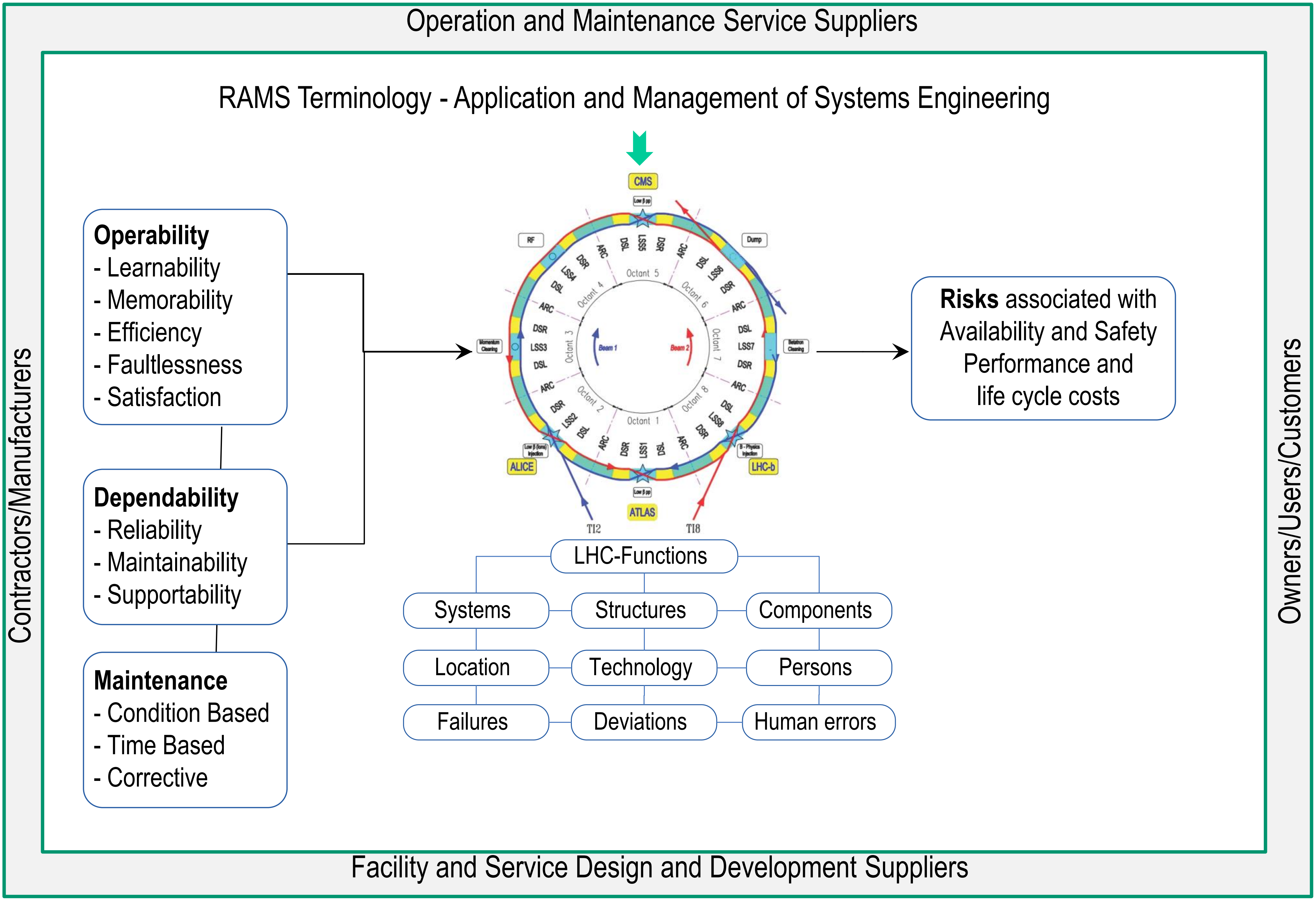
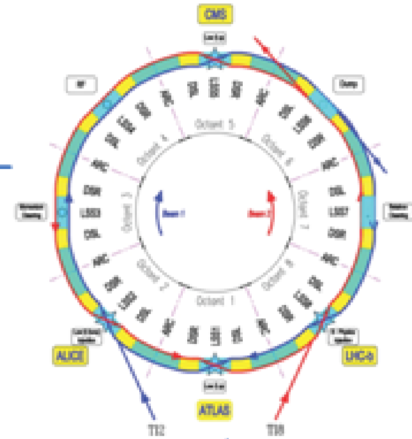
PURESAFE Final Conference
Tuesday 20 January 2015, 14:20 – 14:40

RAMS Methods and Tools: From LHC to FCC

Prof. Seppo Virtanen


Operation and Maintenance Service Suppliers
RAMS Terminology - Application and Management of Systems Engineering
Operability
- Learnability
- Memorability
- Efficiency
- Faultlessness
- Satisfaction
Dependability
- Reliability
- Maintainability
- Supportability
Maintenance
- Condition Based
- Time Based
- Corrective
CMS
ATLAS
ALICE
LHC-b
RF
Dump
Octant 1
Octant 2
Octant 3
Octant 4
Octant 5
Octant 6
Octant 7
Octant 8
Beam 1
Beam 2
TI2
TI8
Risks associated with Availability and Safety Performance and life cycle costs
LHC-Functions
Systems
Structures
Components
Location
Technology
Persons
Failures
Deviations
Human errors
Contractors/Manufacturers
Owners/Users/Customers
Facility and Service Design and Development Suppliers

Application and Management of Systems RAMS Engineering



Requirements flow down from level above

System Design Processes
1) Stakeholders Expectations and Requirements Definition
2) Technical Requirements Definition
3) Logical Decomposition
4) Design Solution Definition

Requirements flow down to level below

Technical Management Processes
10) Technical Planning
11) Technical Data Management
12) Requirements Management
13) Interface Management
14) Supply Management
15) Configuration Management
16) Design Change Management
17) Technical Risk Management
18) Technical Decision Analysis

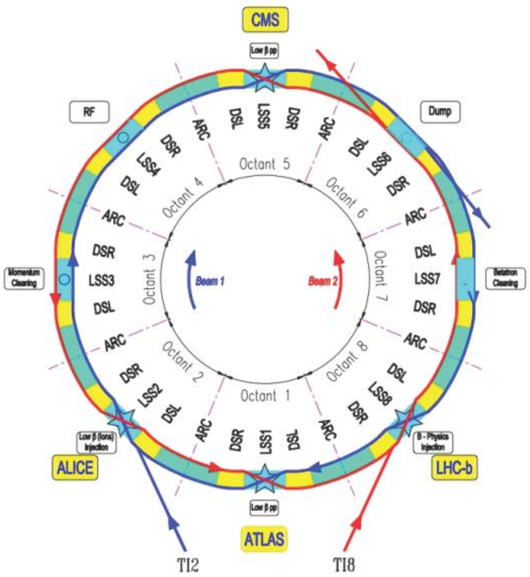
Risks associated with Availability and Safety Performance and life cycle costs

