for current CPS

The automation paradox is more relevant than ever

Indicators/metrics (leading/lagging); roles; safety culture; …

The CPS paradigm shift however imposes new challenges

The million or trillion dollar question?

By FE Bureau: https://www.financialexpress.com/education-2/what-will-shape-future-smart-cities-of-india-find-out-here/968678/

Assurance cases in an era of smart and collaborative CPS

- Initial scenarios
- Analysis:
  Complexity of CPS; Drivers
  Effective SC's/AC's
- Directions:
  Strategy; Complexity;
  Barriers and operational risk management
- Wrap-up

Autonomy: Basic functions

Observation

Localization

Object detection & classification

Planning and generation

Control

Vehicle dynamics

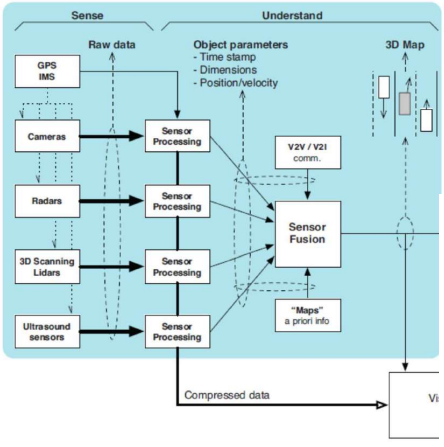
Energy management

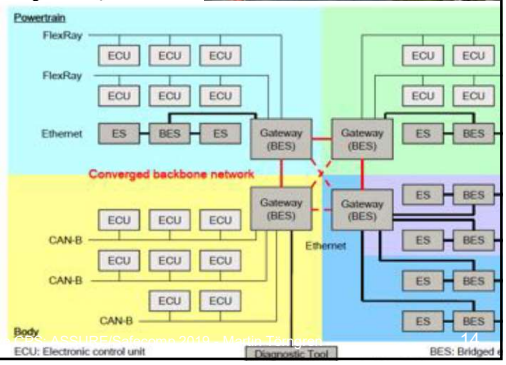
Steering

Propulsion

Braking

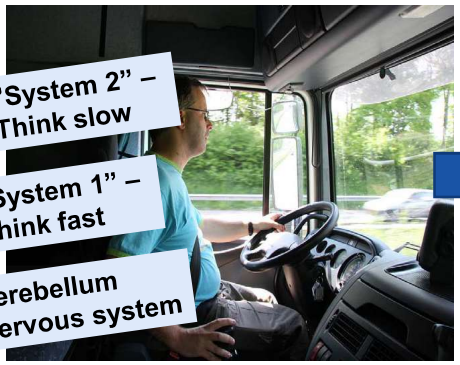
Unprecedented capabilities and complexity





Breaking new ground – generalized knowledge

ADI – ”Autonomous Driving Intelligence”



By Veronica538 (Own work)
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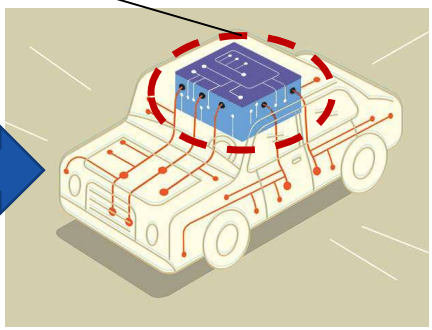
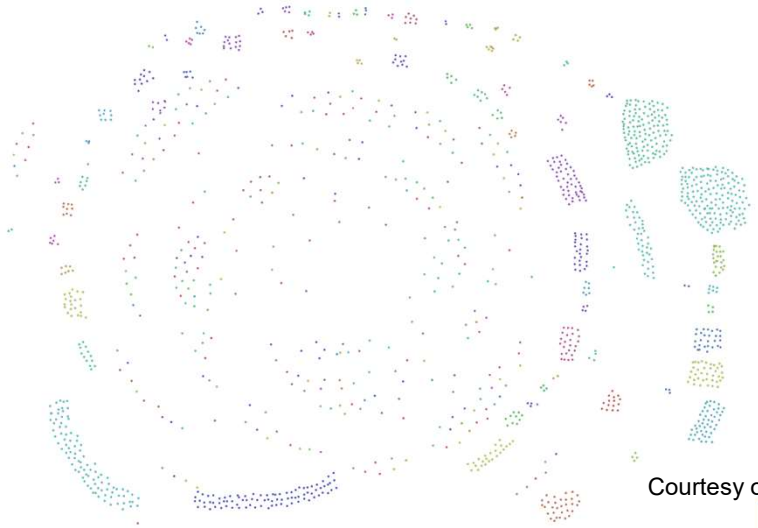


