SERVICE ORIENTED ARCHITECTURE - INDUSTRIAL BENEFITS AND USAGE

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Escalating complexity of software

- 1B lines of code in product is reality
- Test complexity increases exponentially

- Reuse of components increases rapidly

- Software update along the lifecycle becomes a “daily” issue
  - Bugs
  - Changing requirements

- Engineering processes becomes immensely complex

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Escalating complexity in data sharing

- Software complexity becomes part of data sharing in value networks
- Millions of data model used in complex data sharing value networks
- Data model interoperability is low
- Data annotation is a growing problem

Modularization to reduce engineering and operational complexity

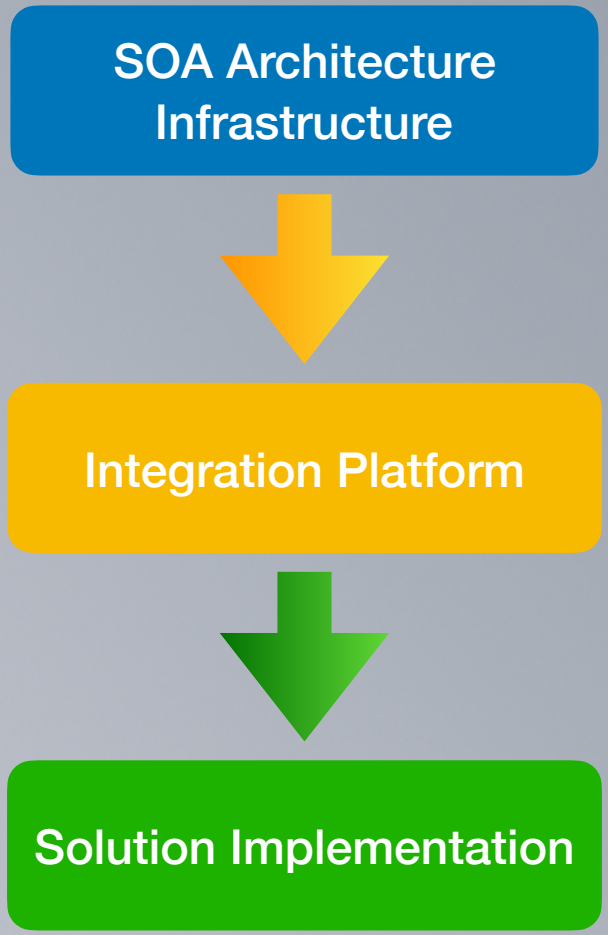
- Most cyber physical systems can be sub-divided
  - Functional relationships based on time, distance, security, safety …

- Cyber modularization is needed at multiple levels e.g.
  - Functional
  - Operational
  - Stakeholder

SOA - microservice architecture

- Enabling SOA fundamentals
- Enables modularization based on microsystem
- Enables microservice interaction between microsystems)
- Enabler of SoS properties
- SOA Local Clouds enabler of isolation

MICROSERVICE ARCHITECTURE AT THE EDGE



Edge integration with IT SOA approach

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IT/OT architectures

Features	Arrowhead	AUTOSAR	BaSyx	FIWARE	IoTivity	LWM2M	OCF
Key principles	SOA, Local Automation Clouds	Runtime, Electronic Control Unit (ECU)	Variability of production processes	Context awareness	Device-to-device communication	M2M, Constrained networks	Resource Oriented REST, Certification
Real-time	Yes	Yes	No	No	Yes (IoTivityConstrained)	No	No
Run-time	Dynamic orchestration and authorization, monitoring, and dynamic automation	Runtime Environment layer (RTE)	Runtime environment	Monitoring, dynamic service selection and verification	No	No	No
Distribution	Distributed	Centralize	Centralize	Centralize	Centralize	Centralize	Centralize
Open Source	Yes	No	Yes	Yes	Yes	Yes	No
Resource accessibility	High	Low	Very low	High	Medium	Medium	Low
Supporters	Arrowhead	AUTOSAR	Basys 4.0	FIWARE Foundation	Open Connectivity Foundation	OMA SpecWorks	Open Connectivity Foundation
Message patterns	Req/Repl, Pub/sub	Req/Repl, Pub/sub	Req/Repl,	Req/Repl, Pub/sub	Req/Repl, Pub/sub	Req/Repl	Req/Repl
Transport protocols	TCP, UDP, DTLS/TLS	TCP, UDP, TLS	TCP	TCP, UDP, DTLS/TLS	TCP, UDP, DTLS/TLS	TCP, UDP, DTLS/TLS, SMS	TCP, UDP, DTLS/TLS, BLE
Communication protocols	HTTP, CoAP, MQTT, OPC-UA	HTTP	HTTP, OPC-UA	HTTP, RTPS	HTTP, CoAP	CoAP	HTTP, CoAP
3rd party and Legacy systems adaptability	Yes	Yes	Yes	Yes	No	No	No
Security Manager	Authentication, Authorization and Accounting Core System	Crypto Service Manager, Secure Onboard Communication	--	Identity Manager Enabler	Secure Resource Manager	OSCORE	Secure Resource Manager
Standardization	Use of existing standards	AUTOSAR standards	Use of existing standards	FIWARE NGSI	OCF standards	Use of existing standards	OCF standards

