

# The inevitable human factor in CPSoS

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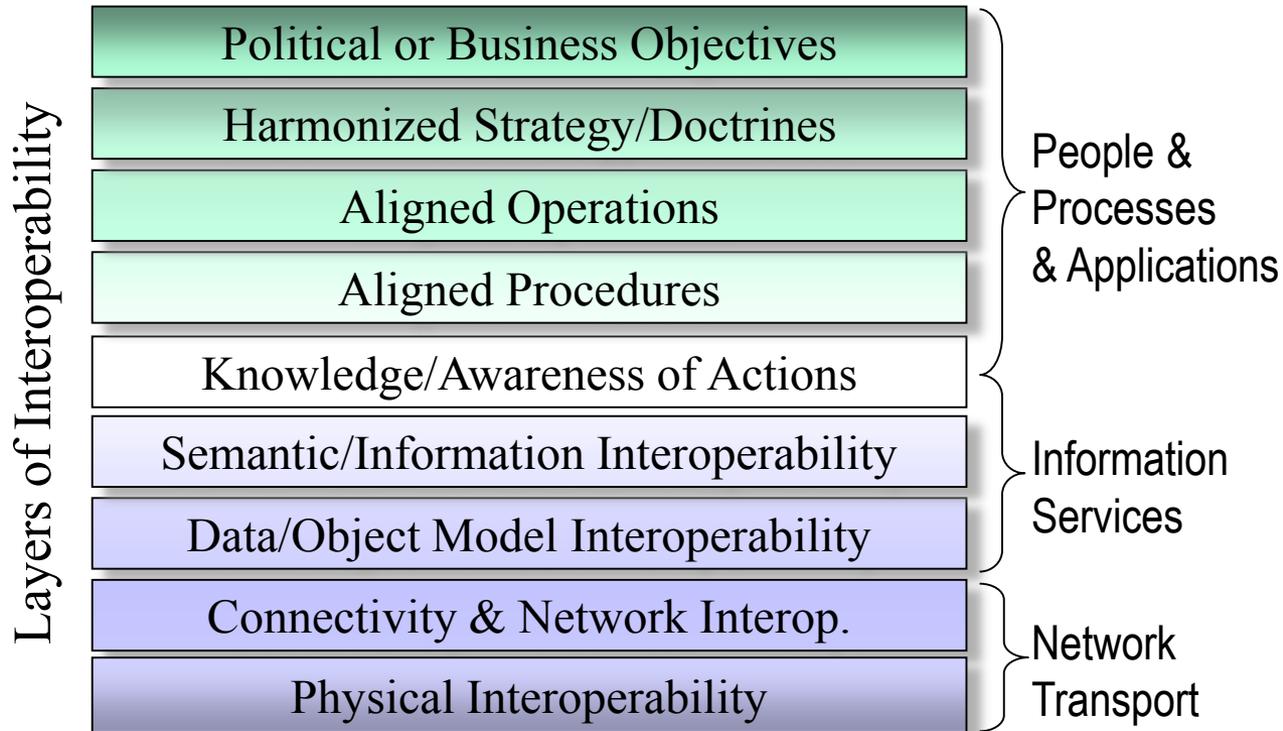
## Three messages

- Humans will be essential within the CPSoS ecosystem for the foreseeable future
- Because CPSoS will reach deep into society, we must engineer socio-technical CPSoS, not just technical CPSoS
- Engineers will deliver these systems; nobody else is competent to do so. This requires added skills and visions

# Contents

- A few fundamentals about humans and their capabilities
- Roles of humans within CPS
- Comments about human-CPS interfaces
- The bigger picture: sustainability
- *All the way through, the emphasis is on the importance of engineers and engineering.*

# NCOIC Interoperability Framework



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## Why do you want people within the CPSoS?

- For functionality; for tasks that are not well-defined, or happen in changing environments, or surprises are likely
- For system resilience, agility, and adaptability in a world of complexity and change; c.f. Heracleitus, BCE 500: “you cannot step in the same river twice”
- For governance, responsibility, & accountability; legal aspects, where CPSoS meet society
- For strategy, social responsibility, and ethical behaviour; appropriate, efficient, effective & robust CPSoS behaviour within society over their lifecycles

# Informed command, consent & situation awareness

- **Informed command:** UK MoD: “the last person to give a command is responsible for the consequences.”
- **Informed consent:** “Yes/No/Wait”, e.g. in response to automated suggestions
- **Situation awareness:** “the perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the prediction of their status in the future.”



