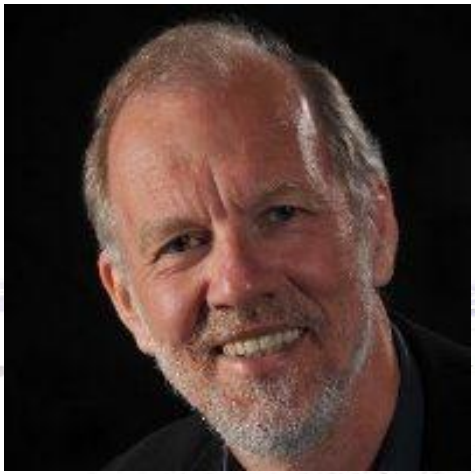
MRO SPARE PARTS MANAGEMENT
A key ingredient of **Asset Management**



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Key trends and developments related to asset management, maintenance and logistics support, exemplified with successful innovations both in the Netherlands and worldwide

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The Challenge of the Aftermarket

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BMS – South Africa, 18/19-11-2015

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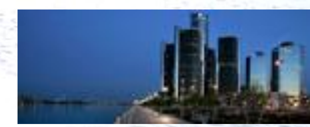
DINALOG: bridging the practicality gap in SCM/Logistics

Why a focus on the aftermarket?

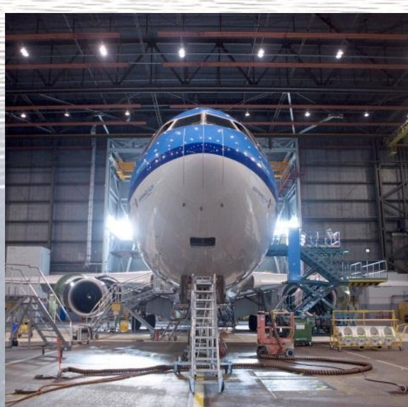
- Since 1990, more and more companies in the US, Western Europe and Japan have **stopped pushing products and started delivering the value** that customers get out of using those products (offering not just products but solutions (Cohen et al., HBR 2006))
- **Life cycle engineering and management:** life cycle design, adequate operational service (conducting repairs, installing upgrades, reconditioning equipment, inspections, technical and logistic support, spare parts and resource management), disposal and re-use**, both reduces Total Cost of Ownership (TCO) and provides significant additional revenues to service providers**
- **US service market: 8 % of GDP** (larger than all but the world's eight largest economies (Aberdeen Group studies)



- **High margins: Service accounts for 24 % of business revenues but generates 45 % of gross profits** (AMR Research, 1999)
- **Studies show that customer loyalty to a company is perfectly predicted by how they rate the firm's after sales service**

Aftermarket Service Management / Service Logistics

- Asset management / MRO / logistic support during the complete commercial life cycle
- All activities needed to not only develop and produce, but also exploit, modify, maintain, upgrade, support and finally discard capital assets



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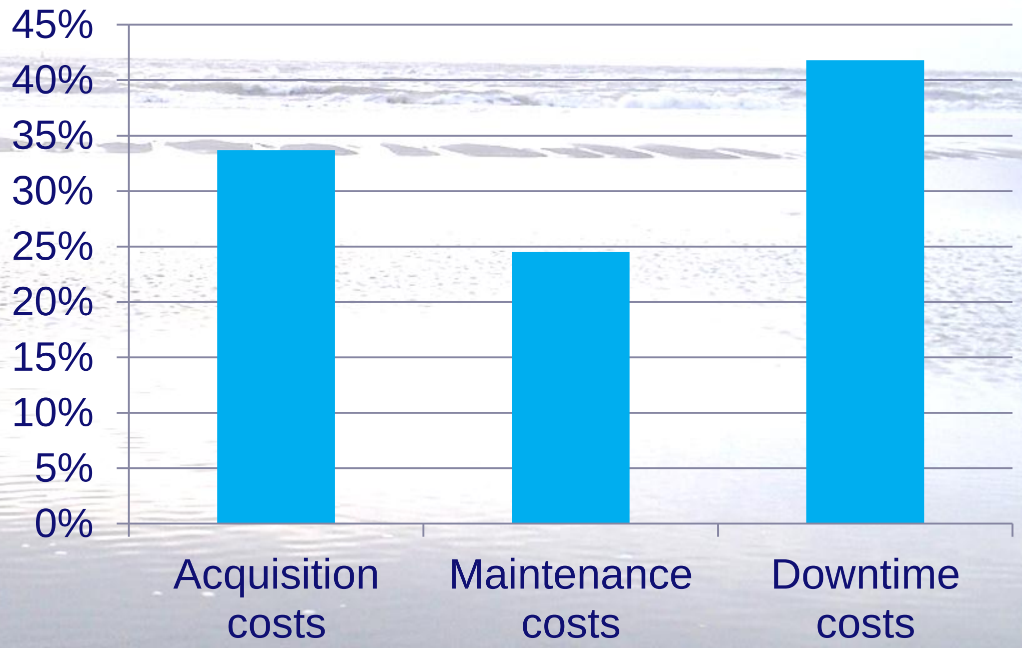
Total Cost of Ownership