Realized systems to level above

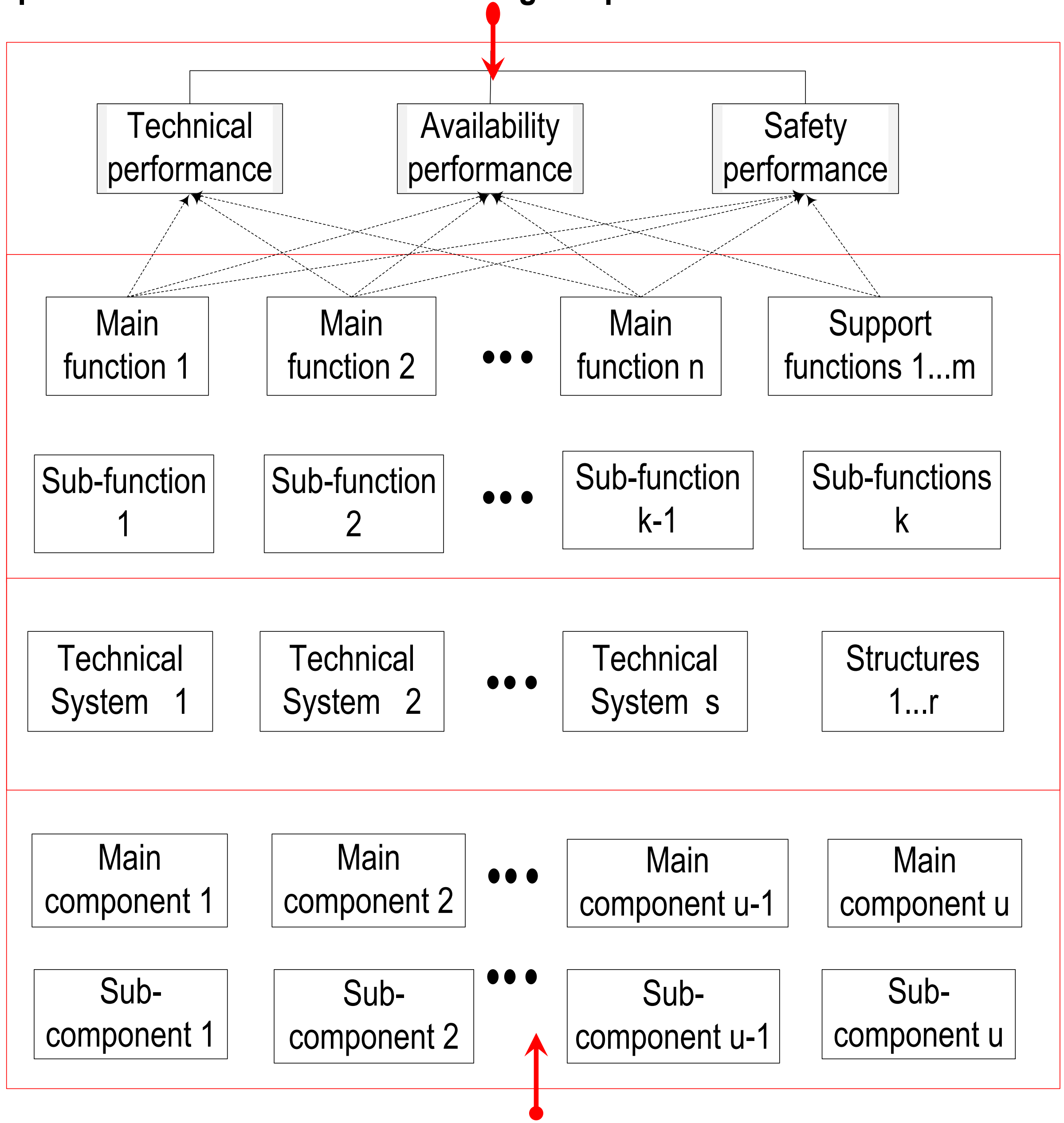
System Realization Processes
5) System Elements Implementation
6) Elements Integration Processes
7) System Verification
8) System Validation
9) System Transition Process

Realized systems from level below

Specification and Allocation of design requirements & basis

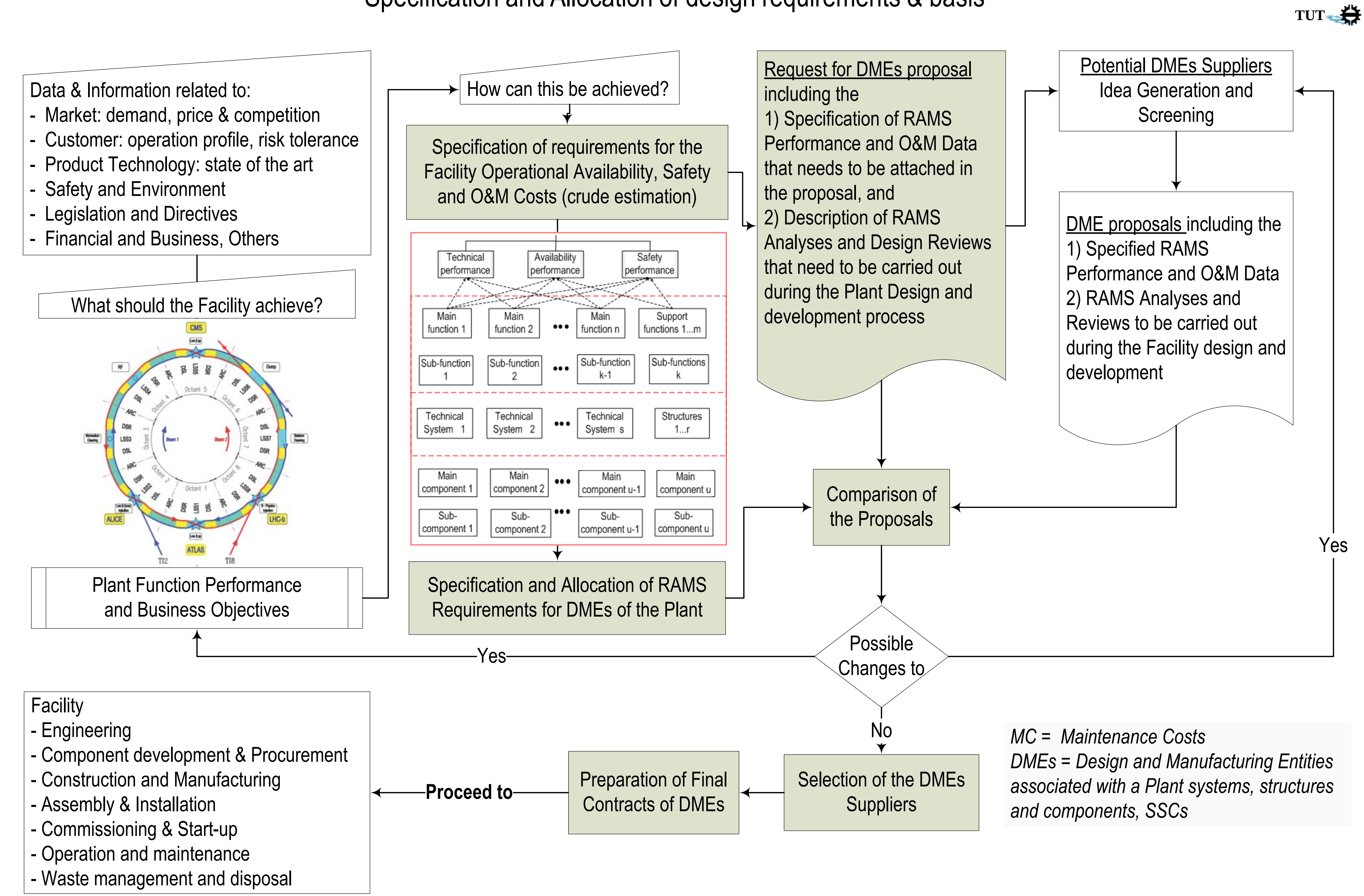


Understanding of Functions’, Systems’, Structures’ and Components’ RAMS interconnections and causal relations to the System Availability and Safety Performance and life cycle costs