## (Re-) Definition of systems (including CPS)

“A community of people,  
pursuing a common purpose,  
supported by a network of peripherals.”

S.V. Deal, 2008

## Significant characteristics of humans

- Evolved over 800 million generations from the first amoeba to what we are today
- Very good at sensing, perceiving and making use of the environment – dangers, patterns, affordances, 'scaffolding'
- Social animals; responsible, emotional intelligence, ethics, team-working and trust
- *Variable; no 2 humans alike – both a strength and a weakness*

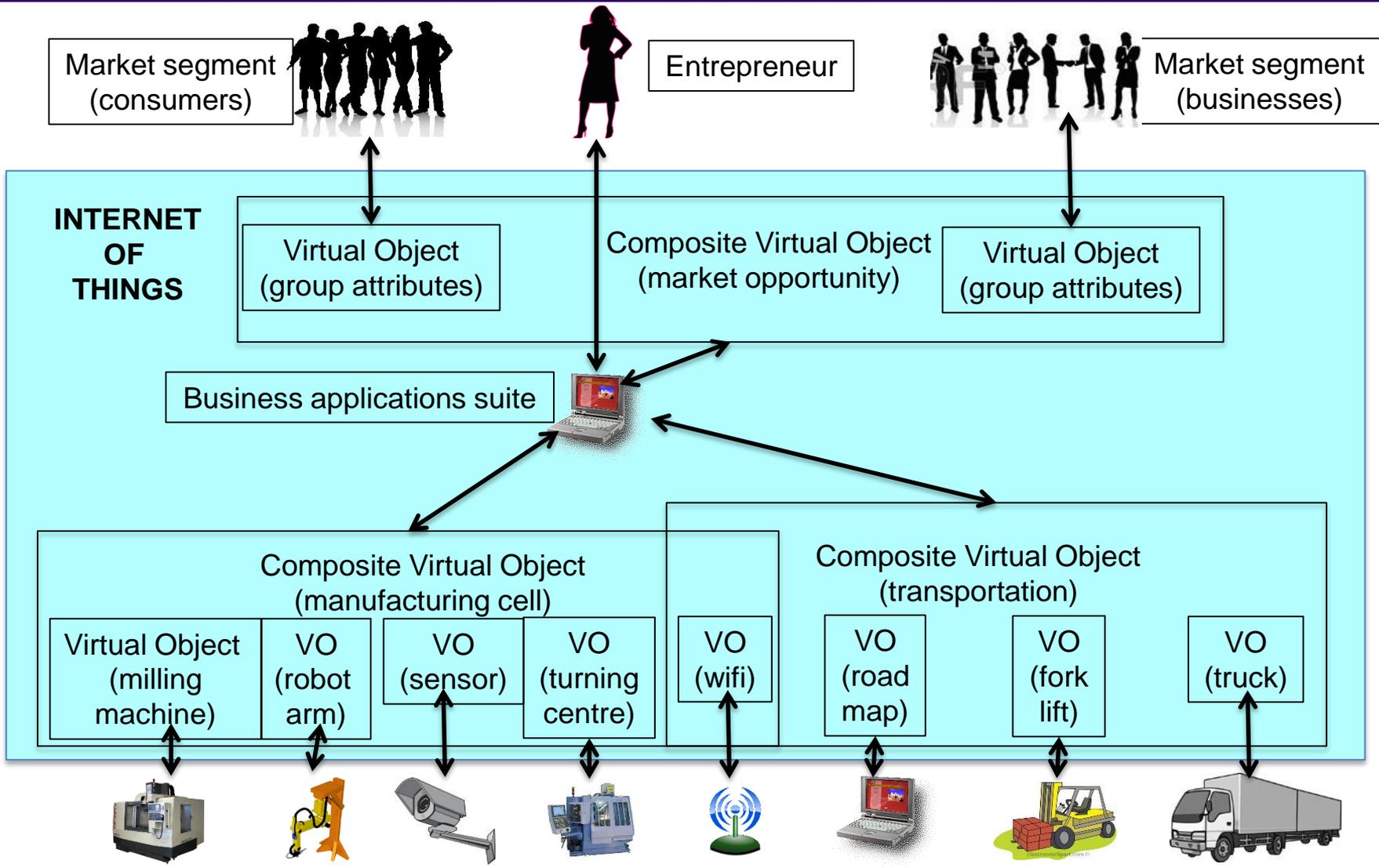
# Human variability and ‘human error’

