Improving Maintenance Decision-Making in the Finnish Air Force through Simulation

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Simulation for maintenance decision-making

- Project initiated by the Finnish Air Force (FiAF)
  - To assess the effect of maintenance on fighter aircraft availability
  - Peacetime and conflict conditions
- Main outcome of the project
  - Successful construction and validation of a simulation model for maintenance decision-making
  - Overcoming severe scarcity of data
- Detailed description in: Mattila, Virtanen, and Raivio, "Improving Maintenance Decision-Making…", *Interfaces,* 38(3),2008

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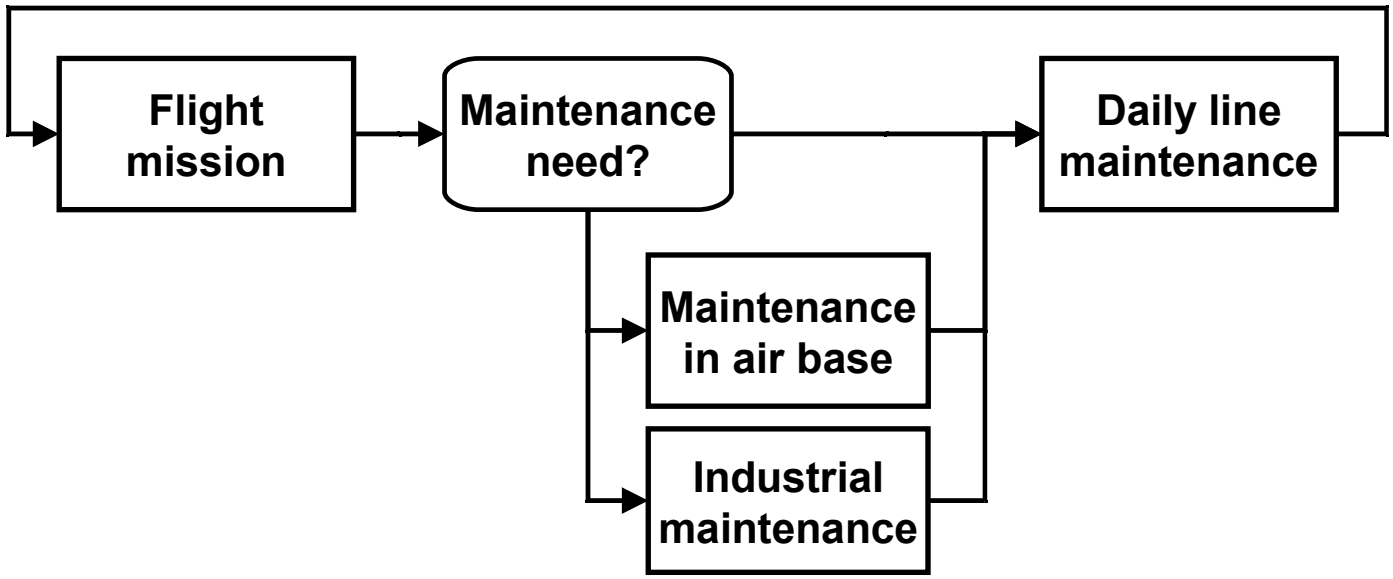
Fighter aircraft maintenance in FiAF

- Fleet of 62 fighter aircraft
- Maintenance
  - Many items including daily line maintenance, periodic maintenance, failure and damage repairs
  - Nearly 1000 people involved
  - The time of activities well exceeds the number of flight hours
  - A complex system with uncertainty