Seeking out and selecting design solutions

Specification and Allocation of design requirements & basis



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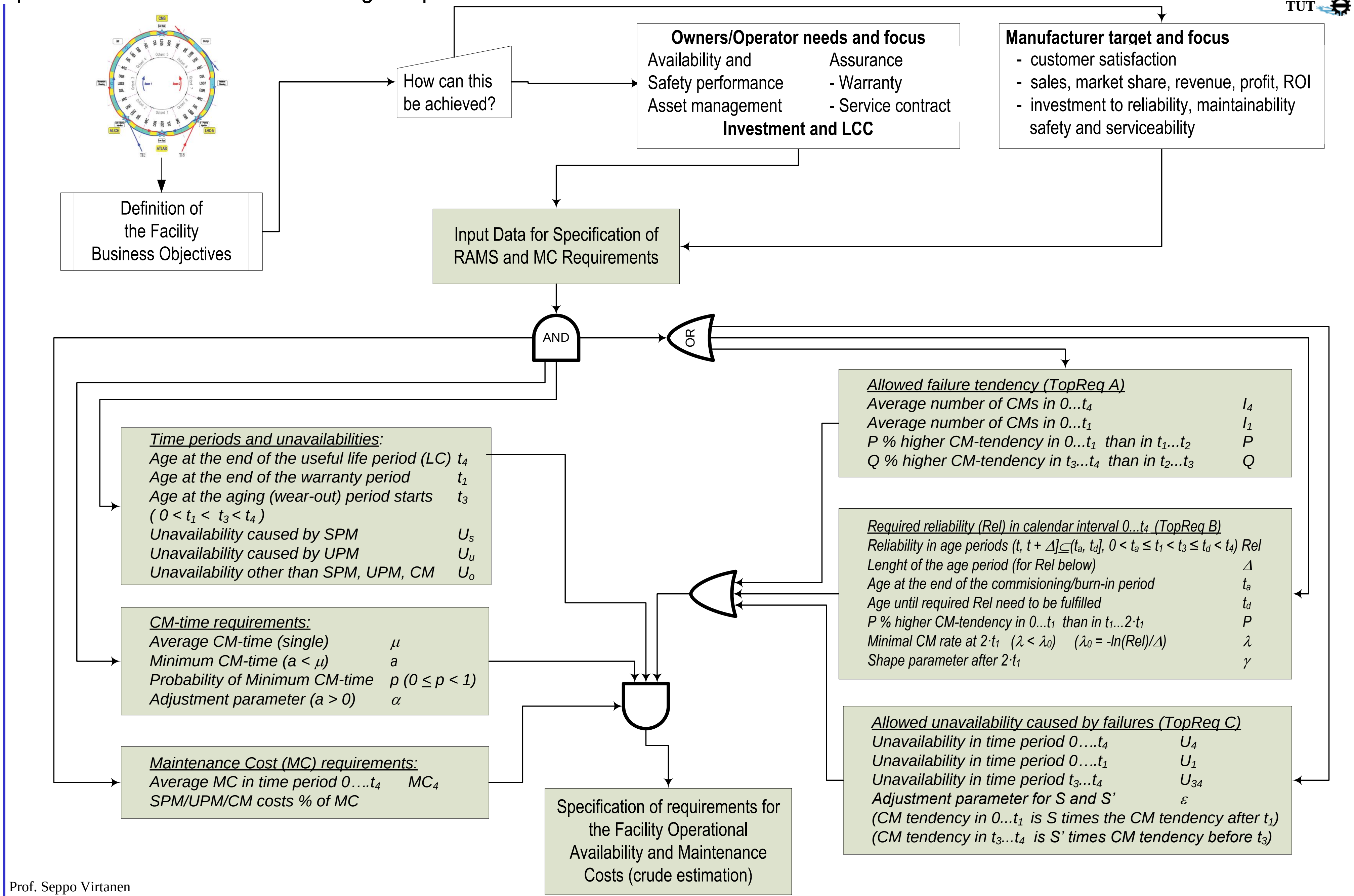
Specification and Allocation of design requirements & basis



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Principle of RAMS Requirements Allocation

Allocation of Number of maintenance actions I(t)

$$I_i(t) = \alpha \cdot w_i \cdot I(t)$$

$$w_i = \frac{\frac{y_i}{(x_i)^{\tau}}}{\sum_{i=1}^{n} \frac{y_i}{(x_i)^{\tau}}}$$

$$y_i \uparrow \Rightarrow w_i \uparrow \Rightarrow R_i, A_i \downarrow$$

$$x_i \uparrow w_i \downarrow \Rightarrow R_i, A_i \uparrow$$

w_i coefficient, represents the relative amount of maintenance actions associated with the *DME*

y_i represents *DME's* complexity from the technical stand point

x_i represents *DME's* importance from the customer's perspective

t weighting importance against complexity

a a gate specific "level parameter"

Allocation of Maintenance action time G(t)

$$G(t)_i = G(t)^{\beta \cdot z_i}$$

$$z_i \uparrow \Rightarrow TTM_i \uparrow$$

$$z_i \downarrow \Rightarrow TTM_i \downarrow$$

z_i coefficient reflects directly the *DME's* relative execution time of maintenance action (TTM_i)

b a gate specific "level parameter"

Allocation of Maintenance Costs (MC)