The total costs during the whole life cycle (perspective: user of the system)



Characteristics of the Aftermarket Business

- Customers don't expect products to be perfect but they do expect manufacturers to fix things quickly when they break down, and are generally **willing to pay for it** (Cohen et al., HBR 2006)
- A large available installed base of long lifetime equipment generates a relative low-risk revenue stream over a long period of time.
- There is a distinct correlation between the quality of after sales service and customer intent to re-purchase.
- Monitoring systems closely for a long period of time yields invaluable information for next generation design and manufacturing.
- There is no better way of finding new customers than to point to proven relations with your existing customer base.
- After-sales services can be a source of differentiation

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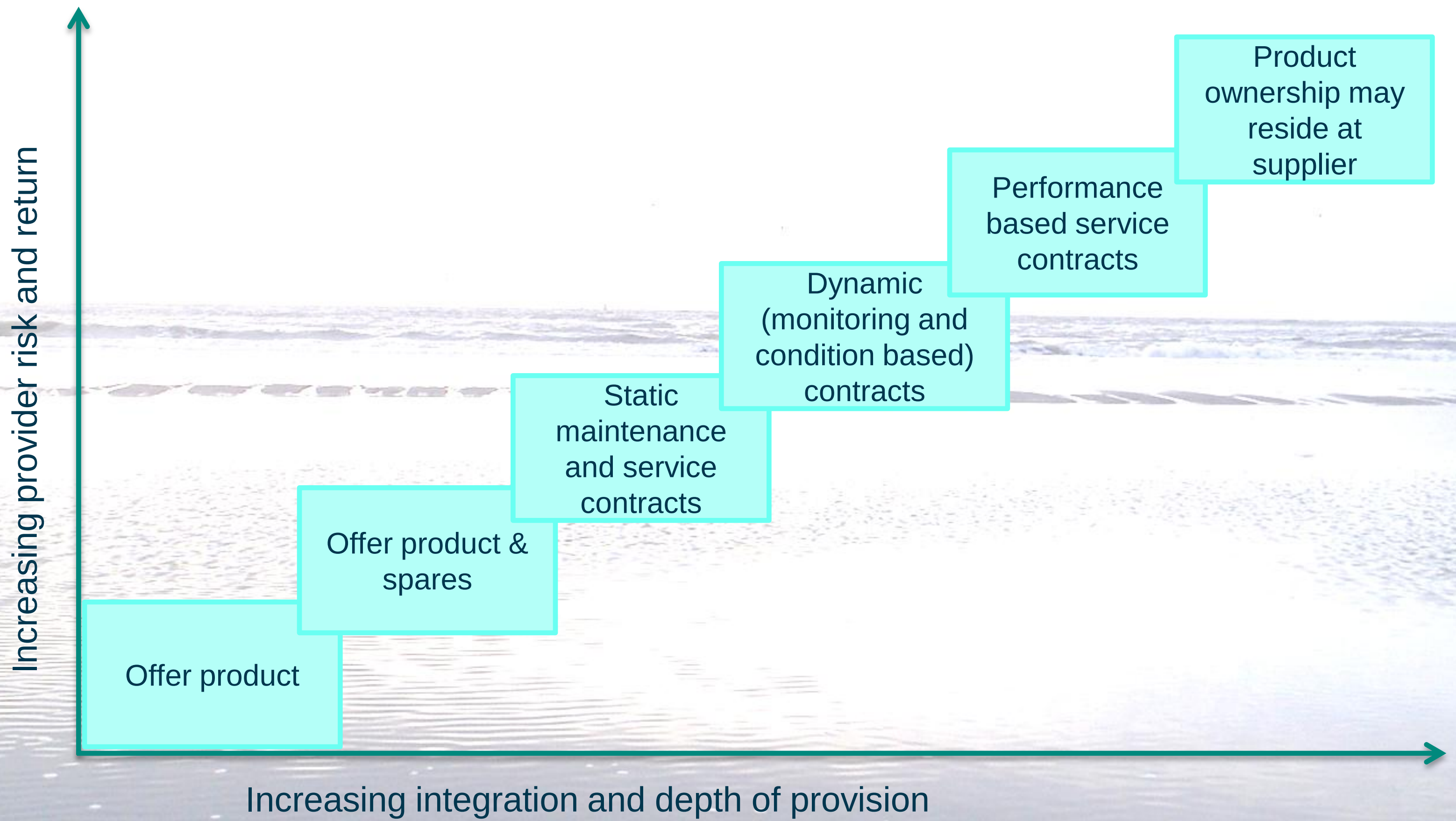
Service Market Developments