“In fact, humans differ enormously from machines, in that they are inherently **variable and unreliable in their detailed behaviour**, while simultaneously being **hyper-adaptable and metastable in their overall behaviour** because they perceive and correct their own errors.” *(T.B. Sheridan, 2002)*

- Well-designed jobs to achieve objectives  
*(meaningful tasks, safe operations, satisfying jobs)*
- Education & Training to know processes, to understand constraints and to minimise bad decisions
- Sufficient time to decide and execute actions correctly, and to realise and retrieve wrong actions

**... and the ‘error’ that remains is governance, responsiveness, robustness, resilience, and agility**

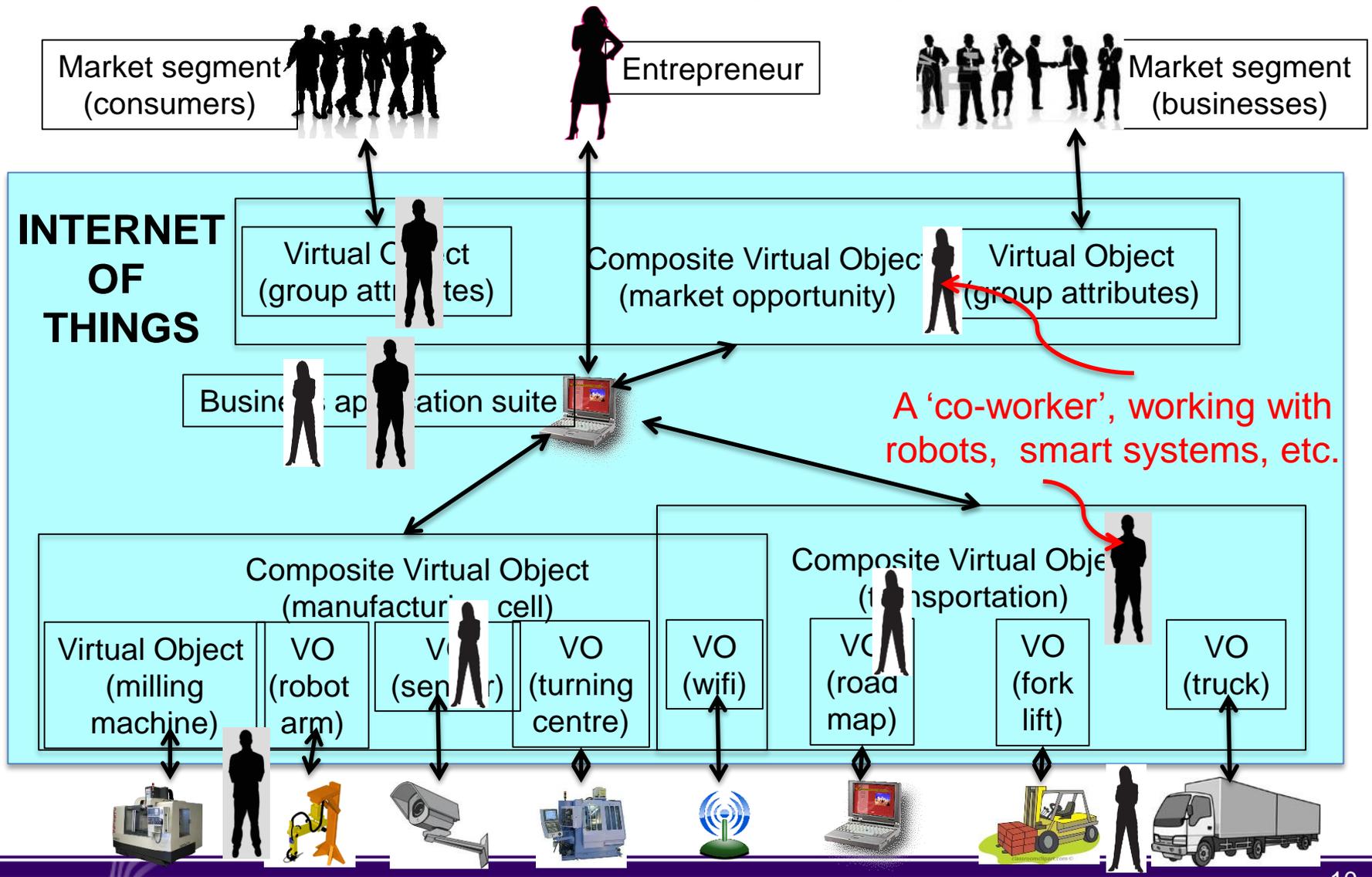