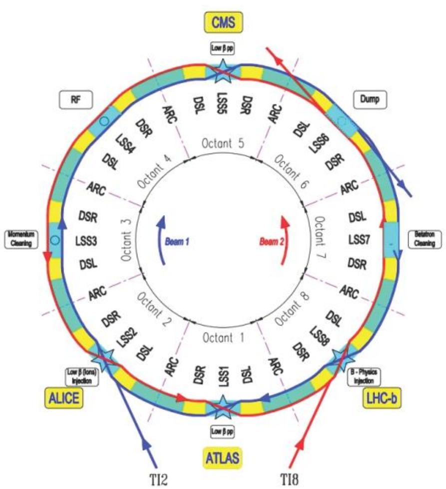
Following assessment for ZE RTG

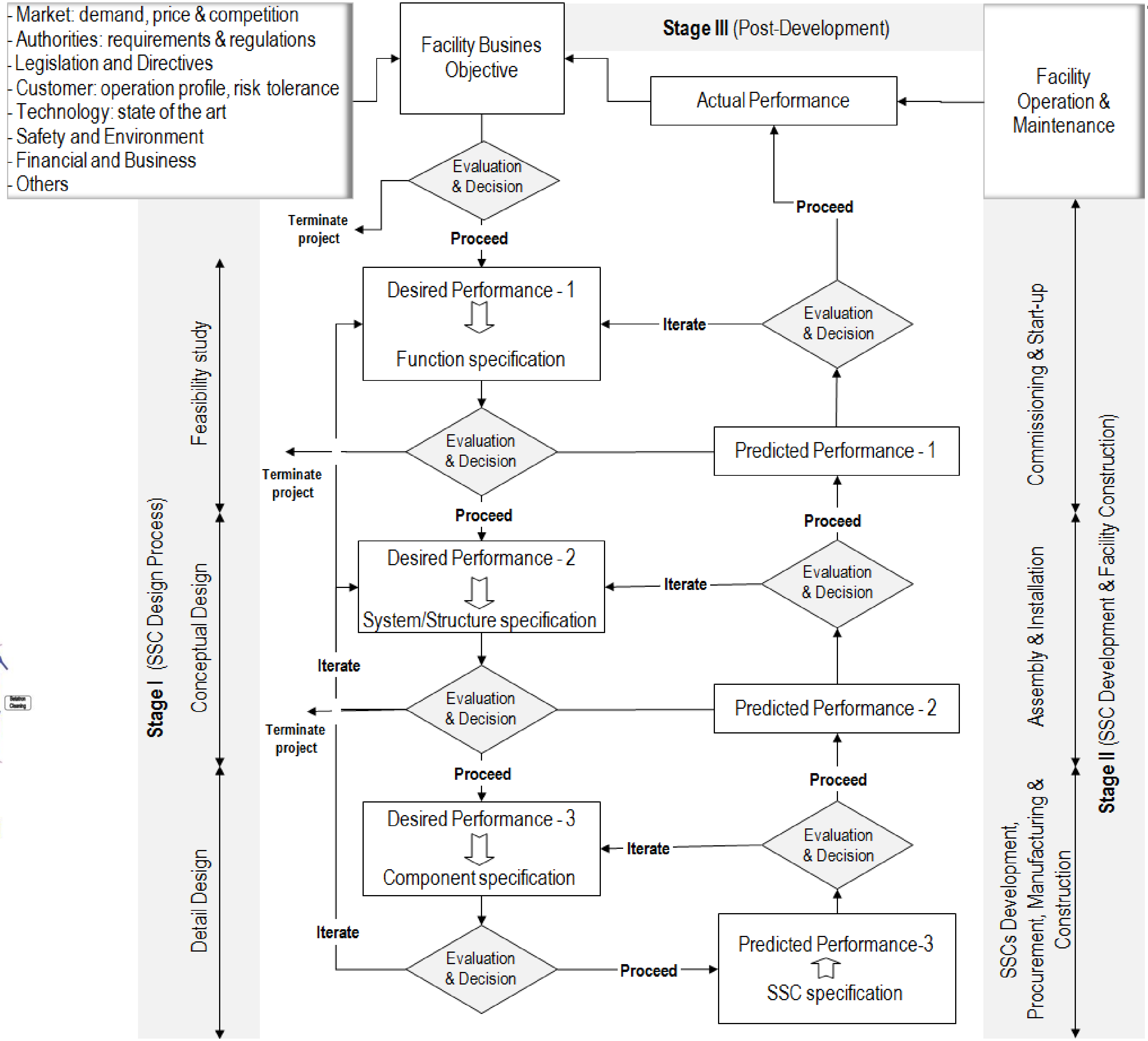
- Total maintenance costs (*MC*)
- Repair costs [%] of *MC*

Following assessment for the *DMEs* (*i*) RAM requirements were allocated

- Cost ration: $\frac{material\ cost_i}{labor\ cost_i}$
- Labor cost per hour, relative:

Management of Design review in Design and Development Process





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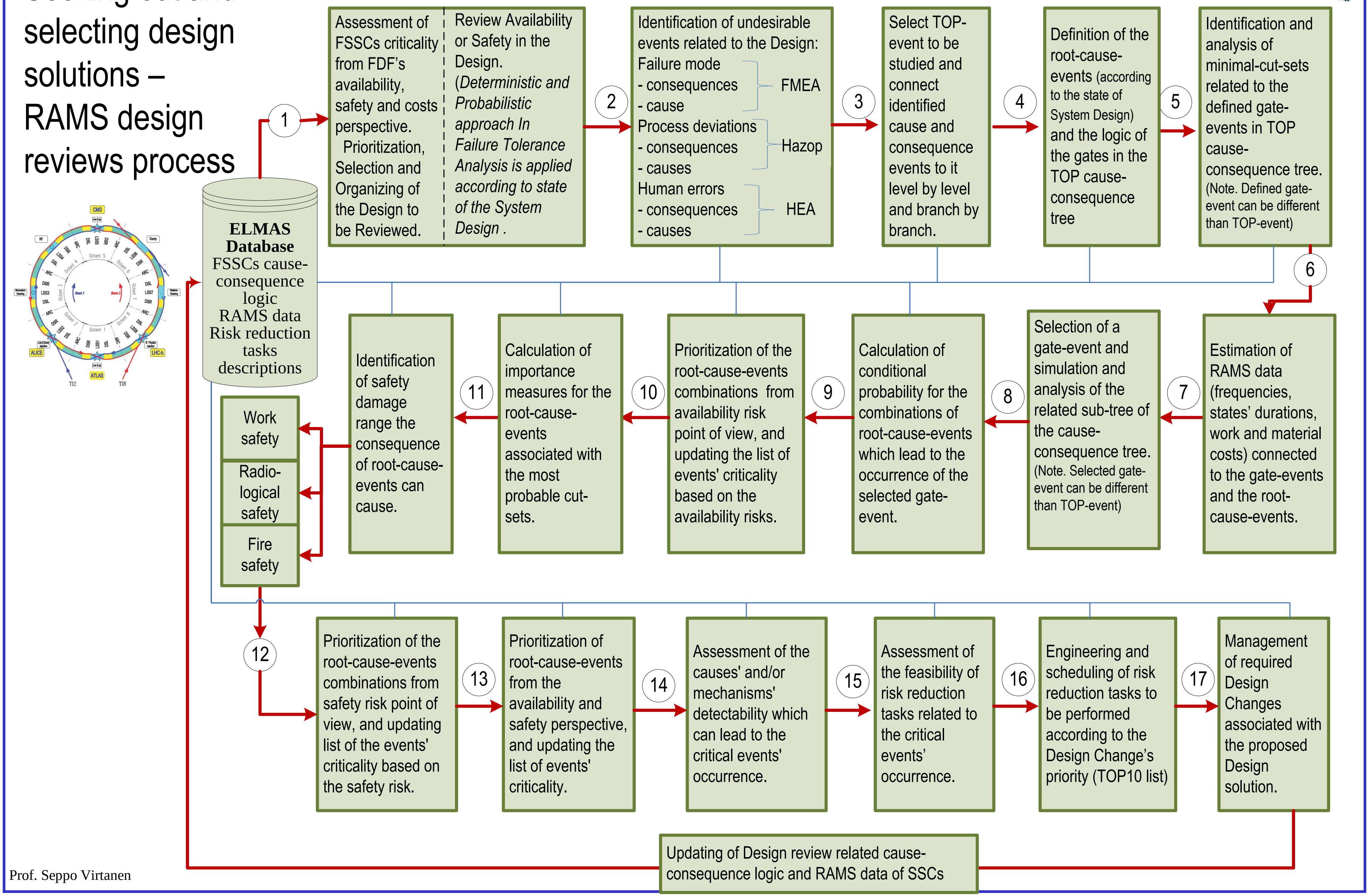
Seeking out and selecting design solutions – RAMS design reviews process