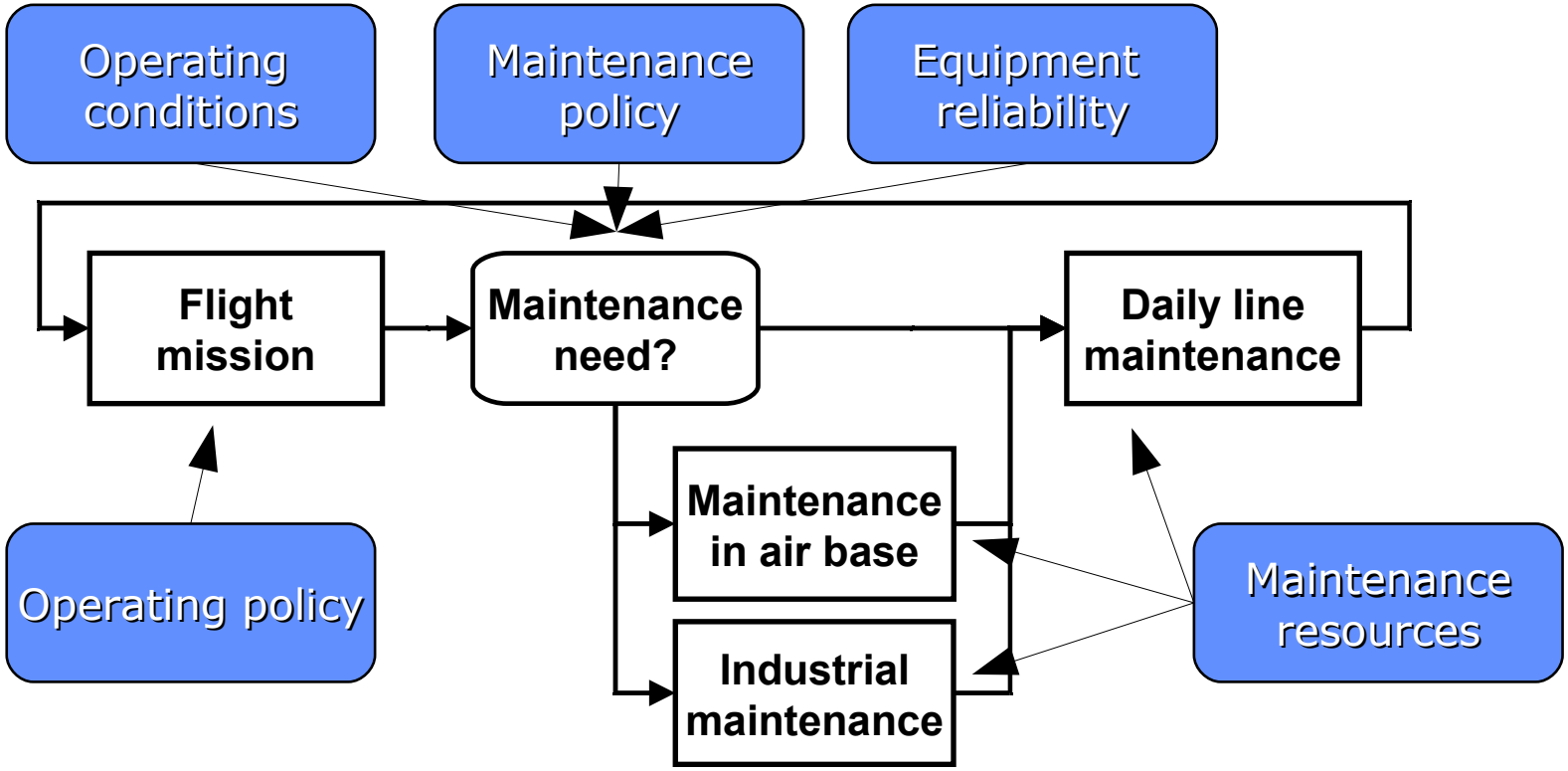
⇒ Difficulty of foreseeing effects of maintenance-related decisions