Modified after Andy Neely, Cambridge Service Alliance, 2013

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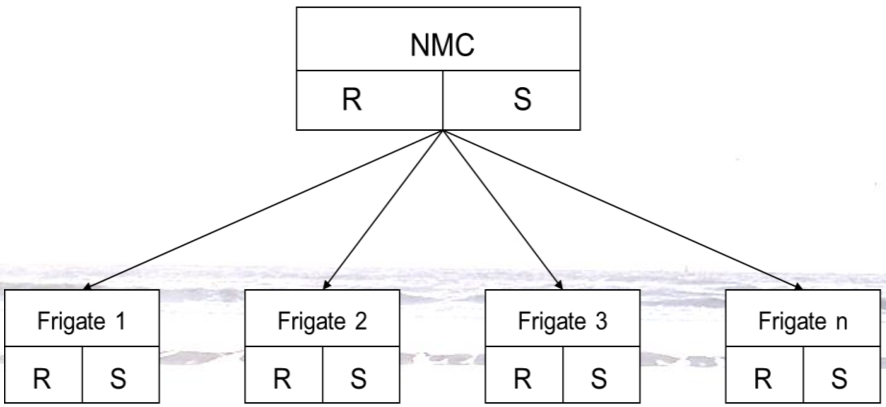
Royal Netherlands Navy Maintenance Company: repair by replacement

A system oriented approach

Geographical and product-based structures

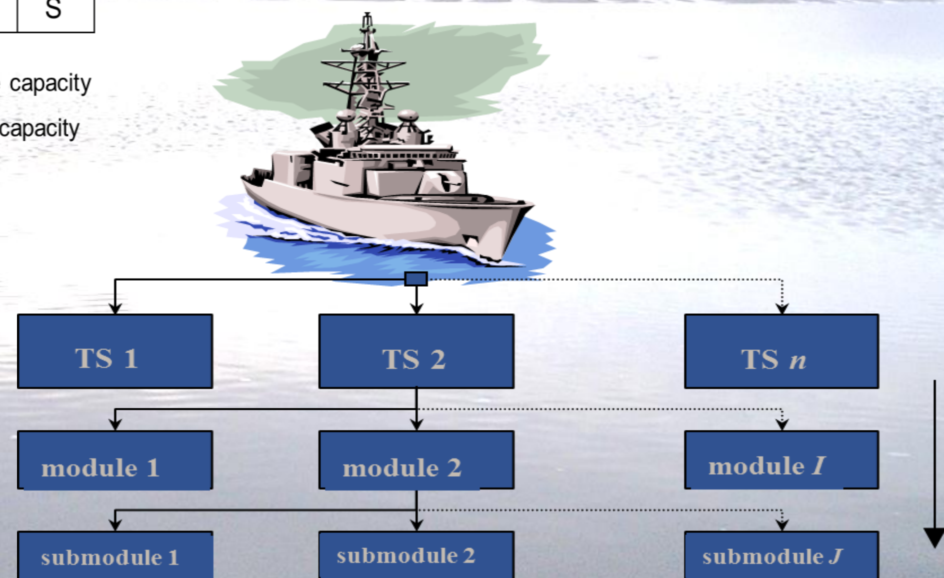


S = Storage capacity

R = Repair capacity

Location of repair facilities and spare parts storage:

- Central
- Geographic base
- At ship



Indenture level op repair:

- Subsystem
- Module
- Submodule
- Part

Radar systems (LW08)

- Spare parts investment reduction: 60 %
- Availability improved from 89 to 91 %

Goalkeeper (incoming missiles defense)

- Spare parts investment reduction: 10 %
- Availability improved from 56 to 90 %

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Typical questions that arise are …..

- What types of maintenance are appropriate (corrective, preventive, predictive)?
- Should we invest in advanced sensor technology as a step to move from TBM to CBM?
- What cost advantages can be achieved by clustering inspection/maintenance?
- What performance improvements can be achieved by system-oriented spare parts management?
- What cost reductions can be achieved by smart scheduling/grouping of maintenance activities?
- What performance improvements can be reached by early information exchange between asset owner and maintenance supplier?
- Can we simplify asset management by more commonality of LRU's / SRU's?
- What is the impact of fast repair and reliability improvement as compared to relying on buffer stocks?
- What values does a life cycle approach bring (and for who)?
- How to share these cost reductions / benefits? What is the business model?