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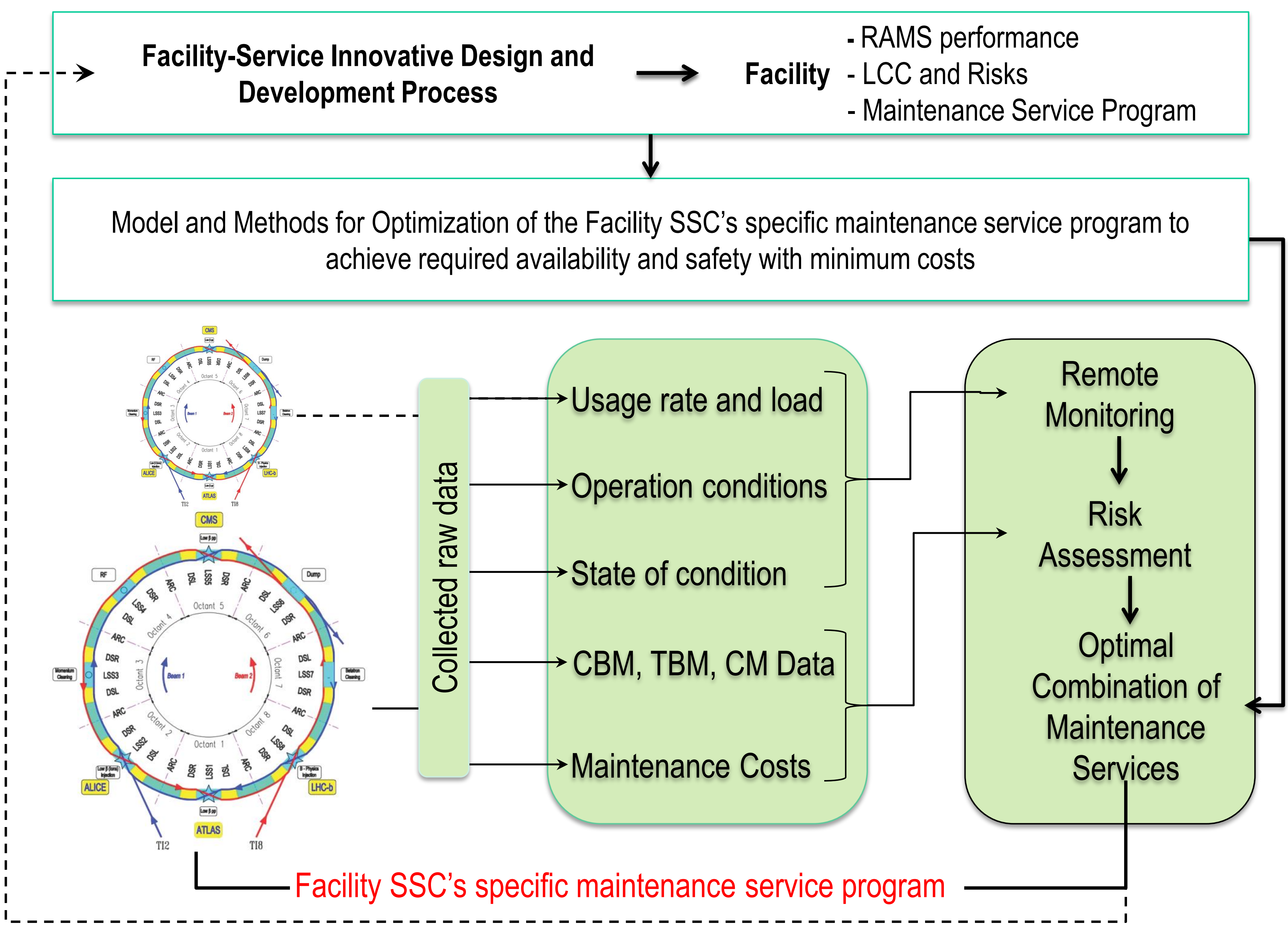
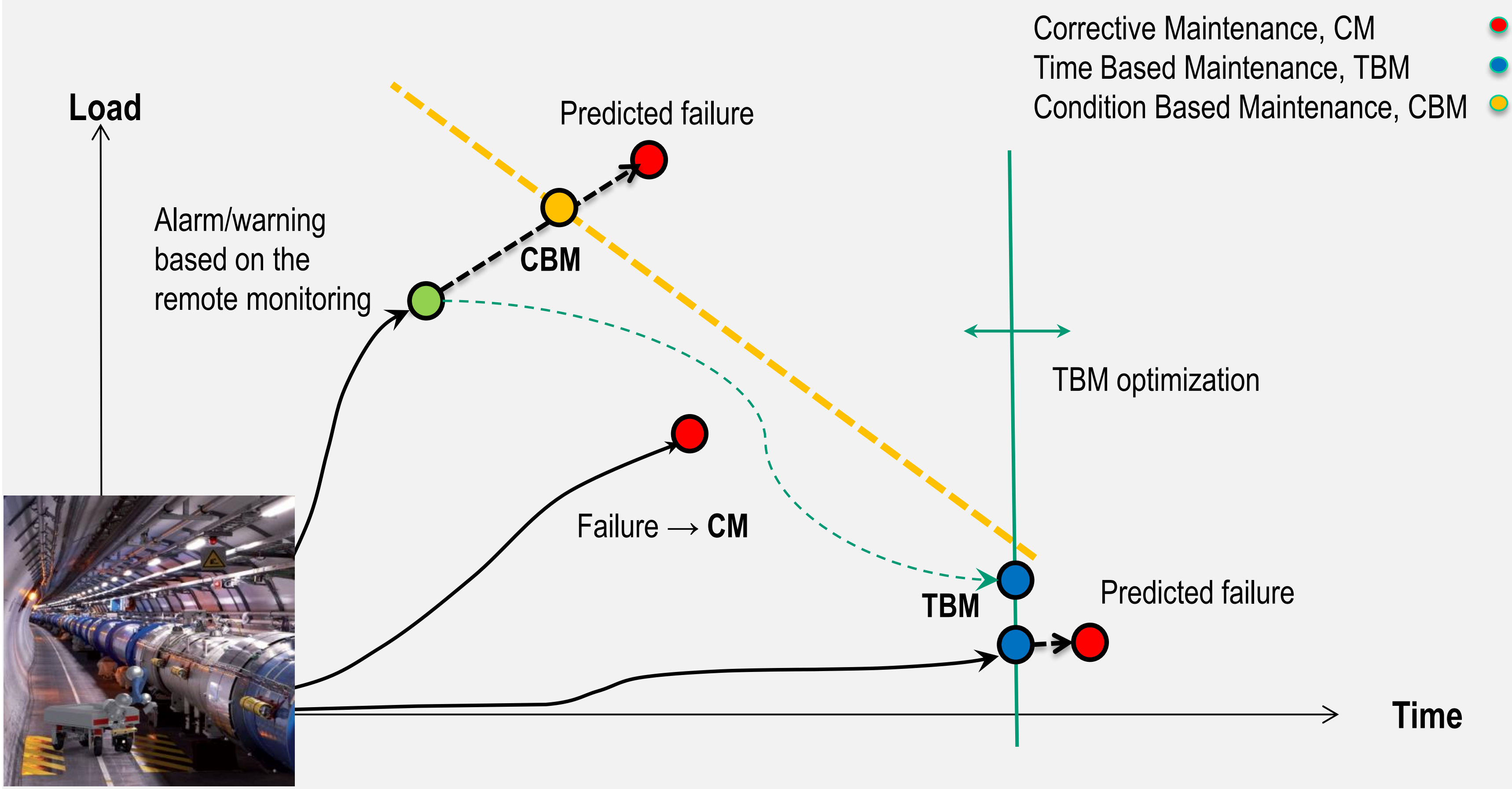