⇒ Need for modeling

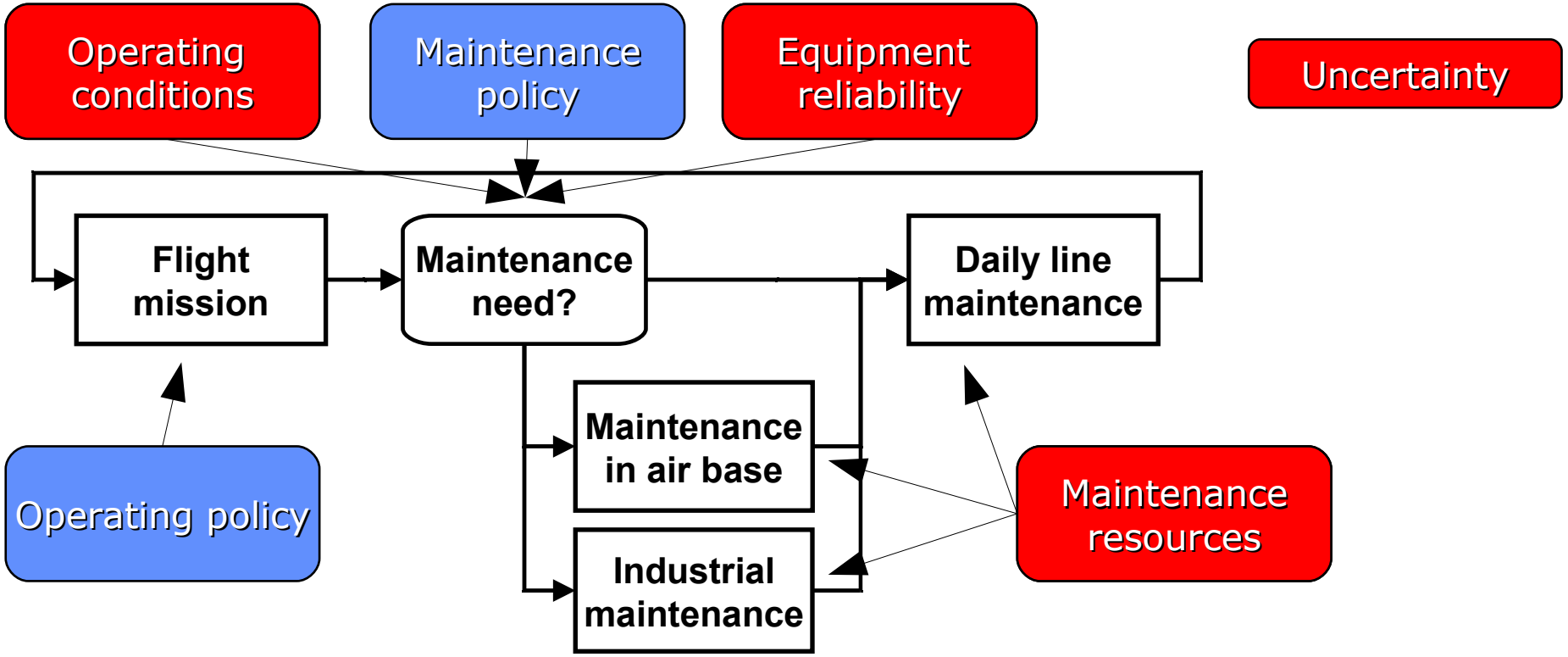
Discrete-event simulation of aircraft maintenance and usage