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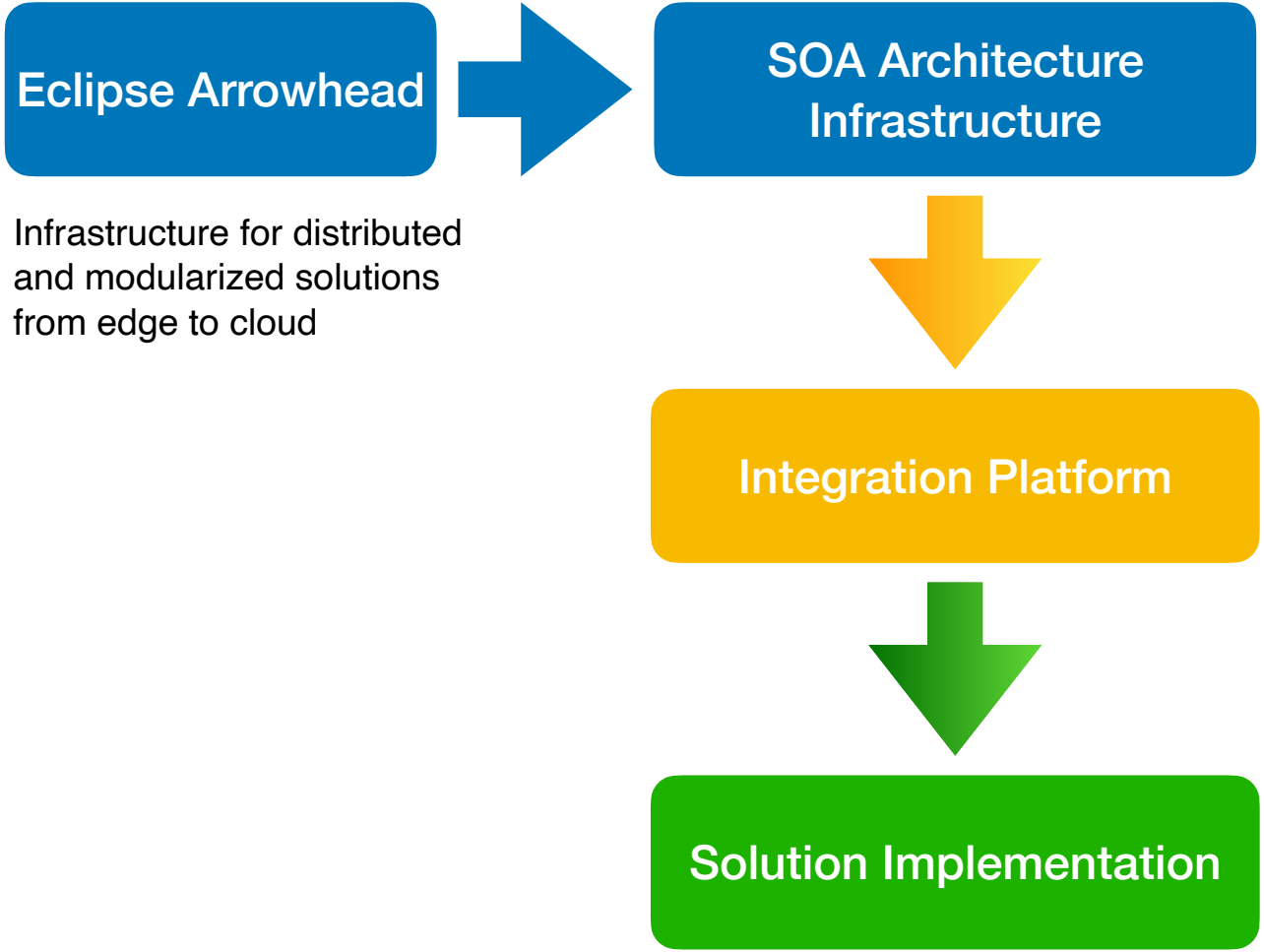

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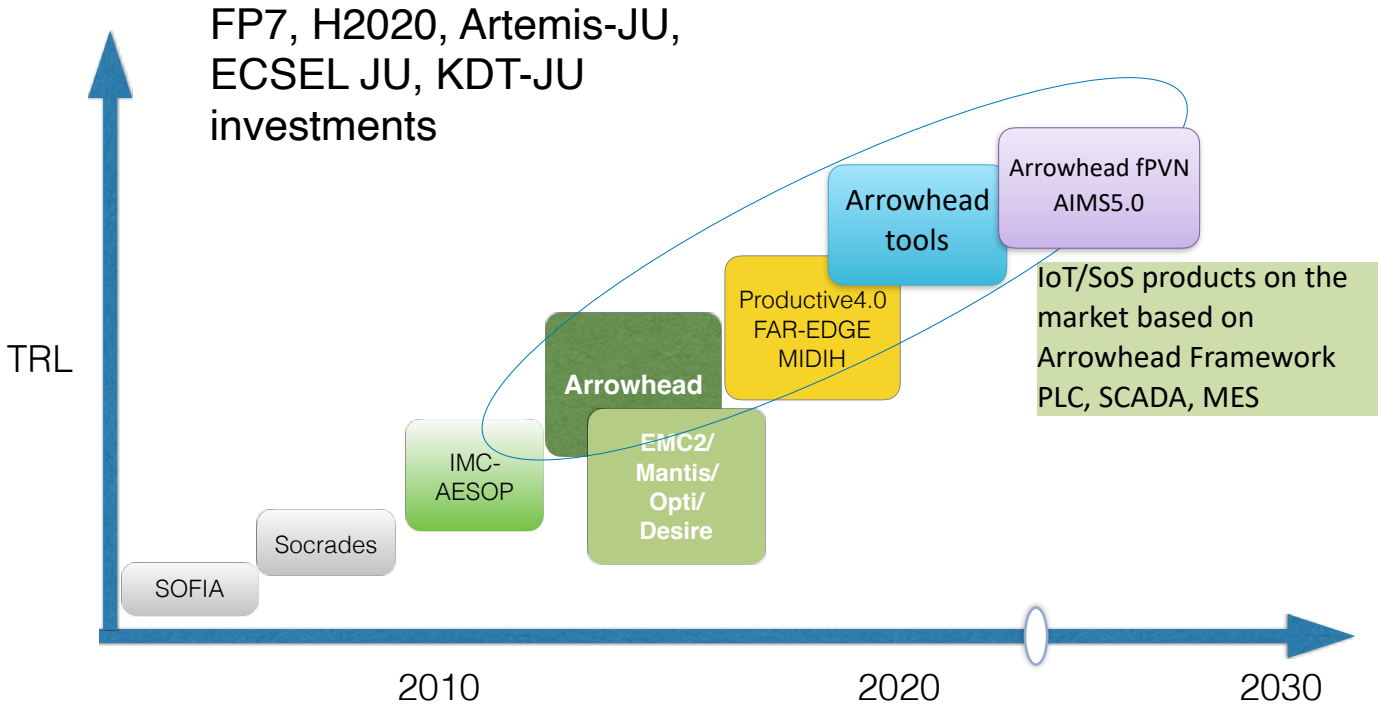
Eclipse Arrowhead