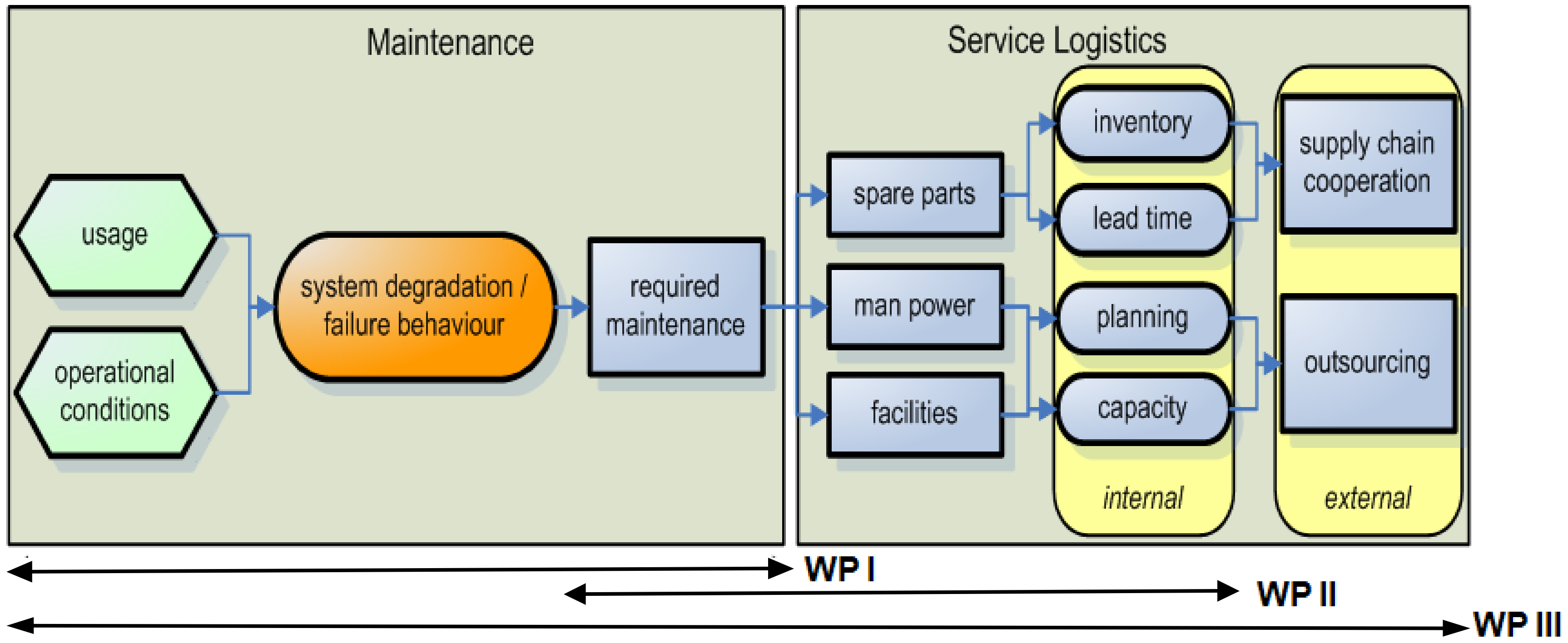
… etc, etc.

Research projects & industrial collaboration

- **SLF-R**: service differentiation
- **IOP-IPCR**: spare parts & LORA
- **ProSeLo**: Pro-active Service Logistics and re-use
- **MaSelMa**: dynamic maritime maintenance/service
- **SINTAS**: Impact of 3D printing on maintenance & service logistics
- **QRF**: Optimal resource exploitation (parts, people, tools)

Example project: MaSelMa

Maintenance and Service Logistics for Maritime Assets



WP I Improve the predictability of maintenance (physics of failure, statistics)

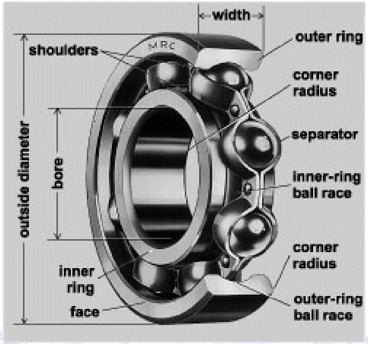
WP II Data driven service logistics planning and control models

WP III Improve/extend service supply chain cooperation; sound business models

Performance Improvement by CBM

Bearing failure:

Degradation signal crossing a pre-specified threshold value



Policy change:

From static time-driven policy
to dynamic sensor-based policy

Results:

Total cost reduction of 55 % (from $ 500 to $ 228)

Ref: Elwany and Gebraeel (2008)

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Clustering condition-based maintenance actions

1. Separate maintenance decision for each component according to (multi-threshold) control limit policy

2. system level: adjust former decision using opportunistic replacement threshold

3. determine next a priori scheduled intervention date.