# A manufacturing CPS



## CPS under-performance is possible...

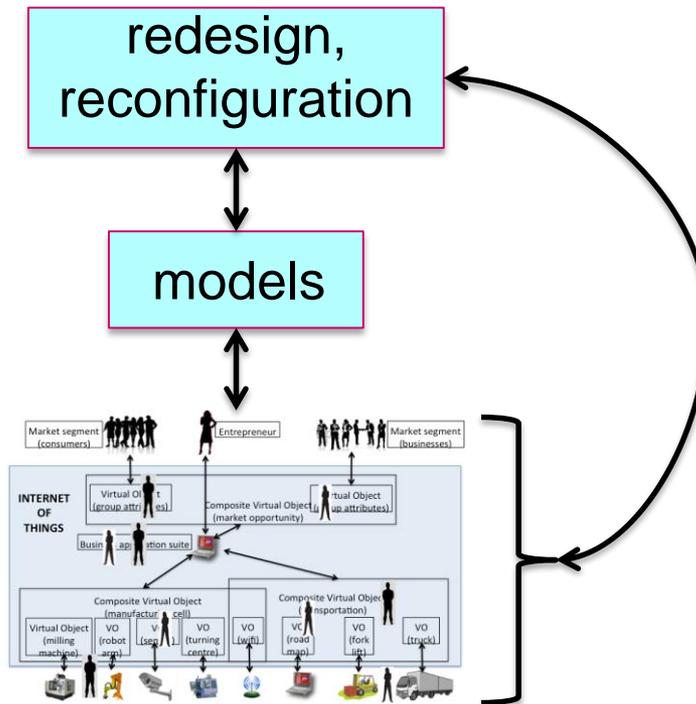
- "... it is worth noting that the findings from Capers Jones and others indicate that deployed software systems contain approximately 0.4 latent faults per function point. To our knowledge, this indicator of dismal [*operational availability*] has improved only about three-fold in the last four decades." (*Ring and Madni 2015*)
- "In one case, we observed an outsourced application with 120 COTS products, 46% of which were delivered in a vendor-unsupported state." (*Yang, Boehm et al. 2005*)
- **"Due to the large scale and the complexity of systems of systems, the occurrence of failures is the norm in CPSoS"** (*CPSoS report D2.4 (2015)*).