An open source
edge SOA architecture infrastructure

IoT/SoS and Industry 4.0/5.0 project time line



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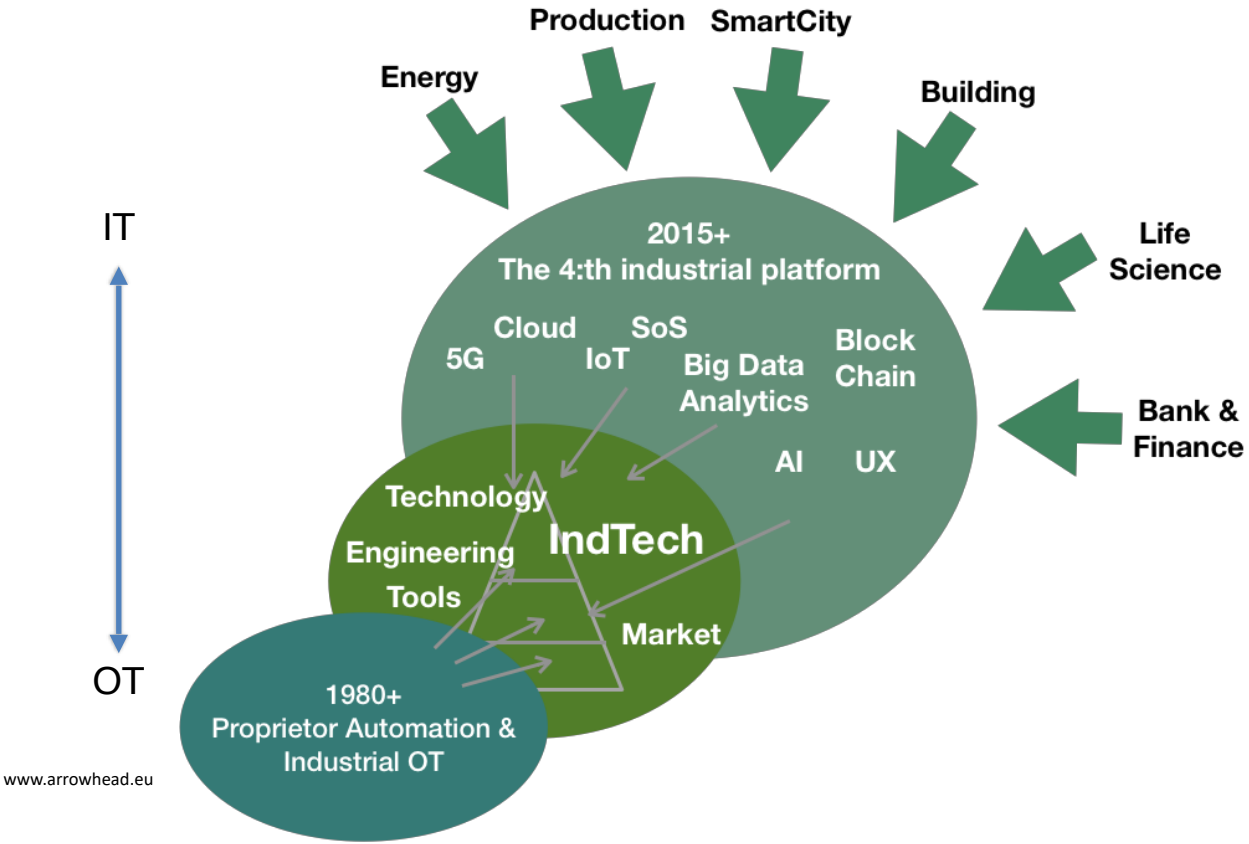
TARGETS FLEXIBLE DIGITALIZATION and AUTOMATION
OT meets IT



www.arrowhead.eu

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Based on industry automation requirements

- Real time
- Scalability
- Robustness
- Engineering efficiency
- Security to the edge
- Safety
- Open standards
- Interoperability - protocol, physical layer
- Light weight - feasible for the edge
- Highly distributed
- Data sharing
- ….

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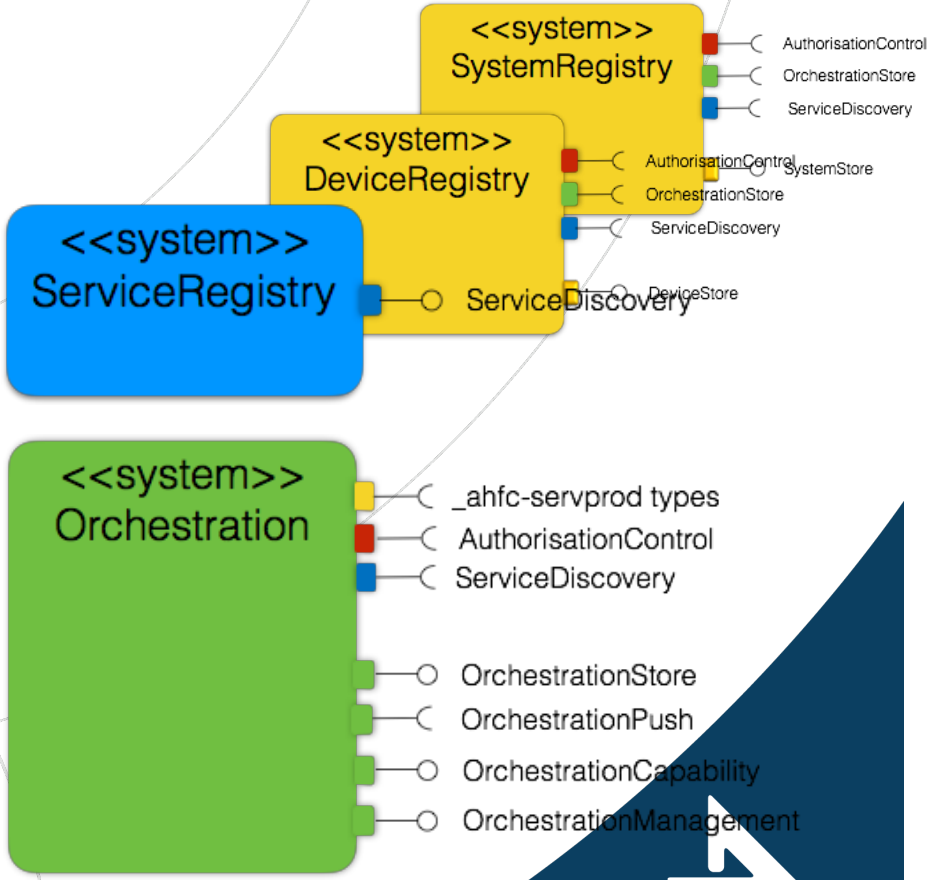
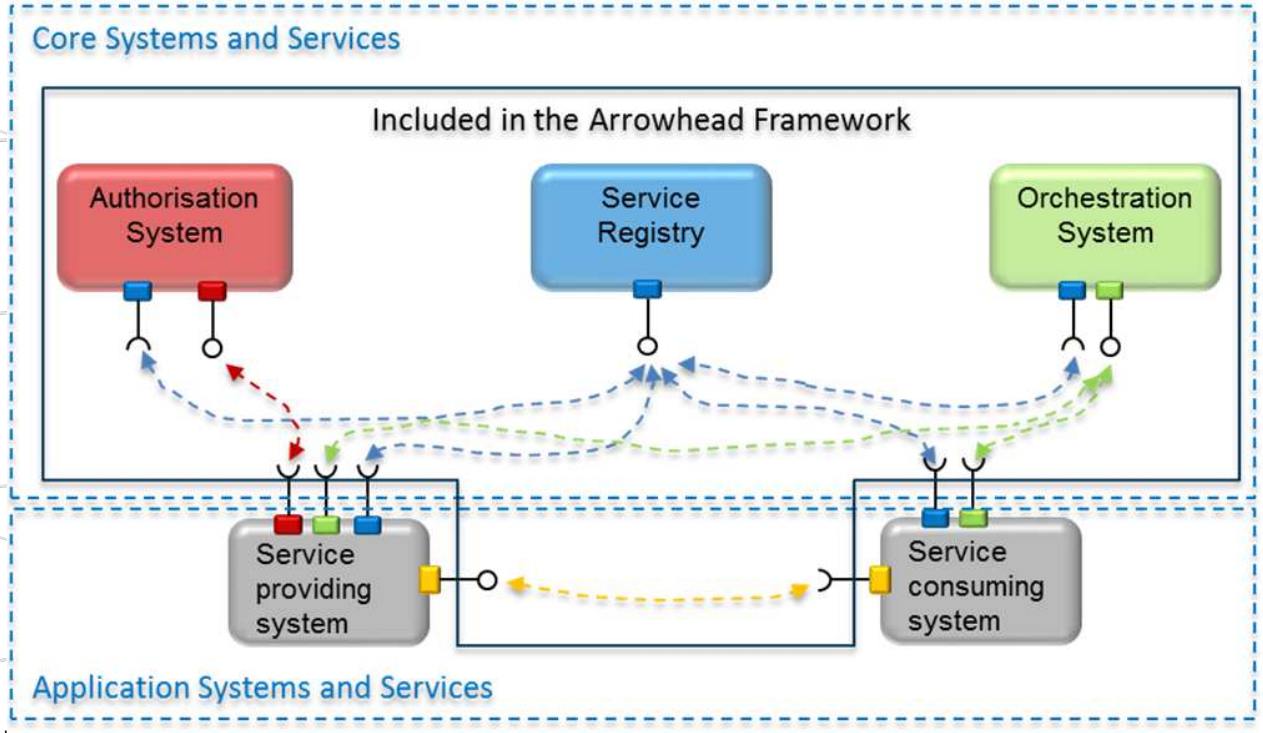
SOA fundamental