Discrete-event simulation of aircraft maintenance and usage



Discrete-event simulation of aircraft maintenance and usage



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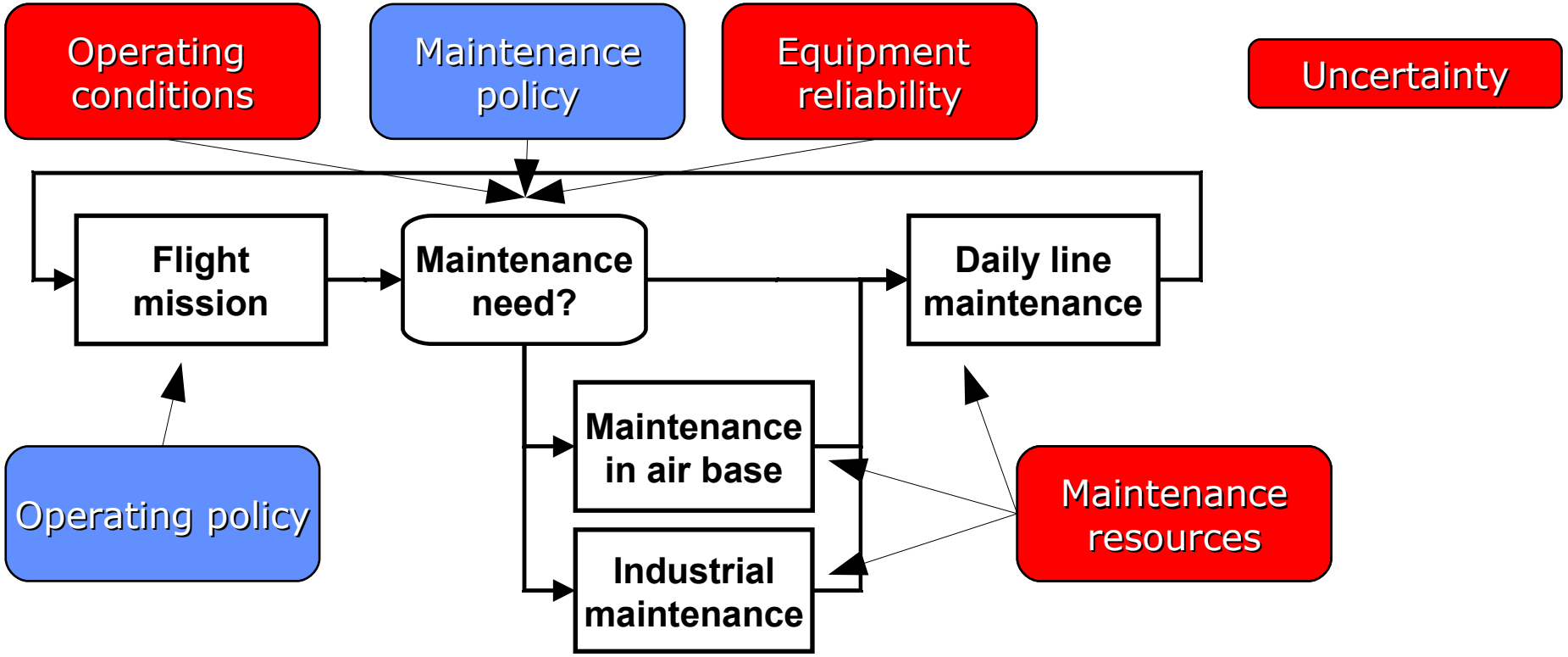
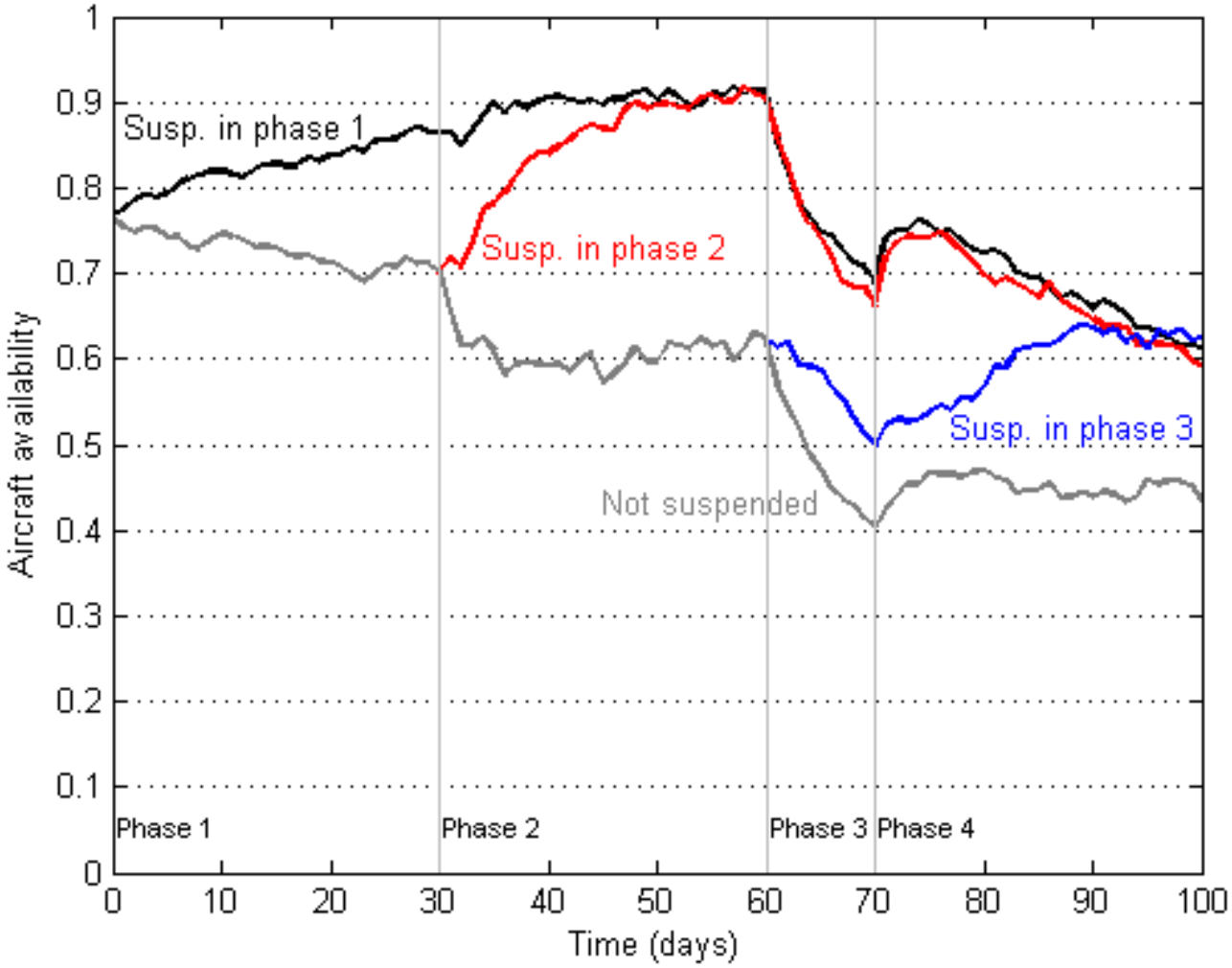