# A 'real' Cyber-Physical System

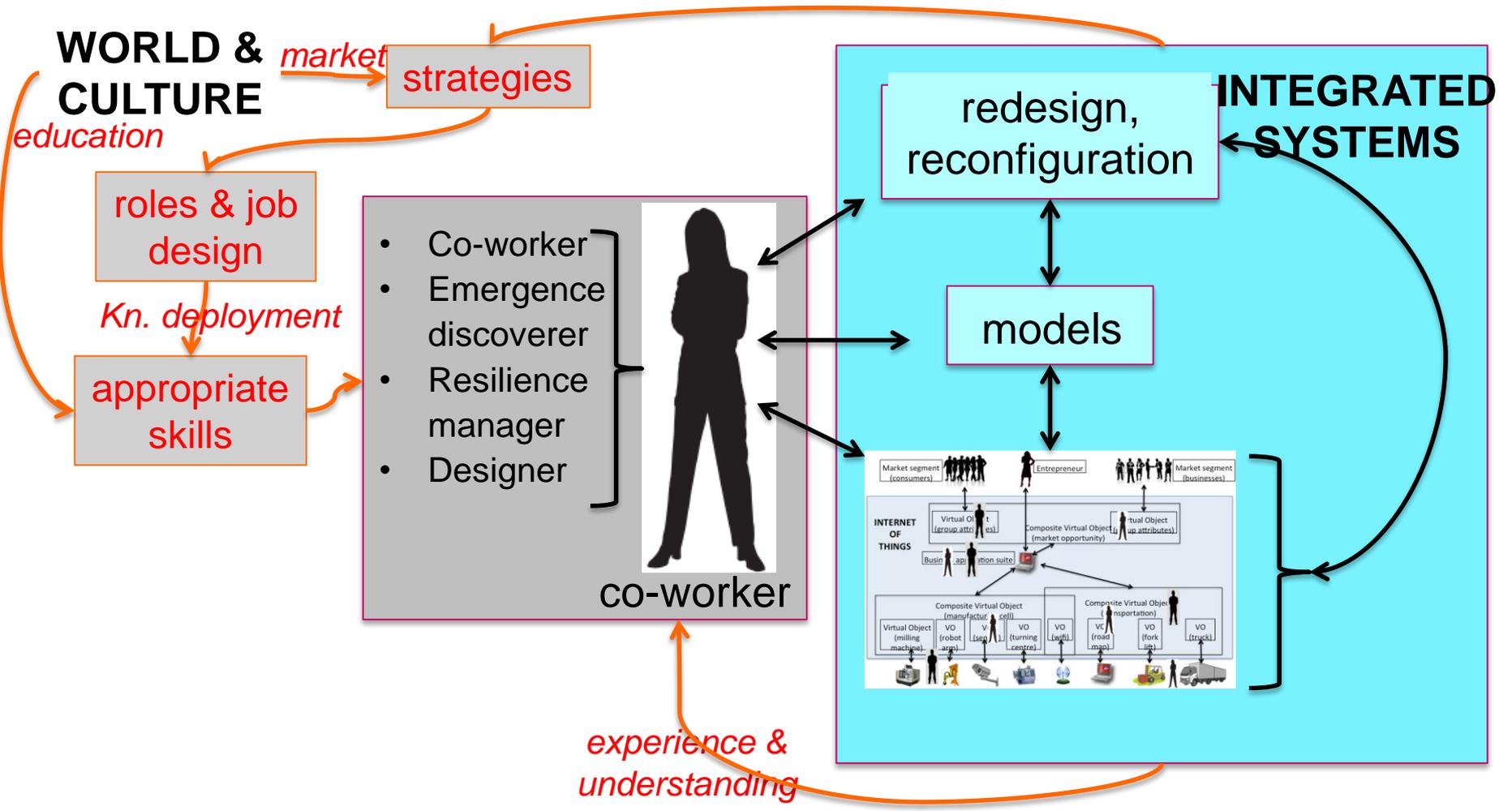


# Model-Based Systems Engineering is necessary

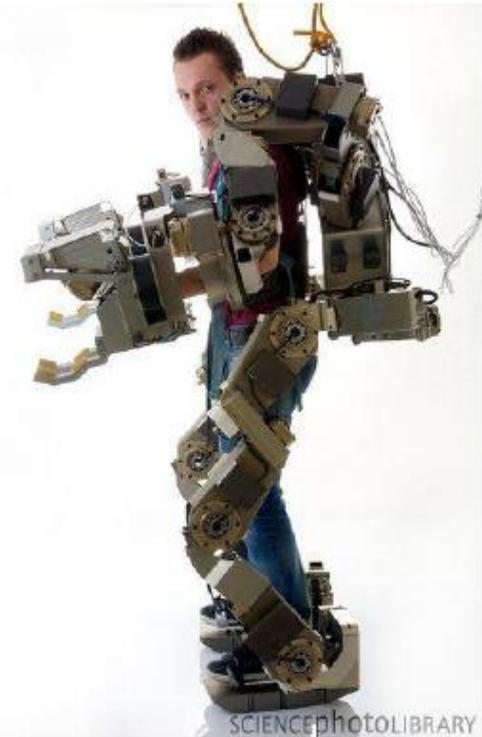
“CPS generally support ... critical processes, making it impossible to turn off the system to make changes ... requiring (re-)configuration, (re-)deployment, (de-)commissioning, update, or enhancement during runtime.”  
*(B. Schätz (2014)).*