- Service/System/Device look-up

- Run-time binding
- Push or pull of orchestration rules
- Associated Management tool
- Integration to Engineering tools through PlantDescription



How to build local cloud?
Fundamental conceptual overview



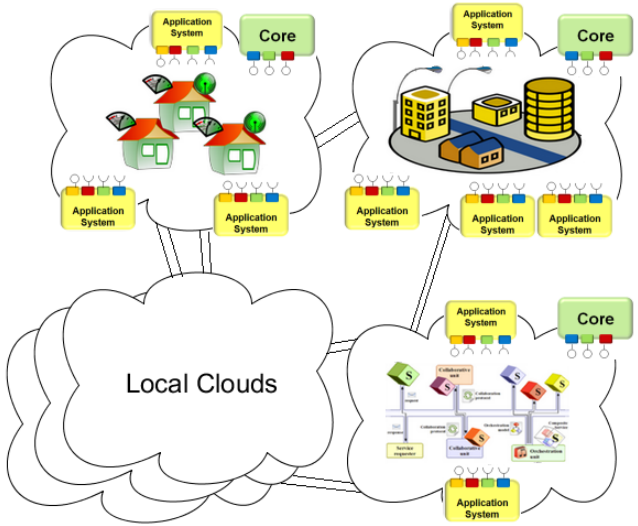
ARROWHEAD

Group of modules - Local Clouds

- Automation is local - requirements on:
  - Real time
  - Security and safety
  - Continuous engineering
  - Scalability

- Local clouds provides a protective fence enabling
  - Latency - real time
  - Security - supporting safety
  - Less engineering dependencies

- Inter cloud service exchange enables scalability



J. Delsing, et.al., Enabling IoT automation using local clouds, Proc. IEEE WorldForum on IoT 2016, Reston, USA

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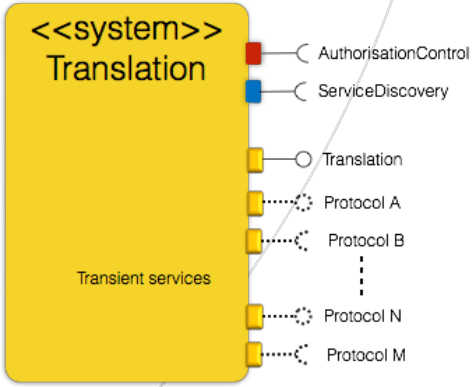
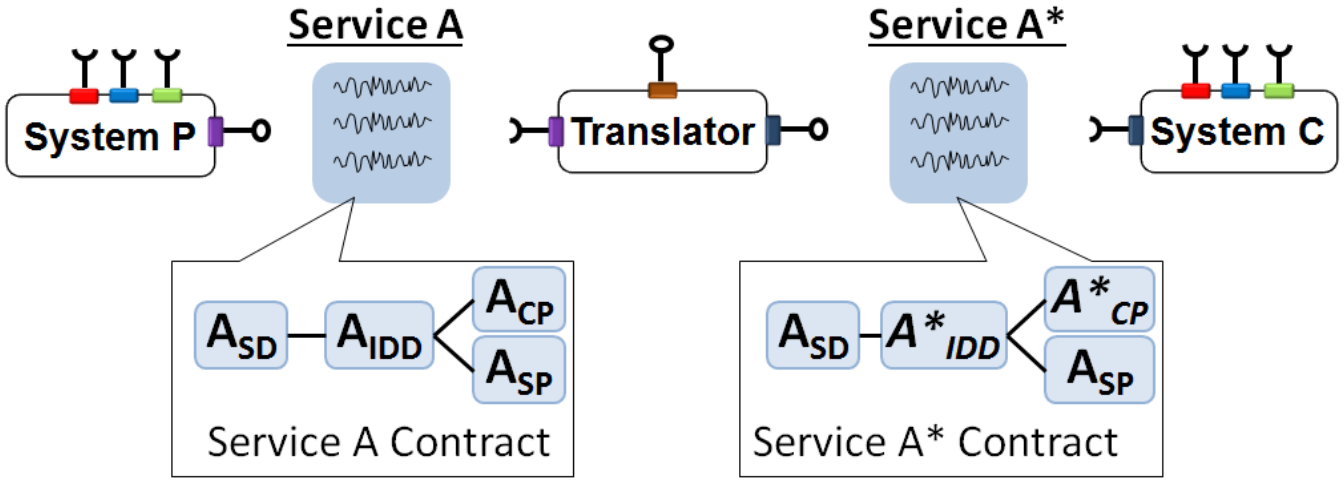
SoS Interoperability

Machine assisted translation like

- CoAP <-> XMPP <-> MQTT <-> REST……..
- Service integrity over protocols, data structures, semantics etc.