Result:

Overall average cost reduction of 25 % of clustering policy, as compared with mono-component policy

Ref: Castanier et al. (2005)
Van Dijkhuizen (2000)

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Clustering condition-based maintenance actions

- Simulation model setting
  - Multi-ship, multi-component model
  - Different components in a single system
  - Each replacement action incurs a setup cost
  - Components with different MTTF and degradation rates depending on environment and usage

- Opportunistic policy
  - Combine dock replacement and harbor replacement of an LRU with opportunistic replacement of other LRUs

Results:

Total cost decrease of 41% as a result of combining replacement of different components, as compared to mono-component age-based preventive policy

Ref: Eruguz and Tan (2015)

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Smart scheduling of inspection/maintenance activities

Static joint maintenance interval

Components are jointly maintained at the upcoming maintenance time if their physical conditions exceed the specified control limits (20 wind turbines, 3 comp.)

Results:

80% cost reduction can be achieved by implementing an optimal maintenance policy, as compared to the former corrective maintenance policy

Ref: Zhu et al. (2014)

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Information exchange between asset owner and service supplier: operations based maintenance

Repair and Maintenance costs represent a value of 60% of the initial purchasing value

Incorporating part conditions (the age of the parts in operation, e.g., flight hours) in an inventory replenishment policy (PABS policy)

Results:

On average a 20% inventory cost reduction

Ref: Deshpande et al. (2006)
Fleuren (2013

The impact of LRU commonality

US Air Force: F-16
30 bases
Engines of:
Pratt & Whitney
General Electric

Pooling:

- Location aggregation
- Product aggregation

Results:

Overall safety stock reduction of 80 %

Ref: Ferrer (2010)

Trade-off between inventory and speed of repair decisions

<u>Study</u>:
critical components of 40 air vehicles
(engine, propeller, avionics computer)

Similar studies at Thales and Nedtrain

<u>Overall results</u>:
Component reliability and repair system efficiency
have a much higher impact on system availability
then repairable spare parts inventory optimization

Ref: Mirzahosseinian and Piplani (2011)
Van der Heijden et al. (2013)
Parada Puig and Basten (2014)

The value of life cycle engineering

TCO analysis related to coating degradation and corrosion of steel vessels

(Westerweel, 2014)

Integration of decisions on reliability level and spare parts planning for critical components leads to a 44% reduction of TCO (Öner et al., 2010)

Ref: Westerweel (2014)
Öner et al. (2010)

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DAF
A PACCAR COMPANY

Preventive Repair Actions in Multi-Component systems @ DAF Trucks N.V.

Repair and Maintenance costs represent a value of 60% of the initial purchasing value

Rule of Thumb:
Costs incurred with one roadside breakdown are equal to the profit margin on a truck of one month

	Savings Compared with Corrective Maintenance
Component 1	17,69%
Component 2	0,00%
Component 3	16,64%
Component 4	18,80%
Component 5	0,00%
Component 6	8,09%

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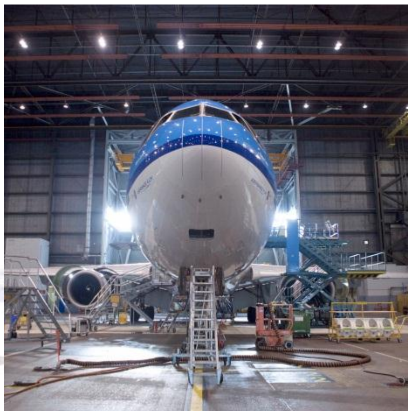
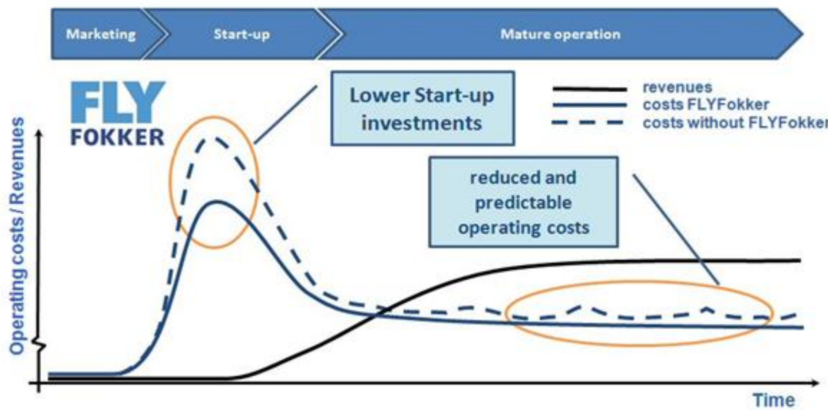
Pooling resources at Fokker Services