⇒ **Aircraft availability: the fraction of mission-capable aircraft in the fleet**

Example analysis of a conflict scenario

- Suspending periodic maintenance during a conflict
  - Releases aircraft to flight missions under heavy demand
- Phases of the conflict
  1. ”Increased flight intensity”
  2. ”Maintenance units decentrelized to remote air bases”
  3. ”Engagements with enemy”
  4. ”Decreased flight intensity”
- 4 alternative courses of action
  - Suspend either at the beginning of phase 1, 2 or 3 or do not suspend

Simulation results



Scarcity of data in model construction and validation

- Non-existent data
  - Historical data on battle damage rates
- Confidential data
  - Estimates of battle damage rates based on training data
- Confidential subject matter expert knowledge
  - Experts' assessments of expected battle damage rates

Overcoming data scarcity under confidential expert knowledge

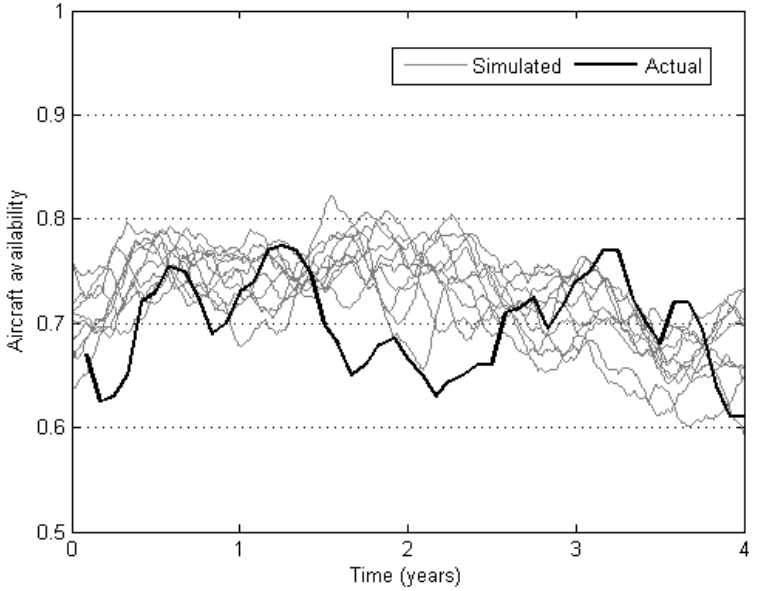
- Expert-assisted construction of model components
  - Components consist of
    - Fixed structure
    - Structure controlled by input data
  - Construction of components based on goals of analyses and underlying assumptions on a rough level defined by experts
  - Confidential knowledge not needed
  - Shift from describing an actual system to defining right model functionality

⇒ Confidential knowledge could be isolated to input data

⇒ Confidential analyses performed independently by FiAF

Model validation under scarcity of data

- Limited amount of 'traditional' validation
  - Based on peacetime data of training aircraft
- Validation through expert training
  - Simulation methodology and model features
  - Aimed to facilitate careful assessment of presented assumptions and results
  - Aimed to assure the validity of analyses produced independently by experts
  - The experts' forecasts of aircraft availability supported the validity of the model



Observations from expert involvement

- Necessary to have diversity of experts
  - Underlying system large and multifaceted
  - Experts contributed in different ways
  - Some could point out a missing detail during a very short involvement
- Promoted practical use of the model
  - Model targeted for many levels of FiAF: headquarters, air commands...
  - Grew understanding as well as acceptance of the model
  - Promotion made the model more likely to be actually used
- Facilitated conversation and innovation among experts

Conclusions

- Outcomes of the project
  - New knowledge of successful completion of simulation projects in FiAF
  - Insight into ways of dealing with scarce data
  - A simulation tool actually used in maintenance decision support
    - Feasibility of modified periodic maintenance programs
    - Resource requirements for international operations
  - Advanced application of simulation in FiAF maintenance and logistics
  - New insights for involved subject matter experts
- Current research includes a multi-objective simulation-optimization approach for scheduling of periodic maintenance