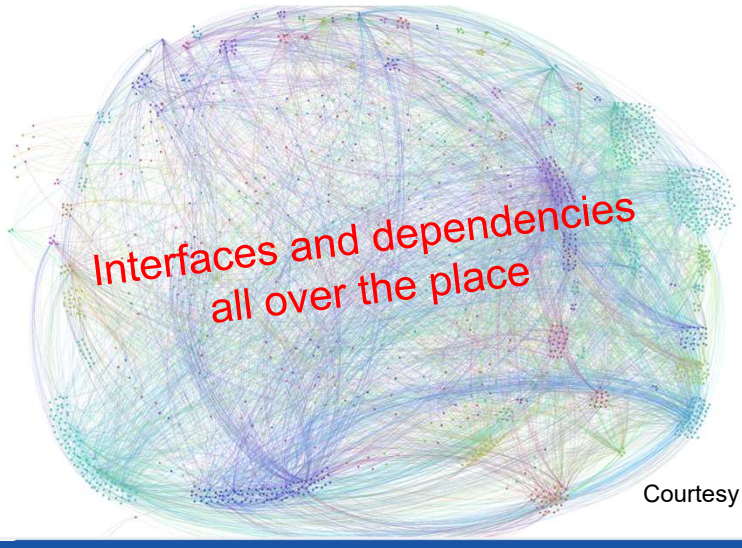
Illustration: Harry Campbell, IEEE Spectrum
http://spectrum.ieee.org/cars-that-think/transportation/self-driving/nxps-bluebox-bids-to-be-the-brains-of-your-car

1500 logical nodes – example Scania production vehicle, 2013



Courtesy of Scania

14000 connections – same Scania production vehicle example, 2013



Courtesy of Scania

The "Cyber Physical" tension

Dimension	„Cyber Domain"	„Physical Domain"
Example Disciplines	Logistics	Aeronautics
Typical Life Cycle	< 2-3 Year	> 10-30 Years
Business Model	Dynamic Value Network	Static Supply Chain
Development Approach	Continuous Delivery	Implement-Commission-Operate –Decommission
Dependability Focus	Security	Safety (and certification)
Platform Approach	Max. virtualization/Cloud	Min. virtualization/RTOS
Example Technologies	Big Data, Online Learning	Control Synthesis

Composability yet an unresolved challenge

A key CPS challenge: Combinations of deterministic models are non-determinstic

Image: Wikimedia Commons

```
void initTimer(void) {
    SysTickPeriodSet(SysCtlClockGet() / 1000);
    SysTickEnable();
    SysTickIntEnable();
}
volatile uint timer_count = 0;
void ISR(void) {
    if(timer_count != 0) {
        timer_count--;
    }
}
int main(void) {
    SysTickIntRegister(&ISR);
    ... // other init
    timer_count = 2000;
    initTimer();
    while(timer_count != 0) {
        ... code to run for 2 seconds
    }
    ... // other code
}
```

$$\dot{\mathbf{x}}(t) = \dot{\mathbf{x}}(0) + \frac{1}{M}\int_0^t \mathbf{F}(\tau)d\tau$$

No notion of timing at the SW level

Courtesy, Edward Lee, UC Berkeley

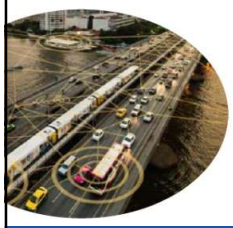
Challenge further aggravated by non-predictable multicore platforms