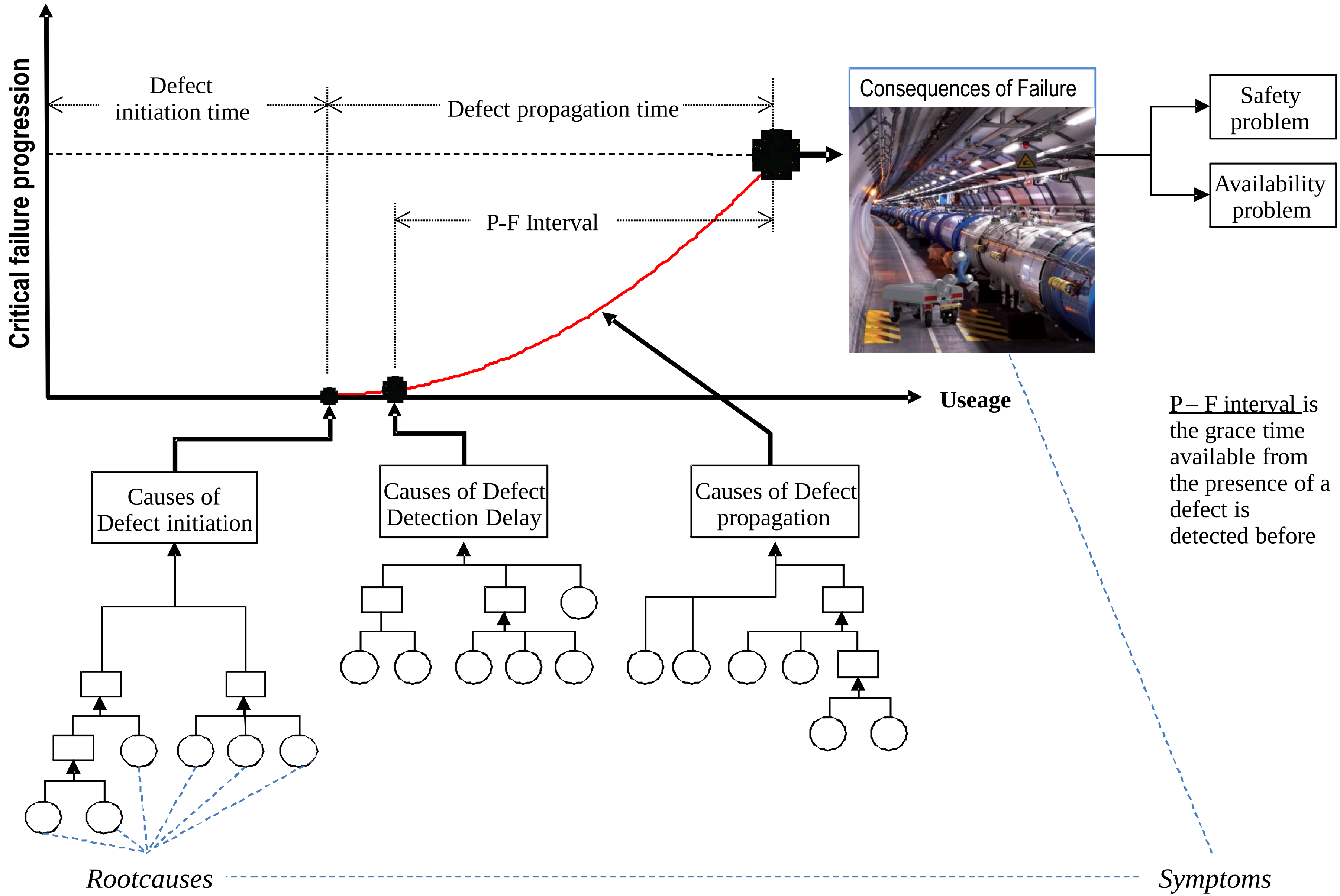
Facility-Service Innovative Design and Development Process
Facility
- RAMS performance
- LCC and Risks
- Maintenance Service Program
Model and Methods for Optimization of the Facility SSC's specific maintenance service program to achieve required availability and safety with minimum costs
Collected raw data
Usage rate and load
Operation conditions
State of condition
CBM, TBM, CM Data
Maintenance Costs
Remote Monitoring
Risk Assessment
Optimal Combination of Maintenance Services
Facility SSC's specific maintenance service program

Optimization of competing maintenance procedures to achieve required availability and safety with minimum costs

"According to IAEA-TECDOC-1590 standard, Reliability centered maintenance (RCM) analysis is a systematic evaluation approach for developing and optimizing a maintenance programme (which consists of CM, TBM, CBM). RCM utilizes a decision logic tree to identify the maintenance requirements of equipment according to the safety and operational consequences of each failure type and the degradation mechanism responsible for failures".