# Re-skilling your people for CPS

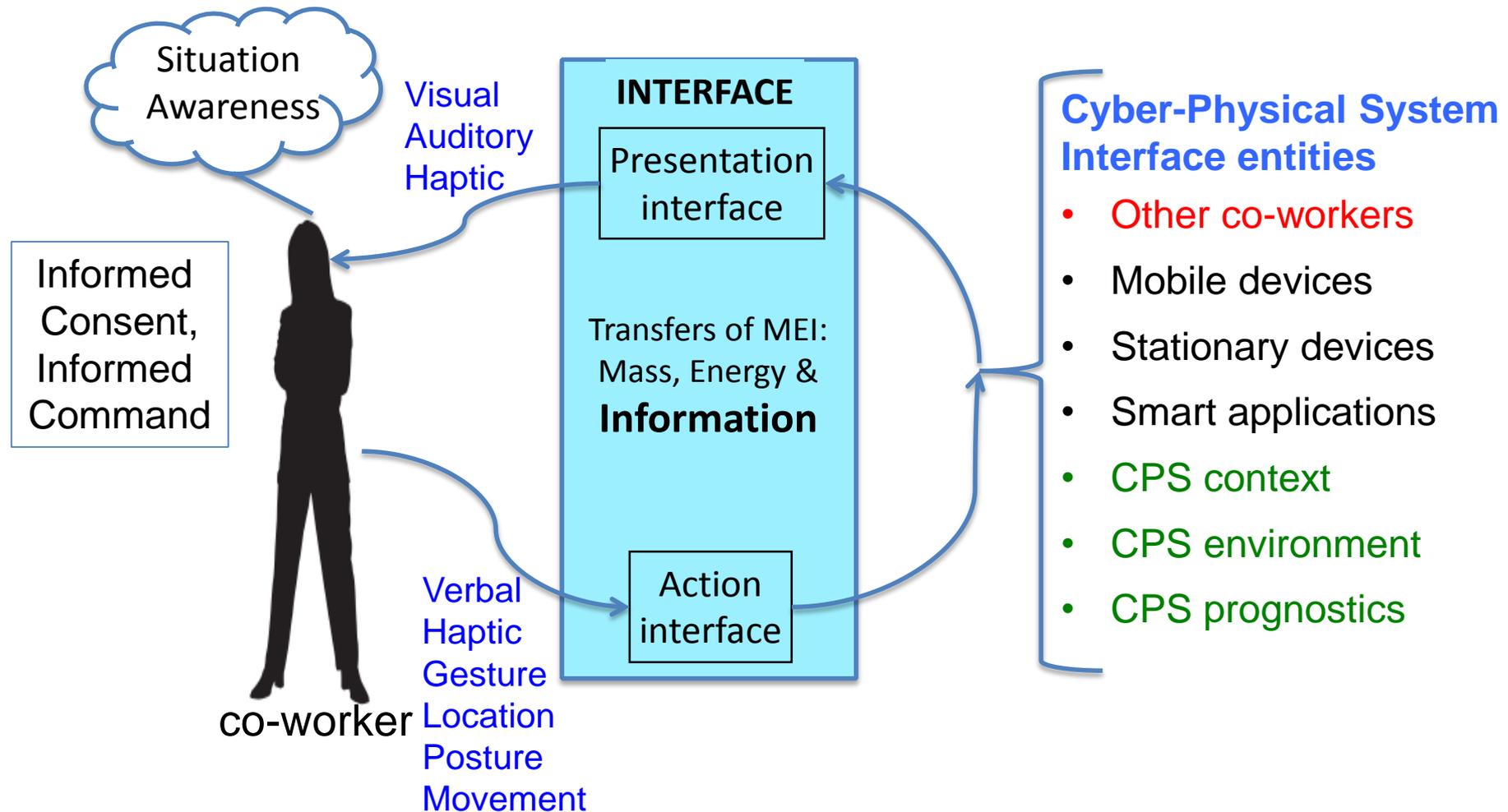


# Co-working with Robots



- Safety standards – different in different countries, also ISO and ANSI
- Sociotechnical systems - Trust is a key issue!
- Setting limits on the level of pain a robot may (accidentally) inflict on a human is a goal of safety standards being drawn up for “collaborative” robots

# Generic CPS interface



# The Co-Worker's questions at the interface

## ■ Awareness questions

- What's happening?
- What isn't happening?
- Why are you telling me this?
- What does this mean?
- Is this answer trustworthy?
- What if ..... ?
- Remind me, how do I find .....?
- Where is ..... ?