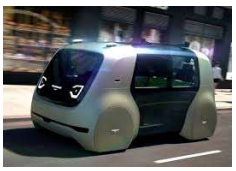
Future CPSoS – some safety challenges

Built in risk metrics – acceptable risk
Collaboration models – behaviors and anomalies
Perception, awareness, assumptions
Openness and uncertainty of environment
Evolution, upgrades, learning
Deep learning robustness and failure modes
Higher levels of automation => Automation paradox
Transitioning periods
Exposure, severity, security
Interactions and governance in systems of systems
…

Cyber-physical systems

Arthur C. Clarke:
Any sufficiently advanced technology is indistinguishable from magic



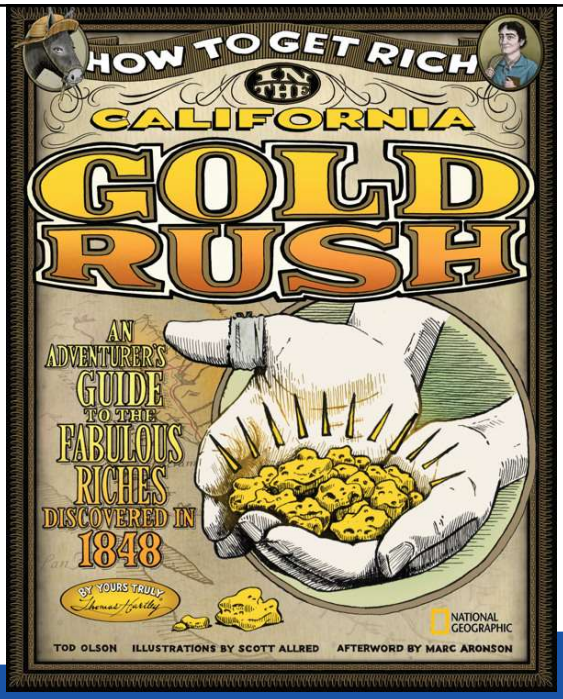


What drives AV development?

Business MIT Tech Review:
- **Can We Put a Price on Autonomous Driving?**

- Transport services: ~ Trillions of dollars!
- Traffic accidents: 100's of billions of dollars
- Traffic efficiency, productivity and public health: - II -

The beginning of wisdom is to call things by their proper name – attributed to Confucius



Today: Billions poured in to get to the Trillions!

Key question: When will the Gold emerge?

1849 – Gold rush

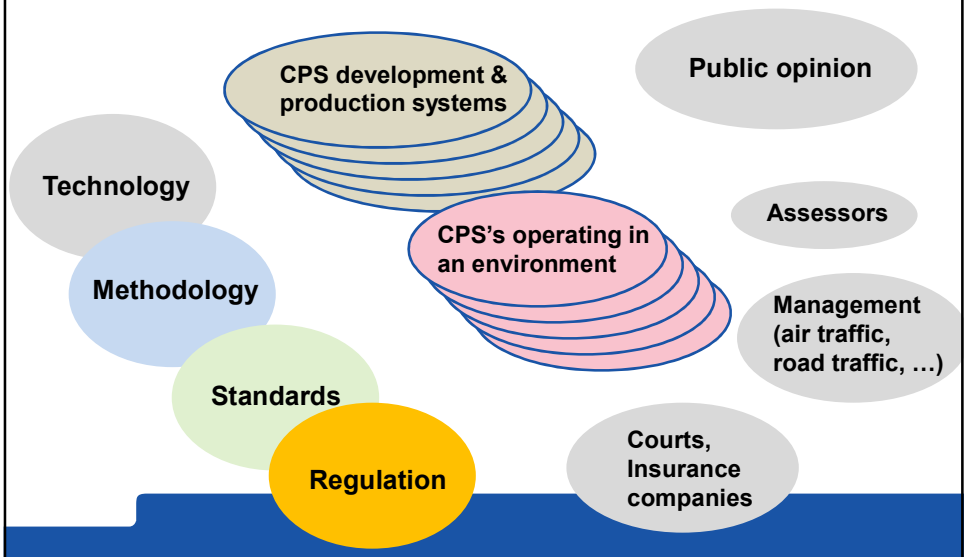
Several parallel gold rushes!

