

On the use of Artificial Intelligence for Product-Service Systems

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PLAN

1	What are Product Service Systems (PSS)?	
2	PSS Engineering issues	
3	PSS Engineering and AI	
4	Conclusion	



Global context – trends & challenges

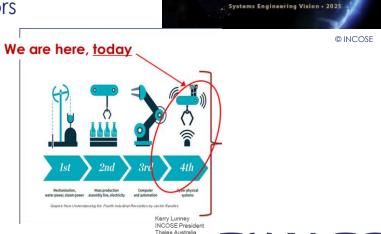
Volatile, uncertain, complex and ambiguous world...

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➤ The Covid-19 pandemic, Ukraine... and their consequences are very tangible examples



- ➤ New players customers, providers, competitors
- Market growth spread world-wide
- Emerging societal needs & constraints
- Accelerated evolution of technology



Building a future we can all trust

Why Product-Service Systems (PSS)?

Societal needs & trends

- Desire for simpler, environmentally-friendly, adaptable and easier-to-use products
- Growth of shared or collaborative economy
- New ways of working: work from home, distant-collaborative engineering

Changing business contexts

Commoditization of products, market saturation, large installed base

Greater responsibility for products use and at end of life

Customers shifting from CAPEX to OPEX

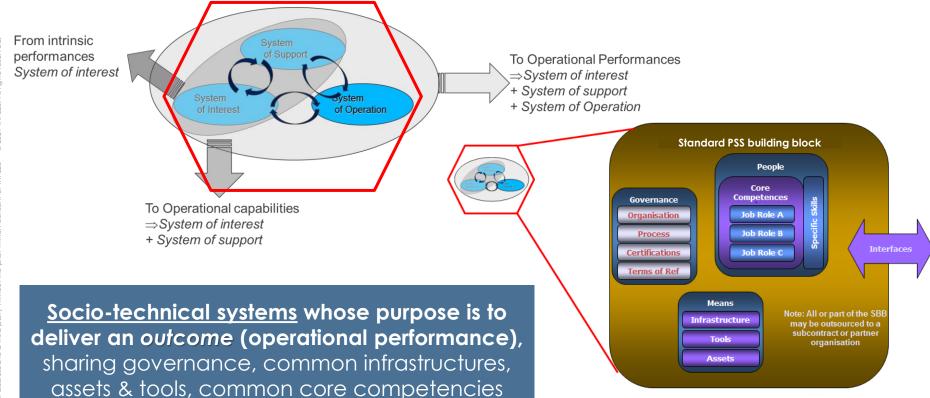
Industry	Margins in Product Business	Margins in Service Business	
Machine tools	1 – 12%	5 – 15%	
Paper machines	1 - 3%	10 – 15%	
Power equipment	2 – 5%	15 – 20%	
Rail vehicles	3 – 6 %	8 – 10%	

Monitor Group 2004

Moving towards service-oriented businesses and offers looks like a "logical" move



What are PSS and PSS Product Lines?

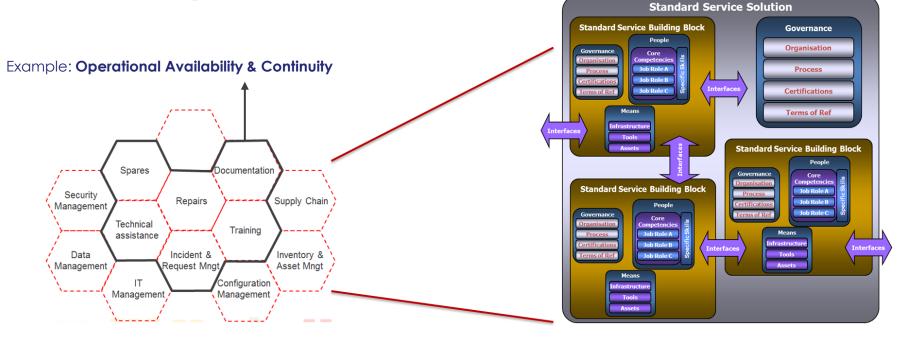


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Building a future we can all trust

Engineering PSS and PSS Product Lines

PSS building blocks configured, assembled and composed to obtain different emergent service capabilities





Specific PSS Engineering issues

Deeper consideration of organizational and human aspects

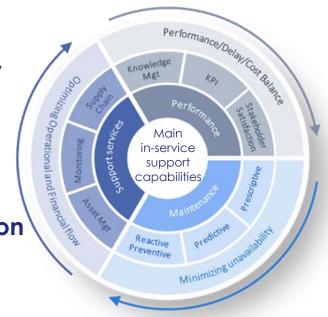
➤ Procedures, languages, cultures, <u>knowledge</u>, capabilities and skills needed to

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develop PSS

Emphasis on customers' business & operational performance, <u>and</u> profitability of the PSS provider

- Requirements: expected capabilities, services
- Measures of effectiveness
 - > SLA, pricing metrics vs customer satisfaction
- Slightly different focus of verification and validation
 - > Operational feasibility and usefulness
 - Effectiveness of support to customer operational and business performance





PSS Engineering and AI – what for?