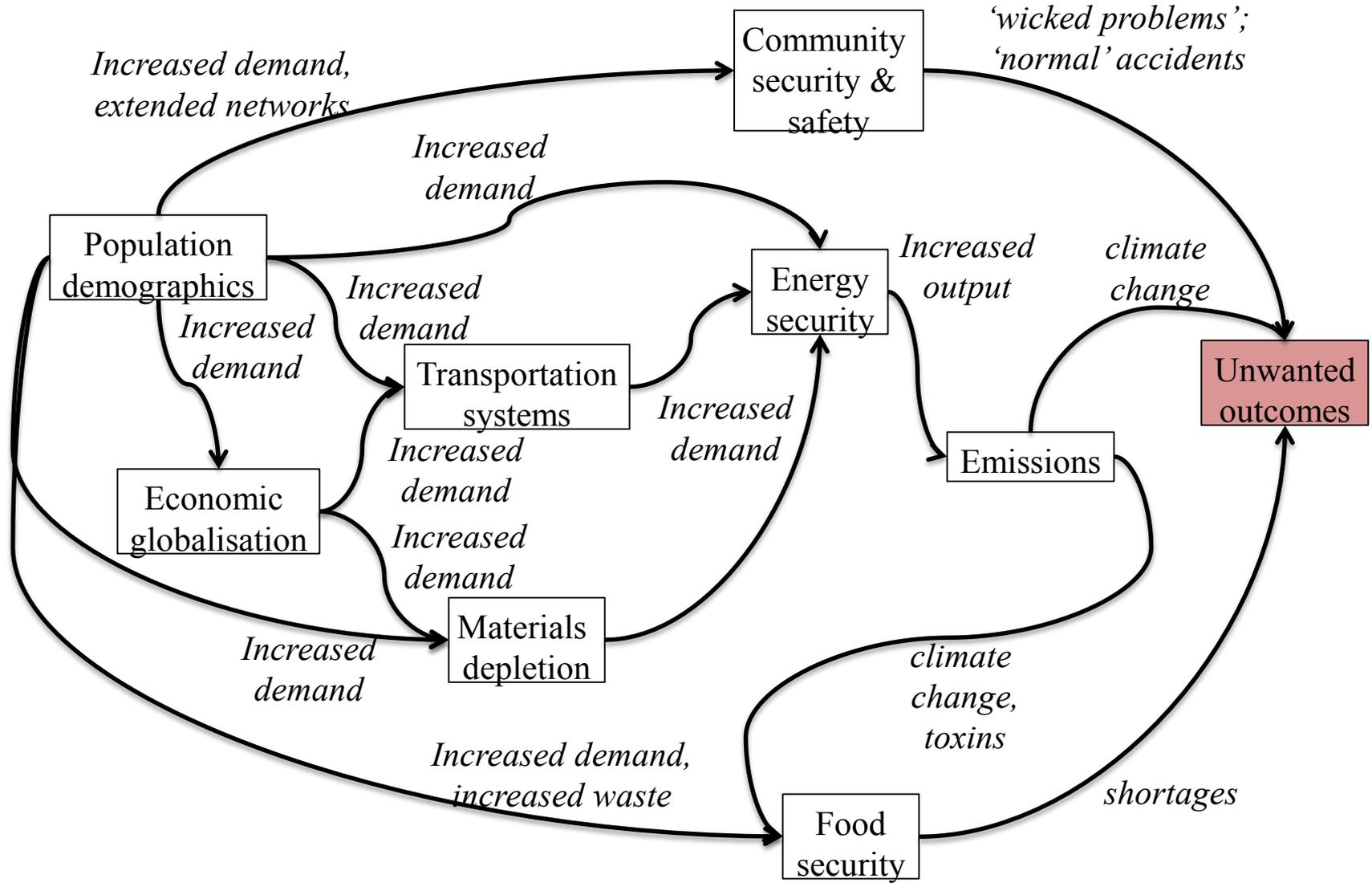
## ■ Action questions

- What did I do?
- How do I undo this?
- How do I change this?
- How do I reach ....?
- What do I do next?
- What can I do next?
- How do I do it?