Fokker SERVICES

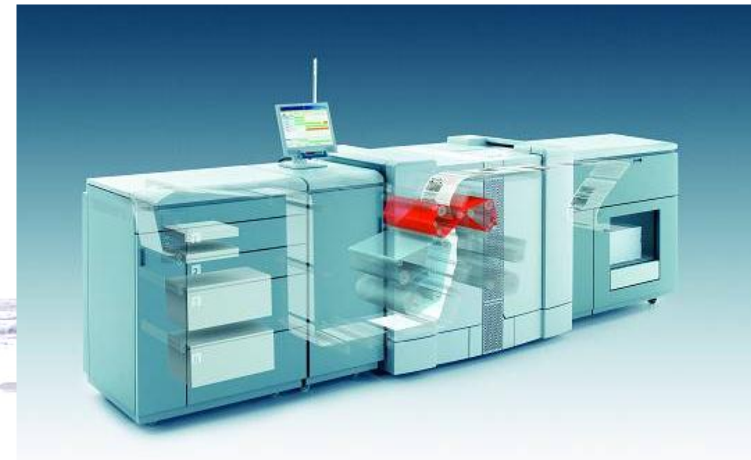




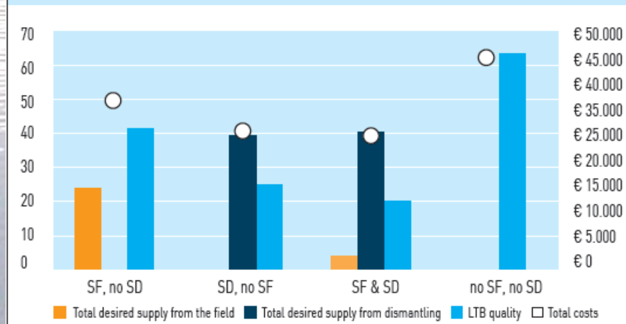
Ref.: http://www.flyfokker.com/Services

Last-time buy decisions and return flows

Result: 22 % lower costs of LTB by dismanting former systems and re-use of their components



Scenario	SF, no SD	SD, no SF	SF & SD	no SF & no SD
Total desired supply from the field	24	0	3	0
Total desired supply from dismantling	0	40	40	0
LTB quality	41	25	22	65
Total costs	€ 36.290	€ 29.757	€ 28.853	€ 45.369



ASML: worldwide service provision

ASML is one of the world's leading providers of lithography systems for the semiconductor industry.

What is Service Logistics at ASML?

Connecting with customers and suppliers and strong focus on directly improving availability and cost of operations, supplying spare parts through worldwide network and commitment to outstanding customer support!

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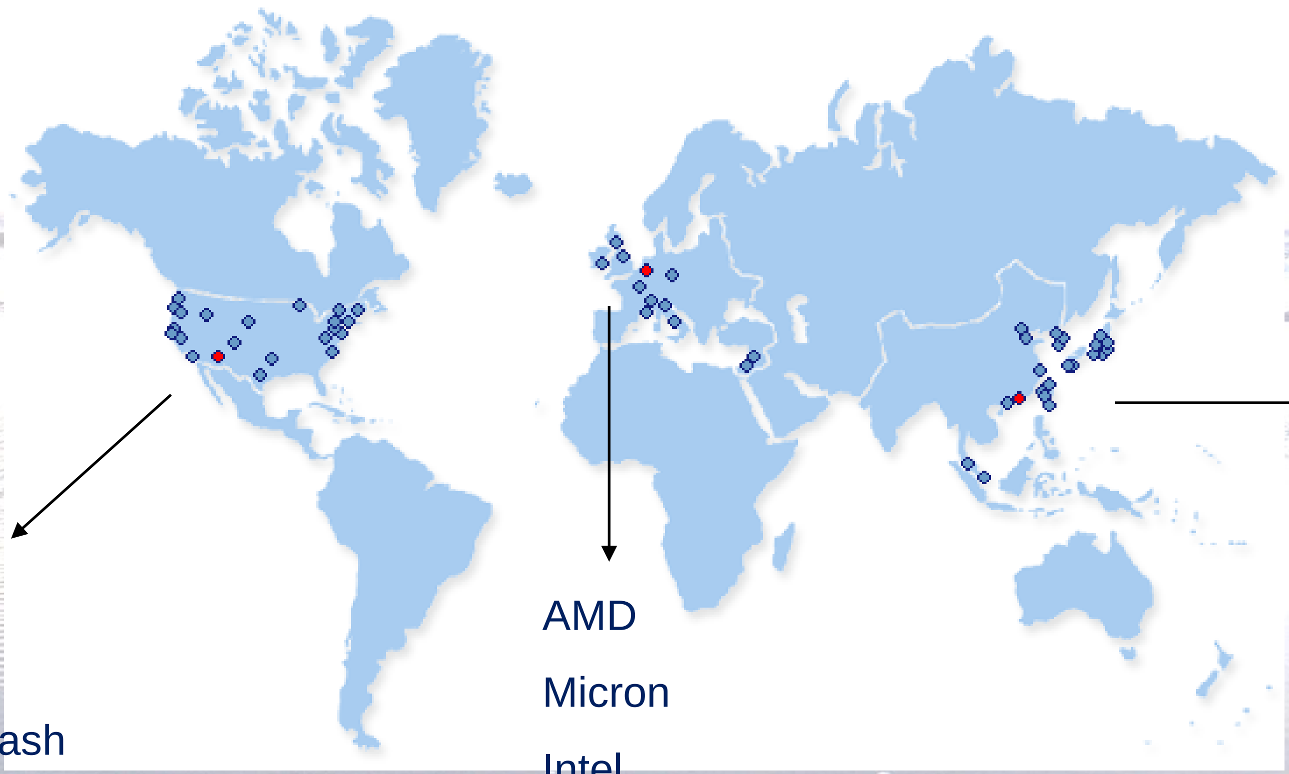
Worldwide Logistics: Different regions