Automated driving/ transportation services

1000? IoT platforms

Strong market forces!
Partly unregulated areas!

Intricate role of safety cases and gaps



Effective assurance cases – essentials (SCC, SafeComp, AD, SCSSS, …) and challenges

Effective: … actually improving safety, providing useful description for certification and court cases/accidents, adding value to the engineering process

Cost and competition pressure

Human – computer interaction

Requires multi-domain expertise, collaboration and humility

- Human psychology and biases

Methodology, mindset and organization (Robin Bloomfield)

- Systematic and Systemic (Hillary Sillitto)
- Safety culture

Assurance cases in an era of smart and collaborative CPS

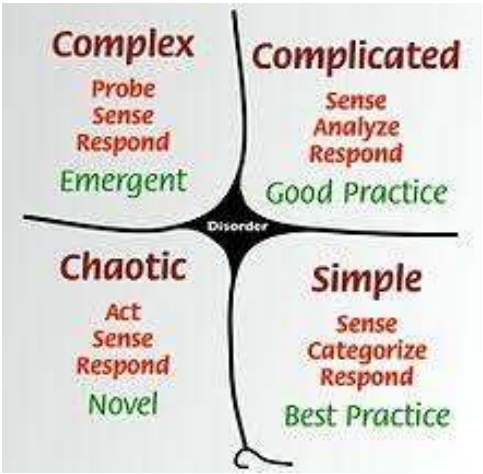
Initial scenarios

Analysis:
Complexity of CPS; Drivers
Effective SC's/AC's

Directions:
Strategy; Complexity;
Barriers and operational risk management

Wrap-up

Systems engineering insights and needs for new methodologies



- ➔ complex environments and uncertainty
- ➔ composability – dependencies, trade-offs and side effects

The Cynefin model

Current level 3 testing for AD/AVs

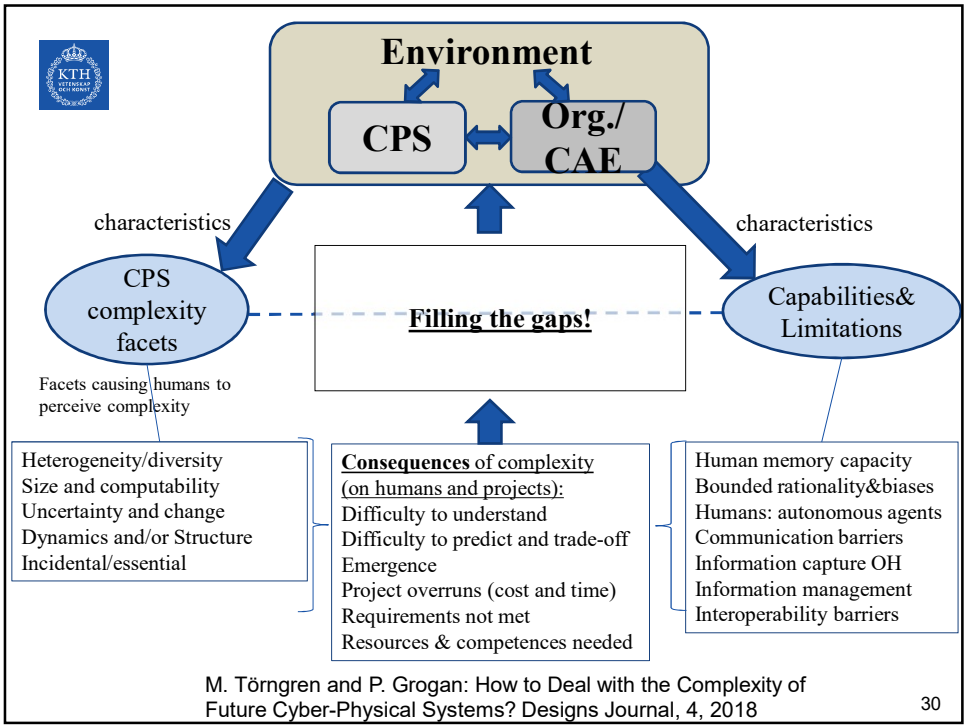
Current tests in the automotive are not well controlled!