- Current translators: REST - CoAP - MQTT - FiWare
- Adaptors: OPC-UA, MODBUS TCP, Z-Wave, IO-LInk, Web of Things, …





Hasan Derhamy, Pal Varga, Jens Eliasson, Jerker Delsing and Pablo Punal Pereira
Translation Error Handling for Multi-Protocol SOA Systems, ETFA 2015, Luxembourg

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Security

Authorisation of service exchange

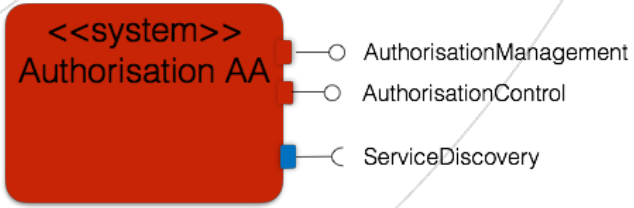
Authentication of service consumer

X.509 certificates

Payload encryption

Protocol level: TLS

X.509 certificates - AA



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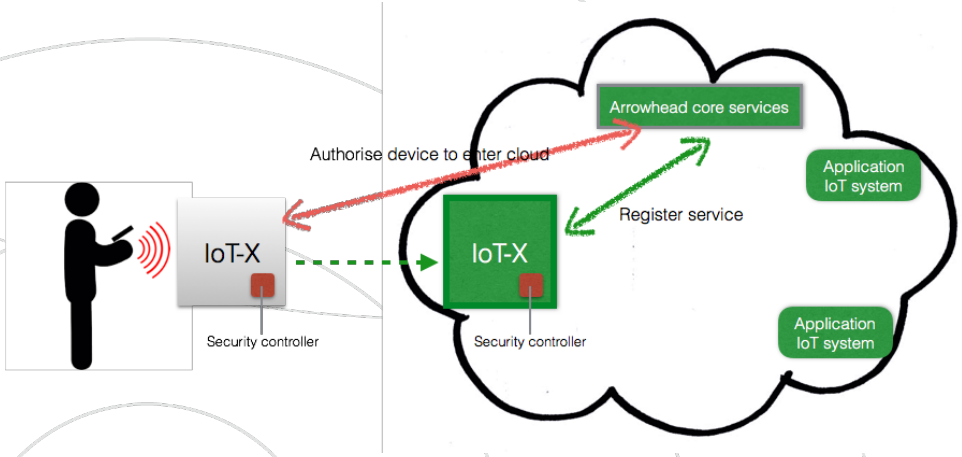
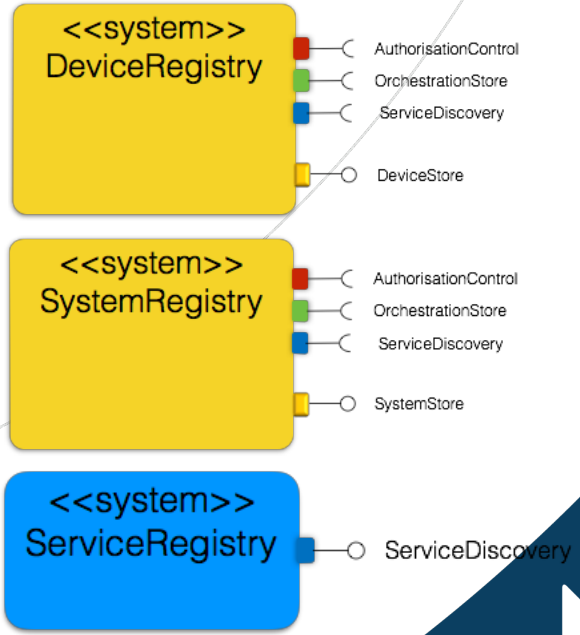
Secure local cloud deployment

- Procedures to securely identify and deploy
  - Device hardware
  - System software
  - System services





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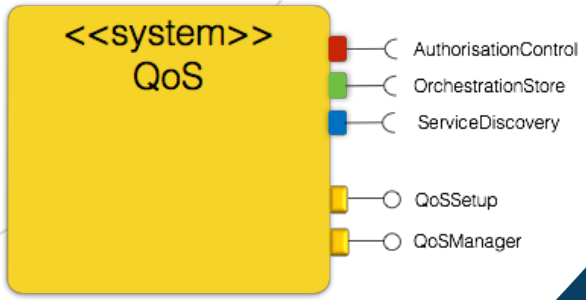
Hard real time IoT local cloud

- Hard real time dependent on underlaying communication capabilities
  - Local hard real time cloud to prescribe communication technology
  - e.g. Industrial ethernet, TTTech, time slotted 802.15.4, TDMA MAC layer
- SOA overhead eats bandwidth
  - Use compression
  - EXI
- QoS Manager system
  - End-to-end delay – hard/soft real-time guarantees;
  - Data bandwidth;
  - Communication semantics – delivery guarantees, and message ordering
  - Message prioritization
  - Local device parameters – on device application scheduling
  - Service configuration parameters – buffer size, middleware parameters and prioritization of requests.



EXIP: A Framework for Embedded Web Development Kyusakov, R., Punal, P., Eliasson, J. & Delsing, J. Oct 2014 In : ACM Transactions on the Web. 8, 4, 29 p.23

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Modularization to protect complicated properties
Local Clouds

ARROWHEAD

Eclipse Arrowhead

Provides an microservice architecture infrastructure for the edge

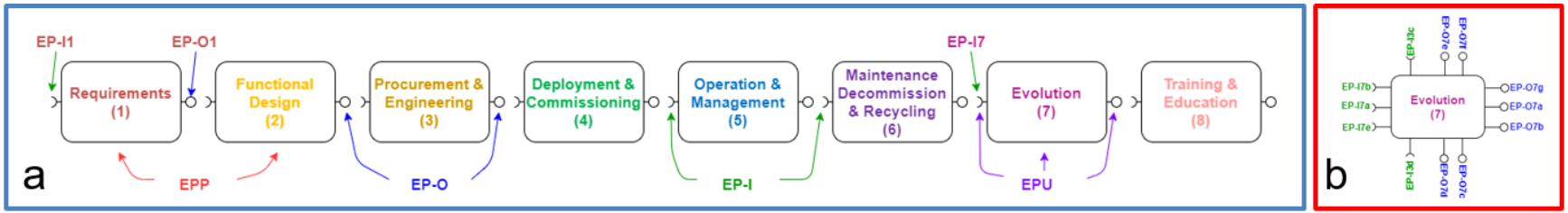
- Interoperable to the cloud
- Interoperability to IT and OT technology and data
- A reference implementation
- A technology stack
- Integration to existing engineering practices and standards
- Engineering tools and automation