Symptom —Defect—Failure—Consequence - Process



Integrated Operations (IO)

IO = Oil&Gas+ICT
= Real time data onshore
+ coverting data to information
+ technical & organizational consequences

JT

1. Instrumented
Automated identification and data capture (AIDC) and automation

2. Interconneted
Digital infrastructure and Information security

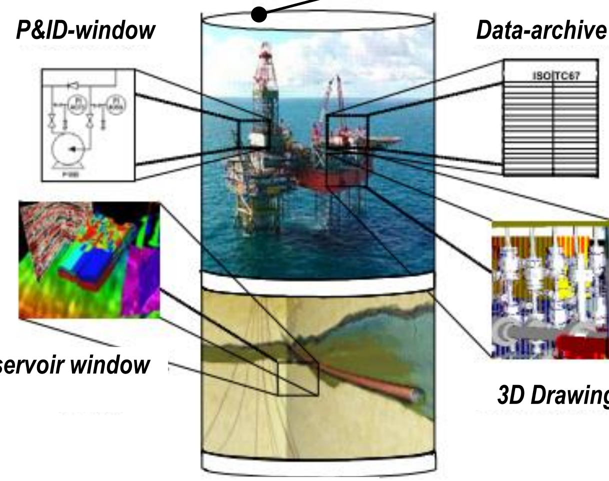
Real Time Data

Data Integration

3. Integrated data information management

P&ID-window

Data-archive window



3D Reservoir window

3D Drawing window

4. Innovative computing and business intelligent software

Operation Centre

Data

5. Intelligent desicions
- Analysis
- Visualization
- Knowledge
- **Risk Assessment & Mgmt**
- Decisions
- Actions

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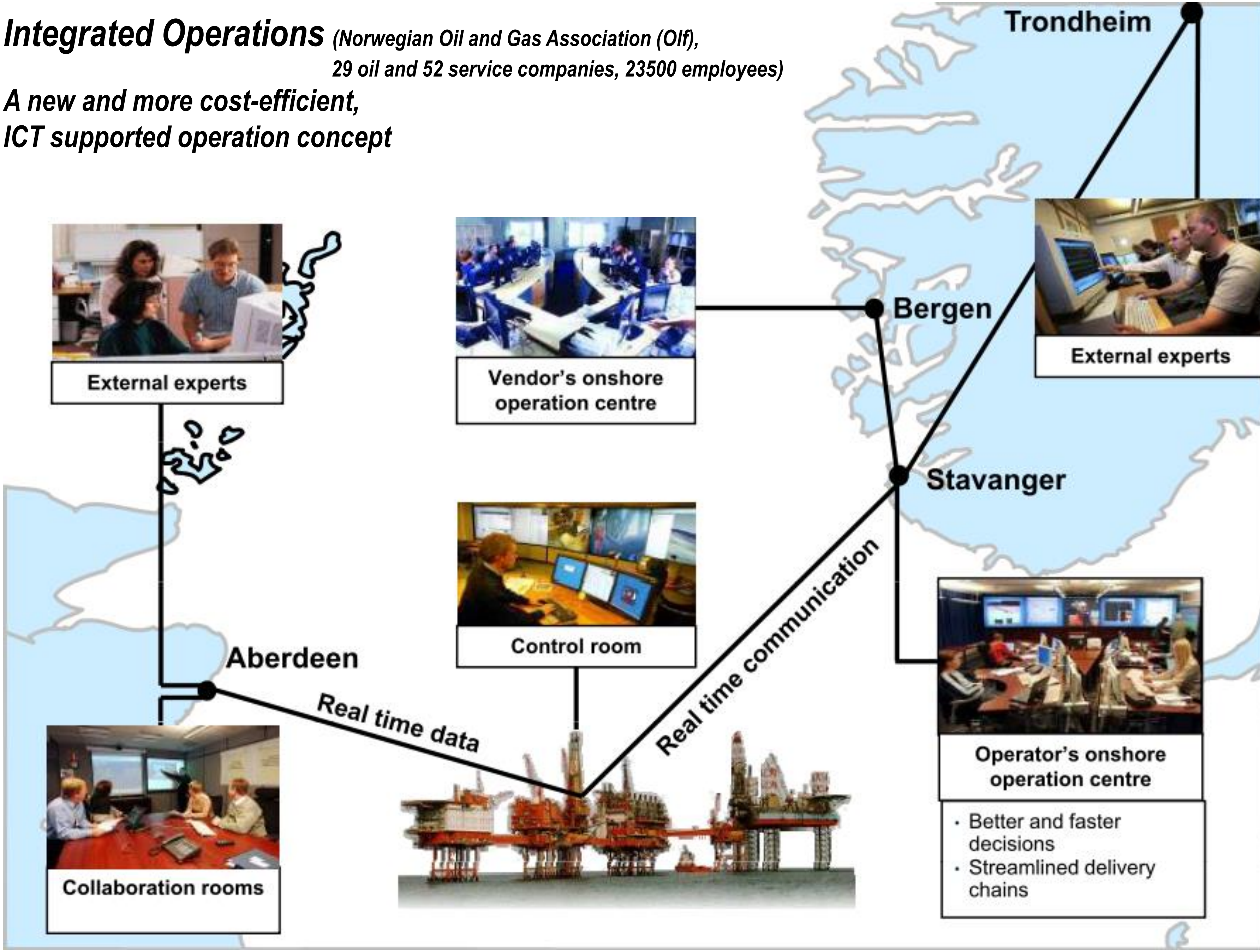
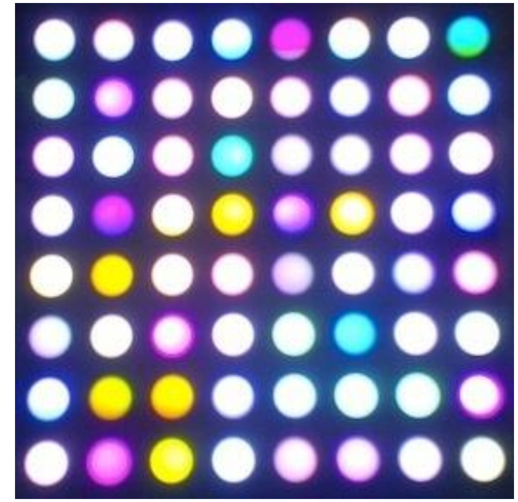
Integrated Operations *(Norwegian Oil and Gas Association (Olf), 29 oil and 52 service companies, 23500 employees)*

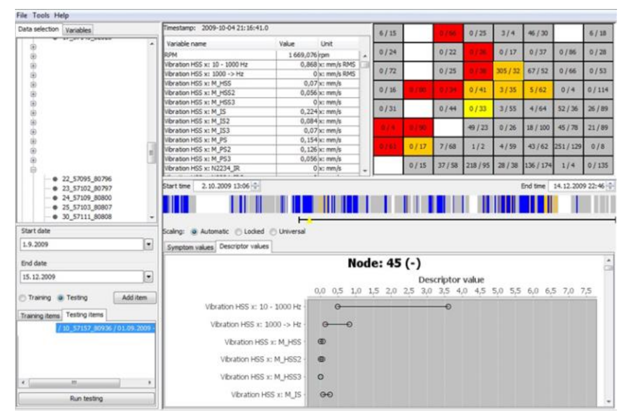
A new and more cost-efficient, ICT supported operation concept