ASML

Regional organized (USA, Europe, Asia)



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IBM
TI
IM Flash
Micron
Samsung

AMD
Micron
Intel
Microelectronics

Samsung
TSMC
Hynix
Toshiba
UMC
Panasonic

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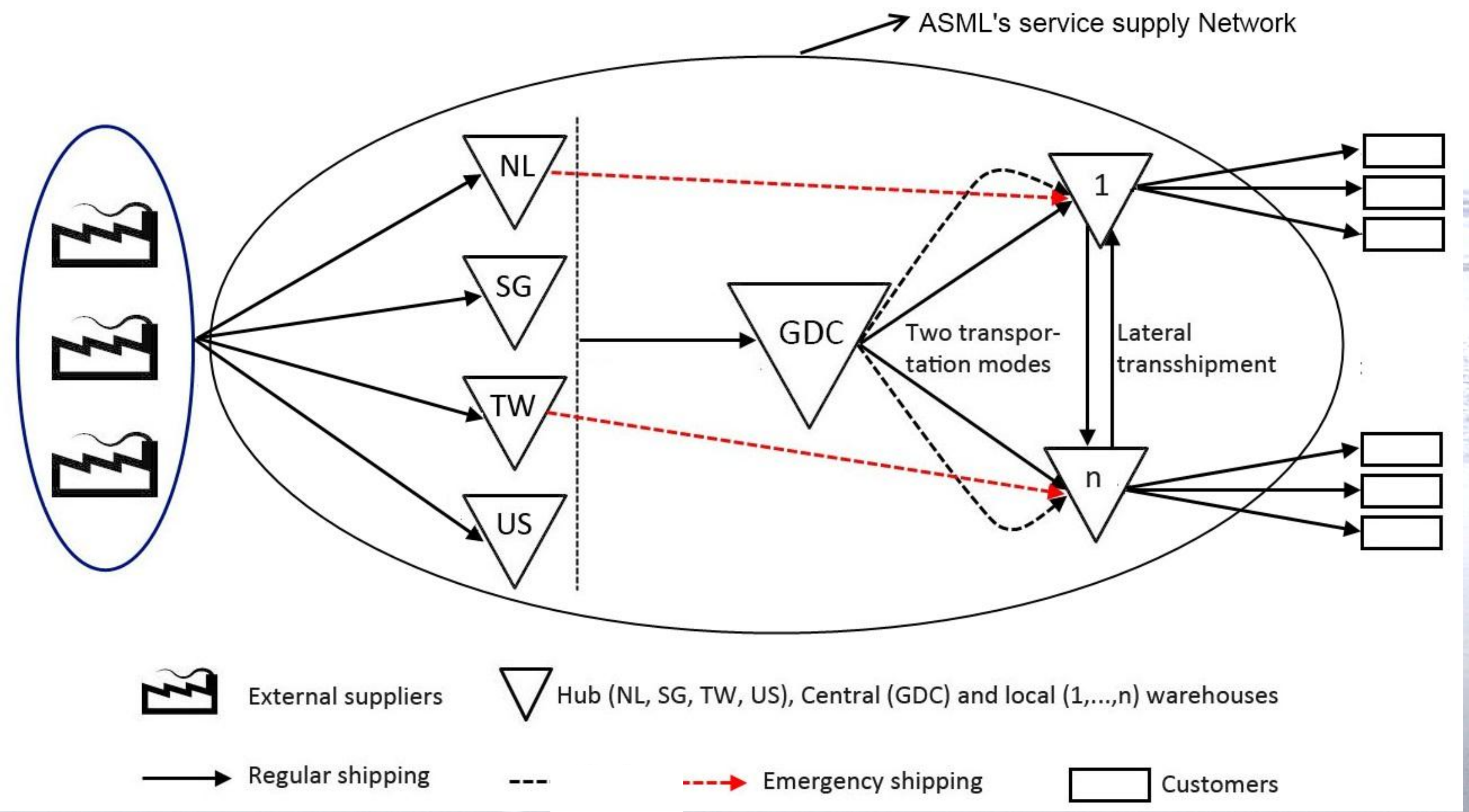
Service Supply Network: Optimization of spare parts allocation