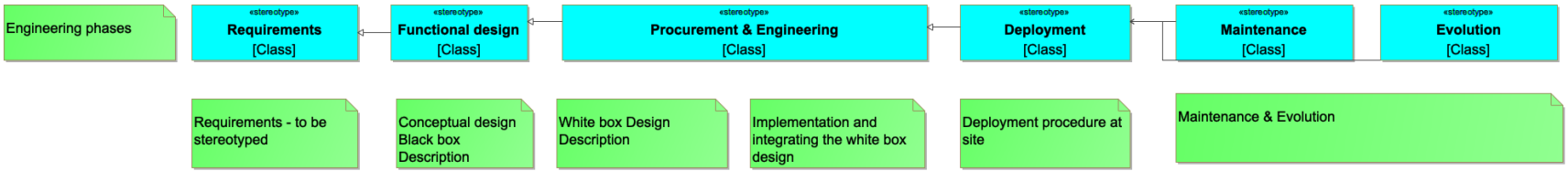
ARROWHEAD


Eclipse Arrowhead Technology Stack v4.6.1
Support systems
Core systems
Documentation & training
Documentation
Documentation model
Training material
Engineering process
Engineering support
SysML DSL
SysML core sys lib
SysML sup sys lib
C++, C#, .net lib
Certificate gen.
Java lib
Python lib
C lib
Test tool
SysML v2 profile
Management support
Management Tool
Safety Manager
Supply chain support
ContractProxy
Auction
Digital twin support
Eclipse Ditto
DigitalTwin
Control strategy support
ControlStrategy
Execution support
Choreography
WorkflowManager
WorkflowExecutor
W2OS-CPN
OrchestrationMitigation
System of Systems support
EventHandler
DataManager
PlantDescription
TimeManager
Configuration
QoS
Eclipse Hono
Eclipse Kura
Eclipse Kapua
Eclipse hawkBit
Inter cloud service exchange support
Gatekeeper
Gateway
Interoperability support
Protocol translation
FiWare
Modbus-TCP adaptor
OPC-UA adaptor
Z-wave adaptor
61499
Can bus adaptor
BaSyx
ROS
Datamodel transl.
Security infrastructure
SystemRegistry
DeviceRegistry
On-boarding
SecurityCompliance
SecurityMitigation
Local cloud core properties
ServiceRegistry
Orchestration
Authorisation
CertificateAuthority
Color coding key
Released
Release candidate
Prototype
ARROWHEAD

Engineering process integrated based on microservices

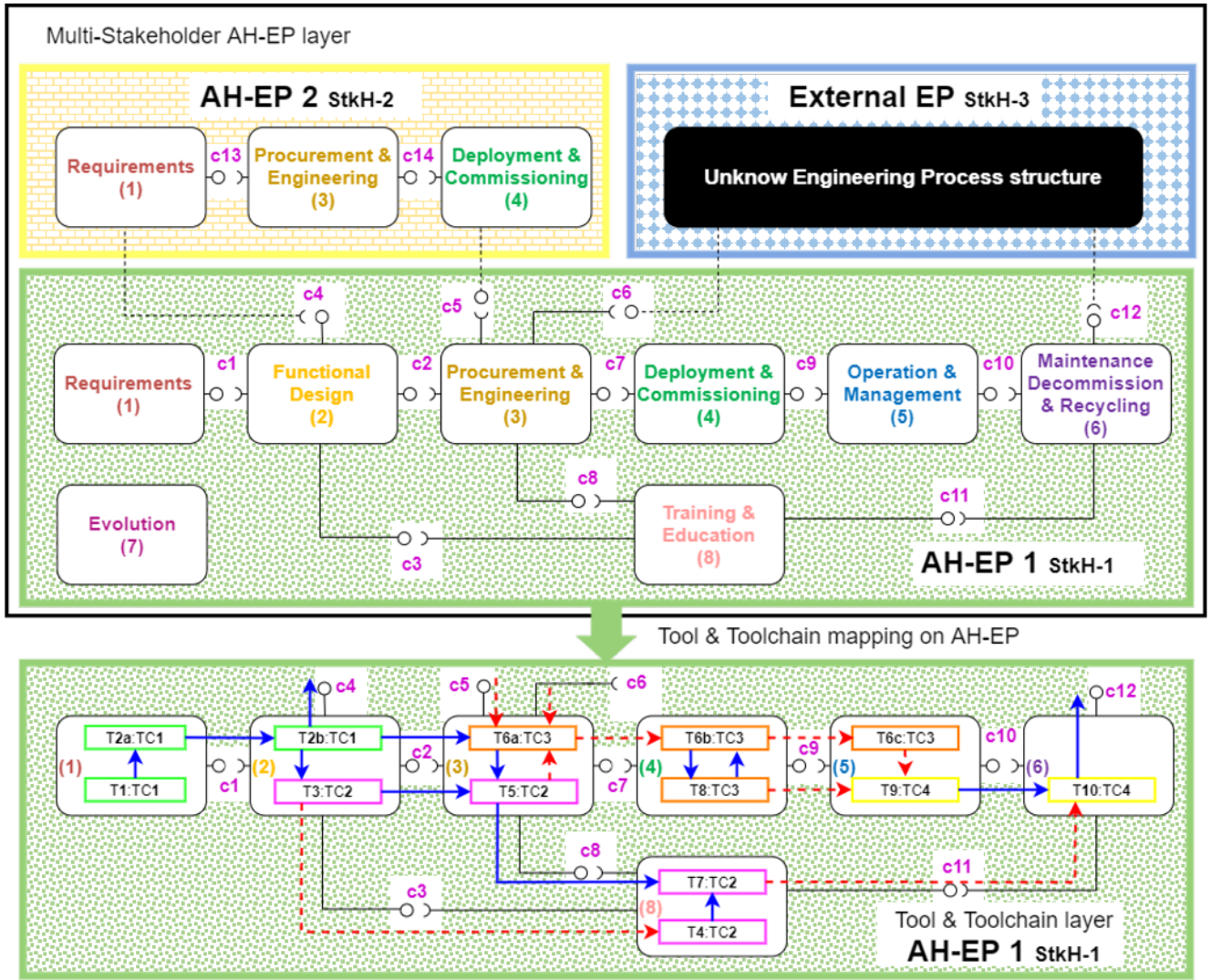
Modelling the engineering process - IEC 81346 + extensions