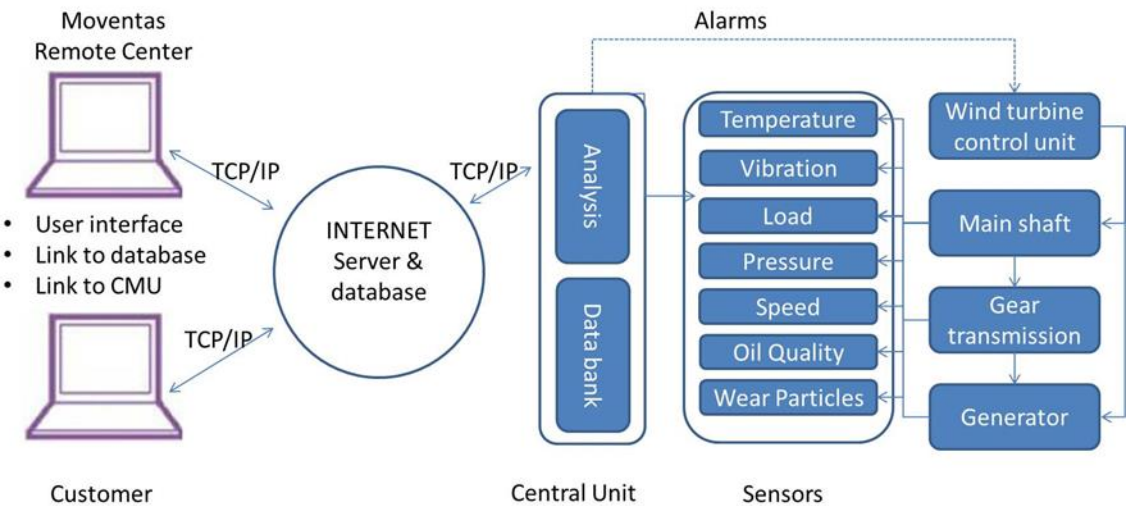


Intelligent Interpretation of Machine Condition Data



User interface





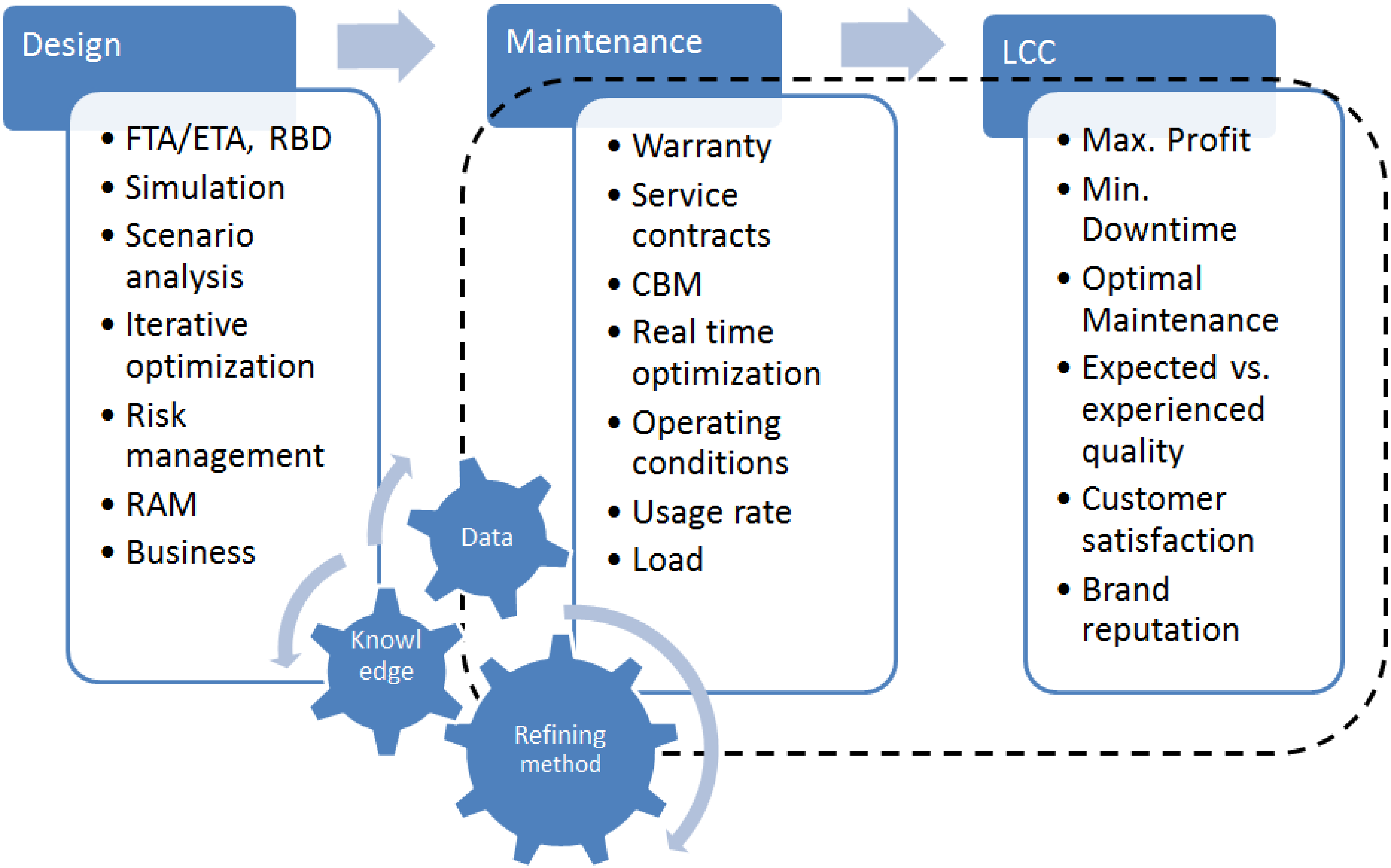
RAMS Methods and Tools: From LHC to FCC

SCOPE OF WORK
• Study RAMS design methods and tools to be applied to particle accelerators (RAMS)

Work Units	
Identifier	**Title**
TUT-RAMS-1	**Reliability, Availability, Maintainability and Safety (RAMS) studies for an accelerator in the Large Hadron Collider (LHC) chain**
TUT-RAMS-2	**RAMS methods and tools**
TUT-RAMS-3	**RAMS technical training**
TUT-RAMS-4	**RAMS Modeling for future accelerators**

WORK UNIT	
TUT-RAMS-1	**Reliability, Availability, Maintainability and Safety (RAMS) studies for an accelerator in the Large Hadron Collider (LHC) chain**
Reference:	3.3.1.9 Reliability and availability method and framework
Objectives:	Evaluate the suitability and effectiveness of RAMS methods and tools in the area of particle accelerators by: ○ selecting a suitable set of CERN accelerator subsystems for a case study ○ modeling cause-consequence logic of system failures ○ collecting and analysing operation and maintenance data ○ modeling accelerator availability at the system level and RAMS impact on key performance indicators by comparing results with historic operational data ○ assessing potential performance improvements

The Total Concept of Data Lifecycle Management



ELMAS

Event	Logic	Modeling	Analysis	Software
• MTTF, Failure distribution • MTTR, Repair distribution • Maintenance actions • Break and downtime loss • Repair Costs • Hazards • Usage and stress profile • External events	• OR • AND • K/N-Voting • XOR-Exclusive • Limits • Conditional probability • Delays • Throughput, fuzzy logic • Dynamic coding	• Fault tree • Event tree • Cause-consequence-tree • Reliability block diagram • Process diagram • Waiting and redundancy • Buffers • Failure modes, RCA	• Simulation • Availability, Safety • Risk Analysis • Importance measures • Conditional probabilities • Spare part consumption • Resources • FMEA, Classification, RCM, Decision tree, Criticality	• Graphical user interface • Excel export and import • HTML report • Table summary • ERP interface • Project versioning • Template library • Search • Web start