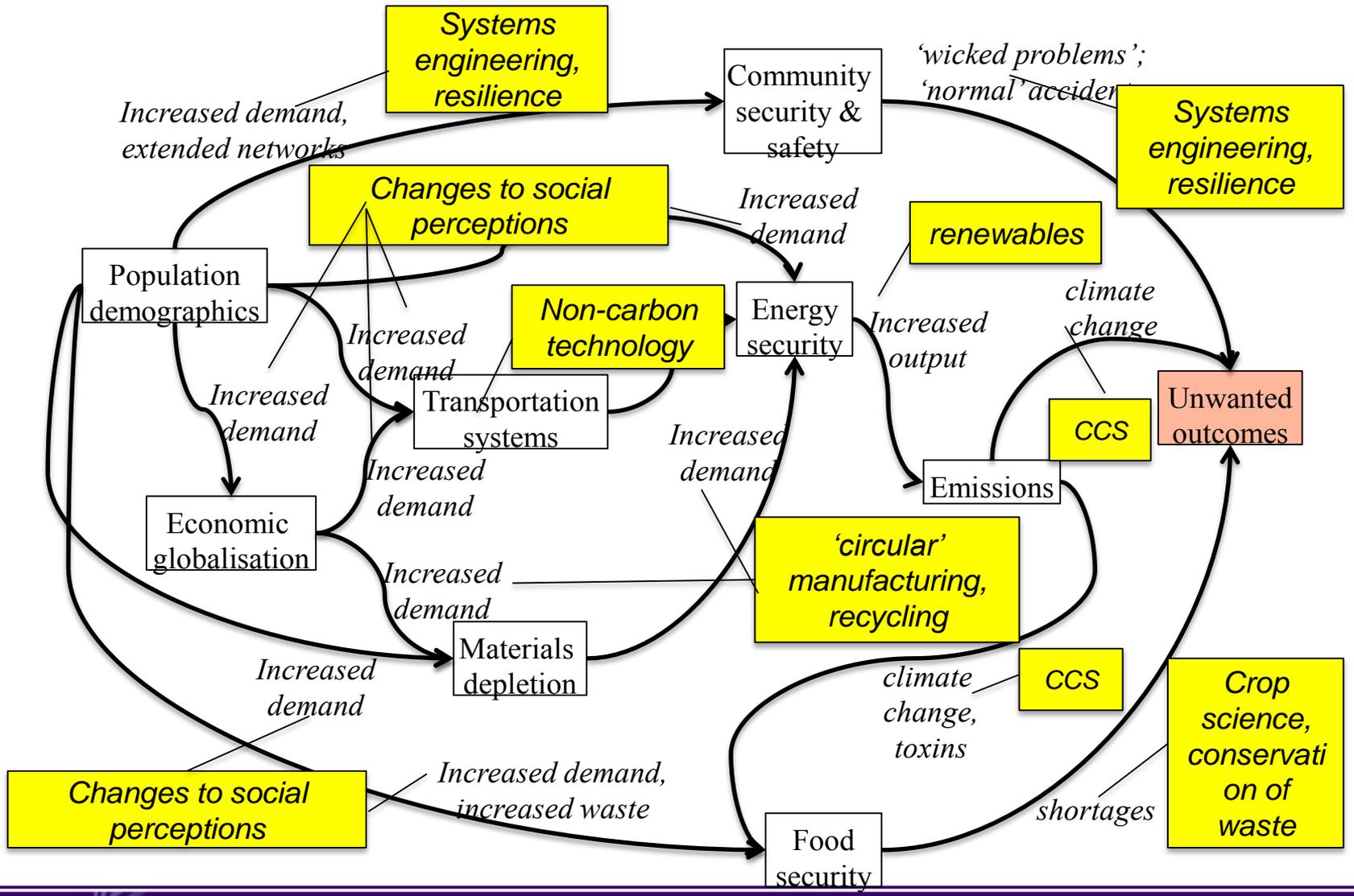
## Global issues, driving change

- Population demographics, especially growth and aging
- Food security
- Energy security
- Resource utilisation and re-utilisation
- Emissions and global climate
- Community security and safety
- Transportation
- Globalisation of economic and social activity

# Negative interactions of Global Drivers



# Integrated mitigation approach to negative effects



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**No more!**