Aerospace:

- Simulation, formal methods and rigorous processes.
- Minimizing testing to mitigate risks – Controlled experiments
- **But … safety requires continuous efforts!!!**

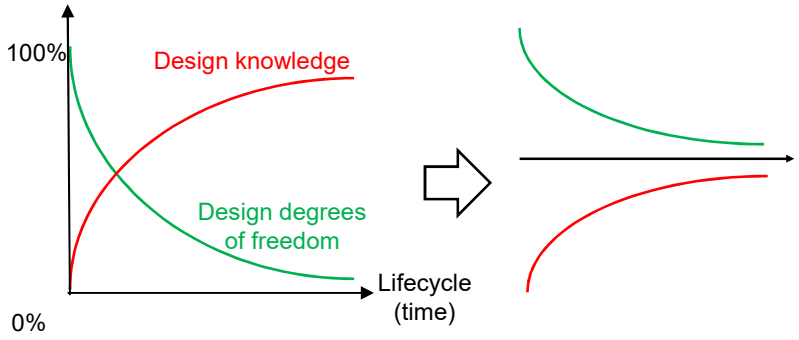
Safety case for level 3 testing (Phil Koopman)

- An AV testing platform with safety driver
- Non fruitful blames: victim, technology, safety driver
- To be expected: Pedestrian on road; Failures; Solo human drop-out
- The better autonomy the more difficult situations!



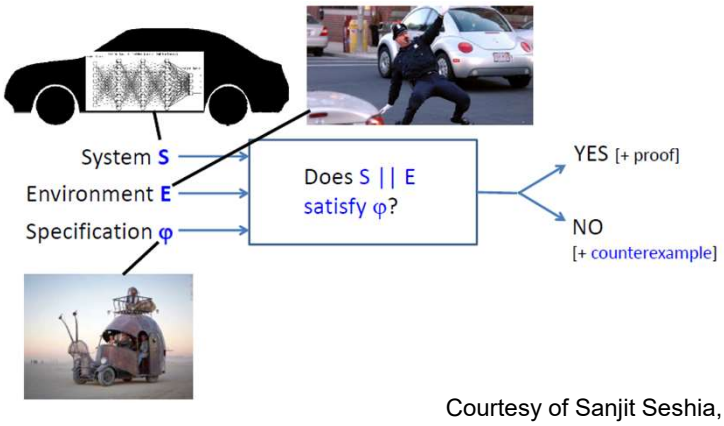
M. Törngren and P. Grogan: How to Deal with the Complexity of Future Cyber-Physical Systems? Designs Journal, 4, 2018

Managing an increasing cone of uncertainty



- **Uncertainties in system and environment**
- **Resilience; fault-tolerance; survivability**
- **Operational management at system and SoS level**

New challenges and opportunities for formal methods



Courtesy of Sanjit Seshia, UC Berkeley

Need for new methods

Abstractions - e.g. smart ways of describing environments, coverage metrics

Systematic uncertainty management; awareness

Platform based design: Supervisor architectures supporting minimal risk conditions

Formal methods, simulation and machine learning

Tools managing heterogeneous, distributed. Interdependent and changing information;

- Multiview modeling and contract based design

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Importance of safety initiatives during a paradigm shift

”Simplicity is complex” (Hermann Kopetz)

- Complexity management; and awareness!
- Architecting and new methods: model-based engineering
- Cynefin: ”Safe” exploration and testing of advanced CPS

Safety cases are non trivial even for current CPS

- Building trust
- The automation paradox is more relevant than ever
- Education and training! Systems thinking!

Leading indicators/metrics

- Risk metrics – and agreements on behaviors at SoS level

Some references for further reading

Martin Törngren and Paul T. Grogan. **How to Deal with the Complexity of Future Cyber-Physical Systems?**, Journal of Designs, Vol. 2, No. 4, 2018

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