Urgese, G.; Azzoni, P.; van Deventer, J.; Delsing, J.; Macii, A.; Macii, E. A SOA-Based Engineering Process Model for the Life Cycle Management of System-of-Systems in Industry 4.0. *Appl. Sci.* **2022**, *12*, 7730. https://doi.org/10.3390/app12157730

ARROWHEAD TOOLS



EPP1	EPP2		
EPP2	EPP3	EPP8	ex2-EPP1
EPP3	EPP4	EPP8	
EPP4	EPP5		
EPP5	EPP6		
EPP6	EPP3	ex3	
EPP7			
EPP8	EPP6		
ex2-EPP1	ex2-EPP3		
ex2-EPP2			
ex2-EPP3	EPP3		
ex2-EPP4			
ex2-EPP5			
ex2-EPP6			
ex2-EPP7			
ex2-EPP8			
ex3	EPP3		

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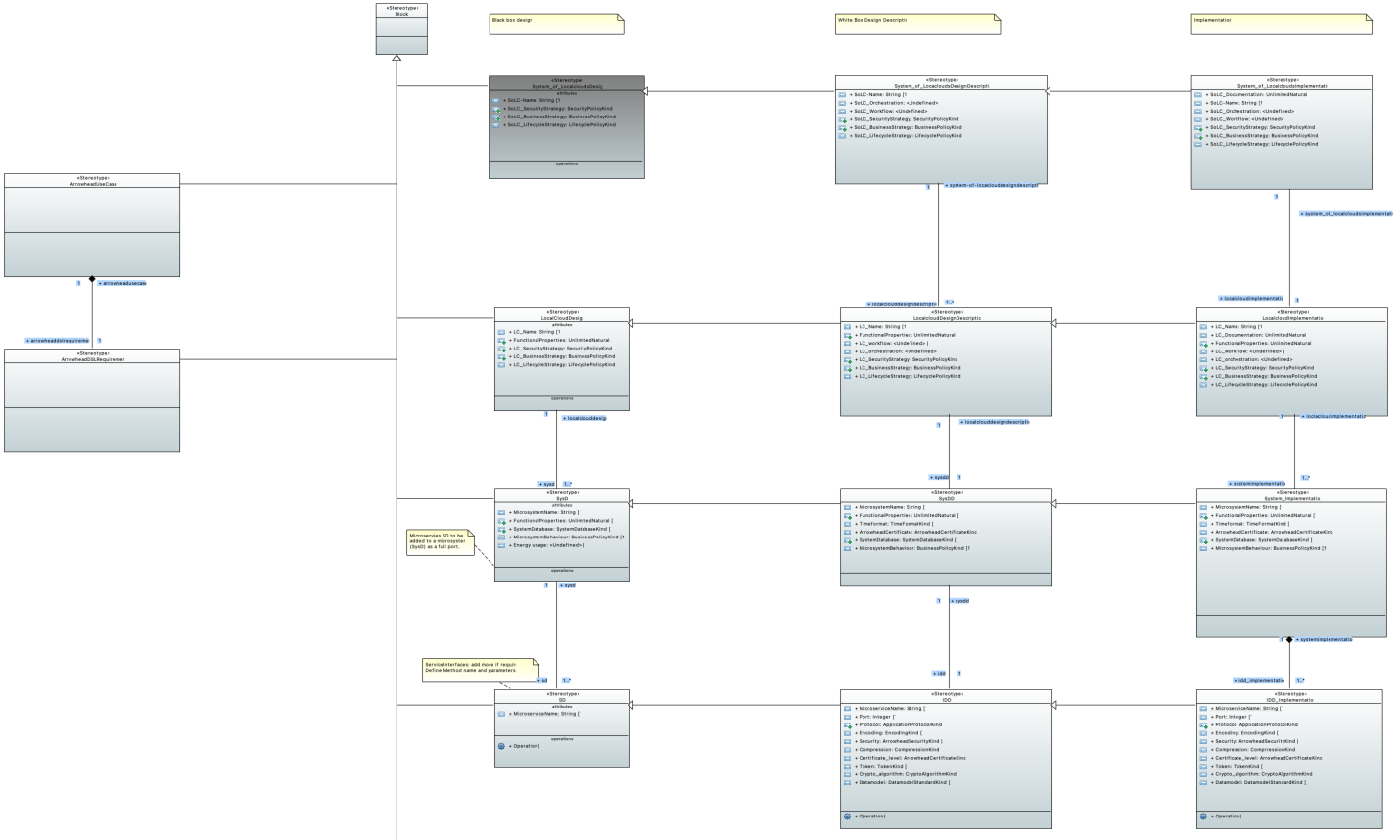
Arrowhead SysML DSL



VHEAD

Arrowhead Tools figures

80 partners from 18 countries

90M€ budget

2019-2022

Core technology results provided as opens source

Eclipse Arrowhead

This research work has been funded by the European Commission, through the European H2020 research and innovation programme, ECSEL Joint Undertaking, and National Funding Authorities from 18 involved countries under the research project Arrowhead Tools with Grant Agreement no. 826452.

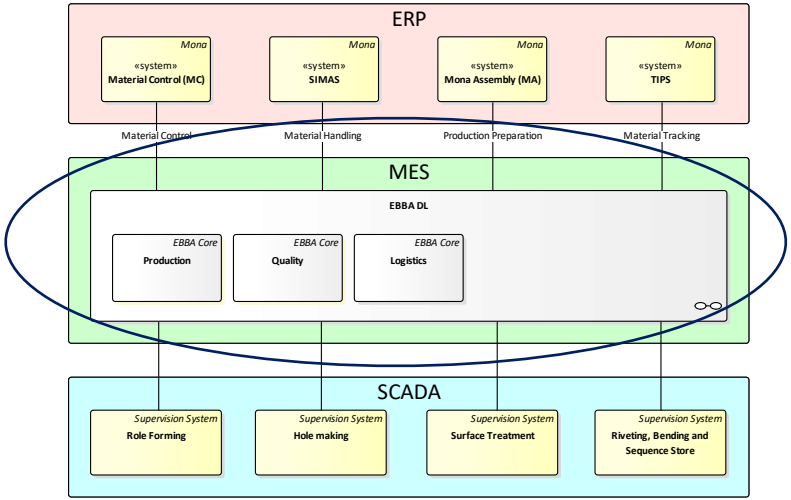
ARROWHEAD TOOLS

Primary objective

20-50% reduction of **engineering costs** of automation and digitalisation solutions in industry