ASML



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Remote condition monitoring to prevent unplanned maintenance

ASML

Impact at ASML:

- Based on data mining, algorithms were devised that predicted 70 % of breakdowns correctly, with no false predictions
- Preventive maintenance has gained significantly, leading to better planned maintenance and a severe reduction in spare parts stocks

CBM Implementation

CBM design

- Selection of a unit to monitor
- Selection of the condition indicator(s)
- Determine a prognostic modeling approach
- Determine the maintenance policy

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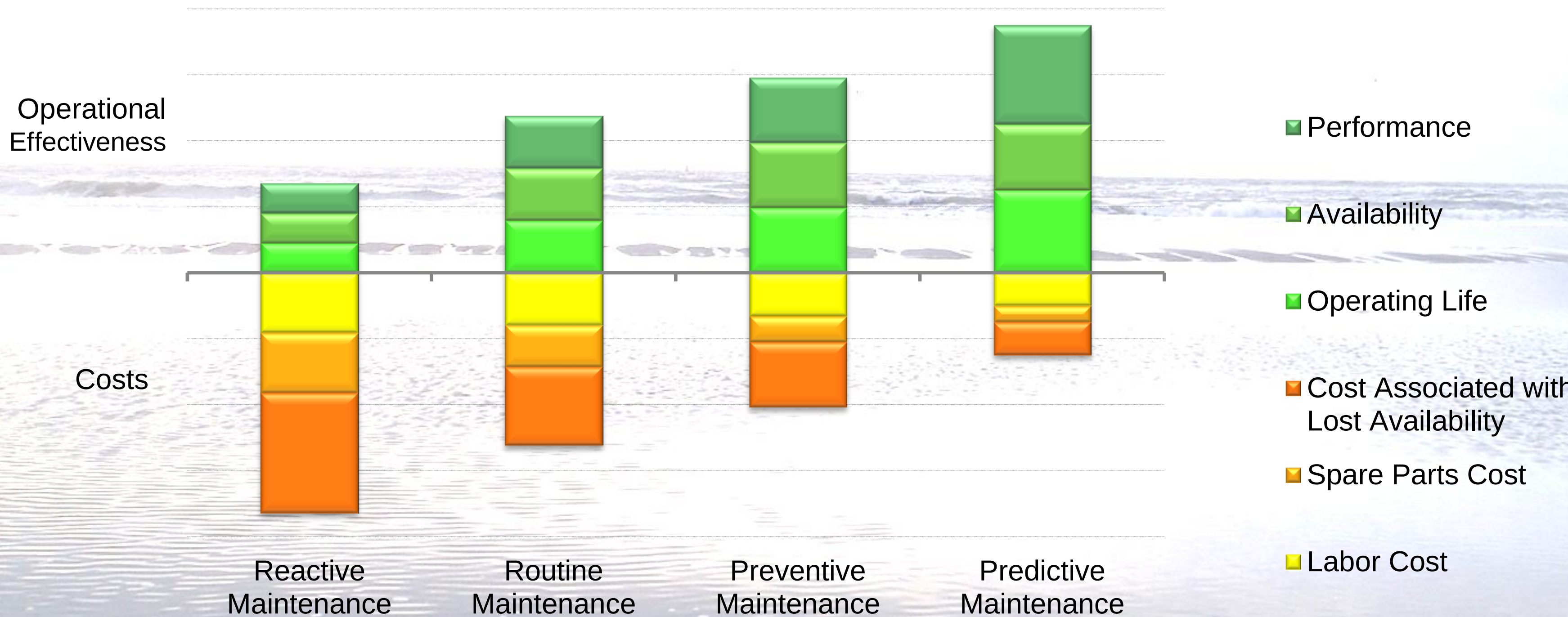
Increasing the Operational Effectiveness and Lowering the Total Cost of Ownership of a client’s Material Handling System



From Maintenance to Asset Management

- Maintenance of complex systems gets increasingly complicated for asset owners
- Asset owners require higher system availabilities (less downtime)
- Asset owners consider TCO as key performance indicator

- Maintenance is outsourced to OEM’s or specialized service providers (pooling of resources, pooling of data, remote monitoring)
- More extreme: One sells the function plus system availability
- Feedback to design (better systems, improved sustainability)

Conclusions

- An increasing number of companies recognizes the potential of smart asset and service management to improve systems performance at reduced operating costs
- Implementation however is not easy and requires careful design of both methods, tools and infrastructure.
- Adequate data recording provides a starting point, while tools based on sound analytical methods are indispensible to reach quantifiable results. In addition, significant effort is needed to train employees / staff
- Impact of new technologies may significantly enhance service possibilities (remote sensing and diagnostics, 3D printing, etc.)
- Even more important is the design of sound business models that clearly demonstrate the win-win, and achieves a fair allocation of the benefits to both asset owners and service providers.

Questions/discussion?