- Reusing and sharing knowledge >> Paramount for PSS PL
 - Experience-based knowledge
 - ➤ Knowledge captured in design documents, Product Data Management or Product Life-cycle Management (PDM/PLM) systems...
- Knowledge as the foundation of digital threads supporting the architecting, design and operation of PSS

PSS Ontologies

share domain concepts, reuse information from many sources encode explicitly PSS knowledge improve collaboration

avoid uncertainty & ambiguities

NLP & FIS/ANFIS

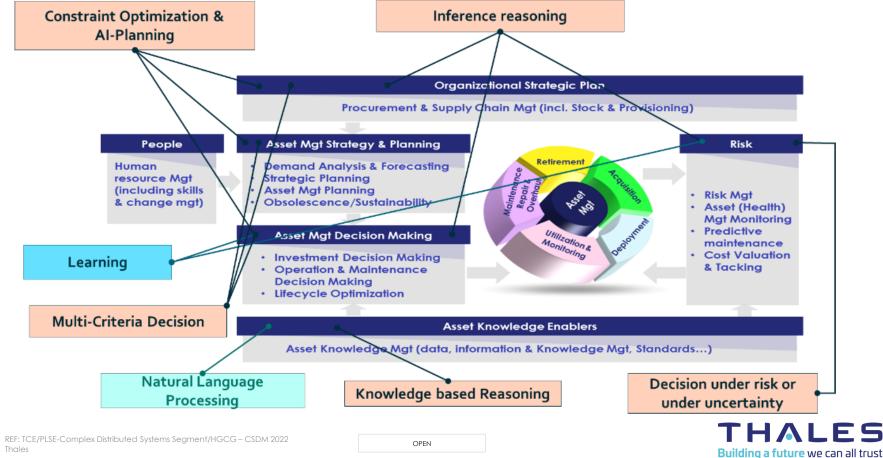
Knowledge graphs

increase (re)use of knowledge from design & operations reduce time and effort to configure a new PSS

Knowledge-based AI can improve knowledge management processes in an enterprise



Al for Asset Management



Al to support Maintenance

Reactive Maintenance is performed when equipment has failed Fault Detection Mathematical and Physical Model Kalman filters · Particle filters a.k.a. Sequential Monte Carlo method Physical Models · Feature selection & extraction · Multi-sensor fusion Statistical decision theory Bayesian hypothesis testing Petri nets Symbolic AI Decision Trees Abductive Reasoning Data Driven Al Pattern matching Data Correlation Artificial Neural Network

Preventive Maintenance is performed regular on equipment to reduce probability of failure Diagnostics Symbolic Al Fault Trees Graph Mining Semantic information fusion Rules based Techniques Case based Reasoning · Knowledge based Reasoning · Pattern of Life Behavioral Analysis Data Driven Al Statistical pattern recognition (PCA, kNN...) Artificial Neural Network

Support Vector Machine

· Reinforcement Learning

Few-shot learning

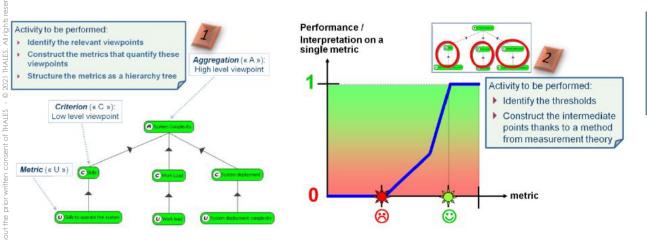
Predictive Maintenance is performed before equipment failure using predictive insights **Prognostics & RUL** Symbolic AI · Reliability prediction Nonlinear dynamics Online Situation Recognition (CEP) · Case based Reasoning Adaptive Neuro-fuzzy inference Data Driven Al · Time series analysis & regression Deep Learning · Recurrent Neural Network Convolutional Neural Network Bayesian Network (Hidden) Markov Models · Reinforcement Learning

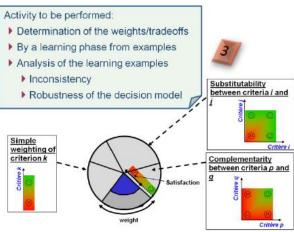
Low-shot deep learning

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Prescriptive Once failure is predicted, solutions are provided to identify what action to take to improve the outcome **Monitoring & Decision** Symbolic Al Operation Research (logistics, planning, scheduling...) Meta-Heuristics Bayesian Optimization Sensitivity Analysis · Game-Based Asset management · Reasoning by analogy · Multi Criteria Decision Decision under risk Data Driven Al · Genetic Algorithms · Reinforcement Learning Graph Embedding

Al for Performance-based contracts





Myriad© to support performance-based contracts



Conclusions

- Architecting and designing Product-Service Systems are often confronted to uncertainties because of the complex nature of the needs and requirements elicitation processes of performance-based contracts, for which traditional requirements development approaches are reaching their limits
- Data-driven and knowledge-based AI can help streamline the entire PSS life cycle by making up-to-date information readily accessible and by supporting complex problem solving
 - Better PSS design and improved global quality
 - Predictive market trending through forecasting analytics
 - ➤ Identification of relevant manufacturing technologies
 - > Optimization of the overall production flow, through automation of operations
 - > Self-learning to detect anomalies and fix them through knowledge-based AI even before the PSS is deployed.



- Asset Management, Supply Chain Management, Total Quality Management, Total Production Maintenance... it is becoming difficult to optimize all MOE's and to anticipate, diagnose and control serious abnormal events in a timely manner
- Al brings to organizations the opportunity to move towards outcome-based commitments, pricing and contracts by using data-driven and symbolic Al algorithms
- Al can reinvigorate productivity and contribute to reducing service downtime of PSS
- By applying AI methodologies and tools, engineers can benefit from a certain automation to detect and fix failures or problems within the PSS, and reconfigure or adjust them efficiently throughout the PSS life cycle