ARROWHEAD TOOLS

Scope PISA-DL – The Scania MES System



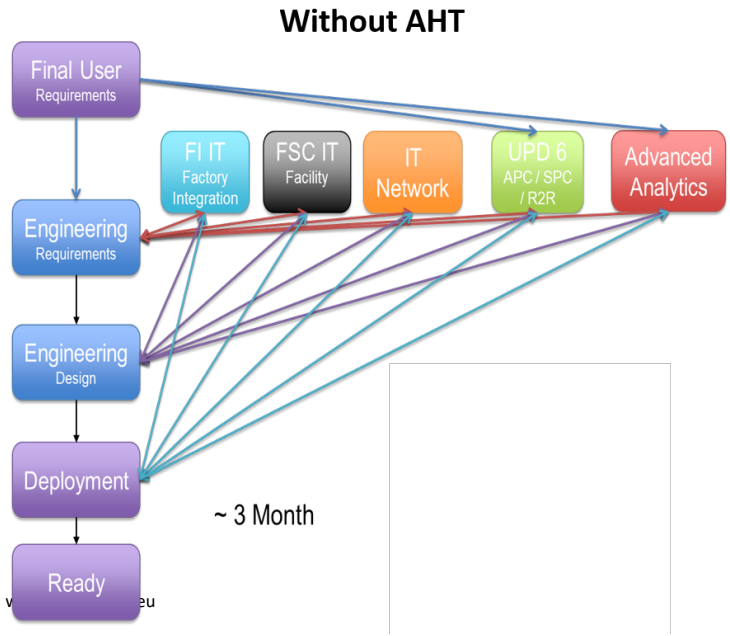
Computerized systems used in manufacturing, to track and document the transformation of raw materials to finished goods.

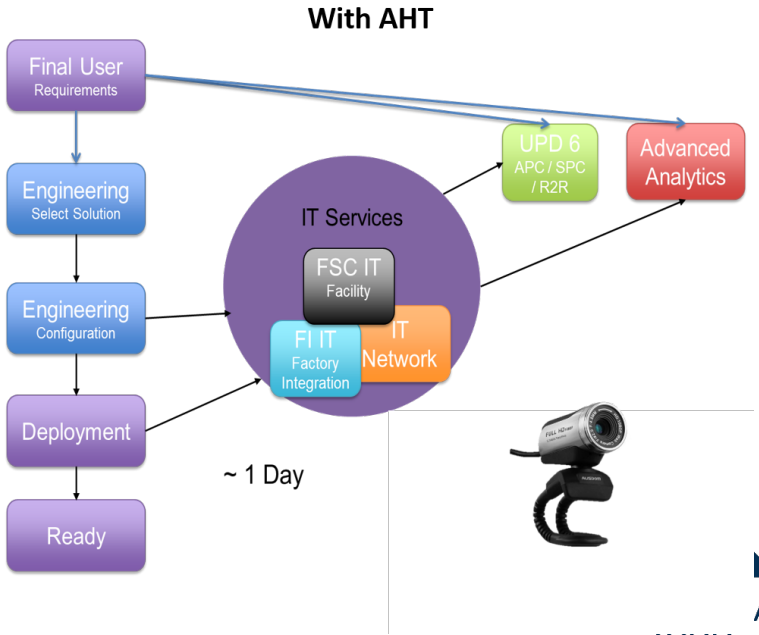
*MES provide the **right information at the right time** and show the manufacturing **decision maker** "how the current conditions on the plant floor can be optimized to **improve production output**."*

***MES work in real time** to enable the control of **multiple elements of the manufacturing process** (e.g. inputs, personnel, machines and support services).*

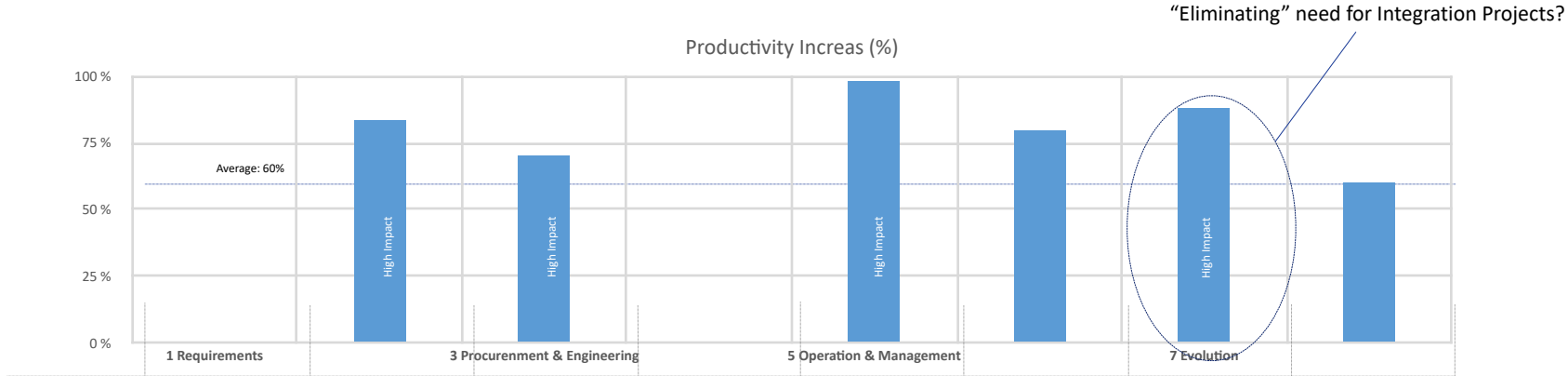
Installation of sensors in semiconductor production

Optimising the process of sensor integration using Arrowhead conform architectures





Impact from Introducing “Micro Services”



Root Cause	Comparable effort	Reduction in effort and time. Change in process impact integrations and connecting systems as adaptation on application site is not needed	Reduction in time and effort driven by simplification in development	Comparable effort for actual deployment once all pre-work is done	A quarter of time needed for operational management of platform compared to legacy	Reduction in effort based on reduced complexity	In legacy approach, major changes are close to new development in effort limiting agile ways of working and continuous improvements. Great reduction in time and effort	Slight reduction in effort

ARROWHEAD TOOLS

Further material

- Youtube
  - https://www.youtube.com/@ArrowheadProject
- Web
  - http://www.arrowhead.eu
- Code
  - http://github.com/eclipse-arrowhead
- Book
  - https://www.routledge.com/IoT-Automation-Arrowhead-Framework/Delsing/p/book/9780367658144

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Conclusion

- The information landscape complexity is sky rocketing!!!
  - So does the engineering and data sharing complexity
- Local simplification seams to be a way to go
- SOA architecture does support vital concepts to use local simplification
- Eclipse Arrowhead provides and open source architecture infrastructure and engineering procedures and tools

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