NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT

PUB REF STO-MP-SAS-114-PPG

ANNEX G
Report on SAS-114 Experiment on Analysis of Competing Hypotheses

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Overview

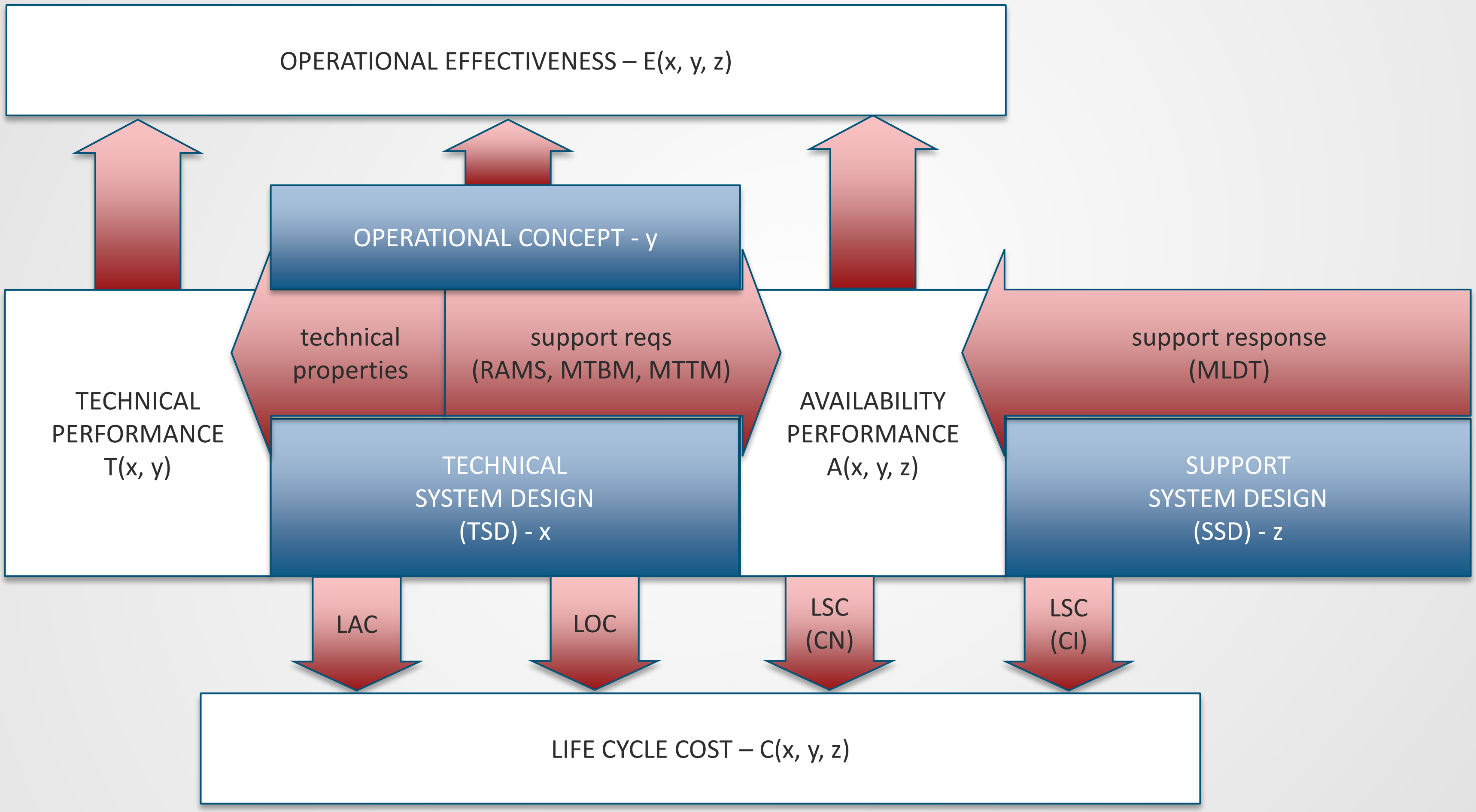
- Background
- Systems and logistic engineering
- Traditional Approach vs Holistic Optimization
- Examples
- Conclusions

Background

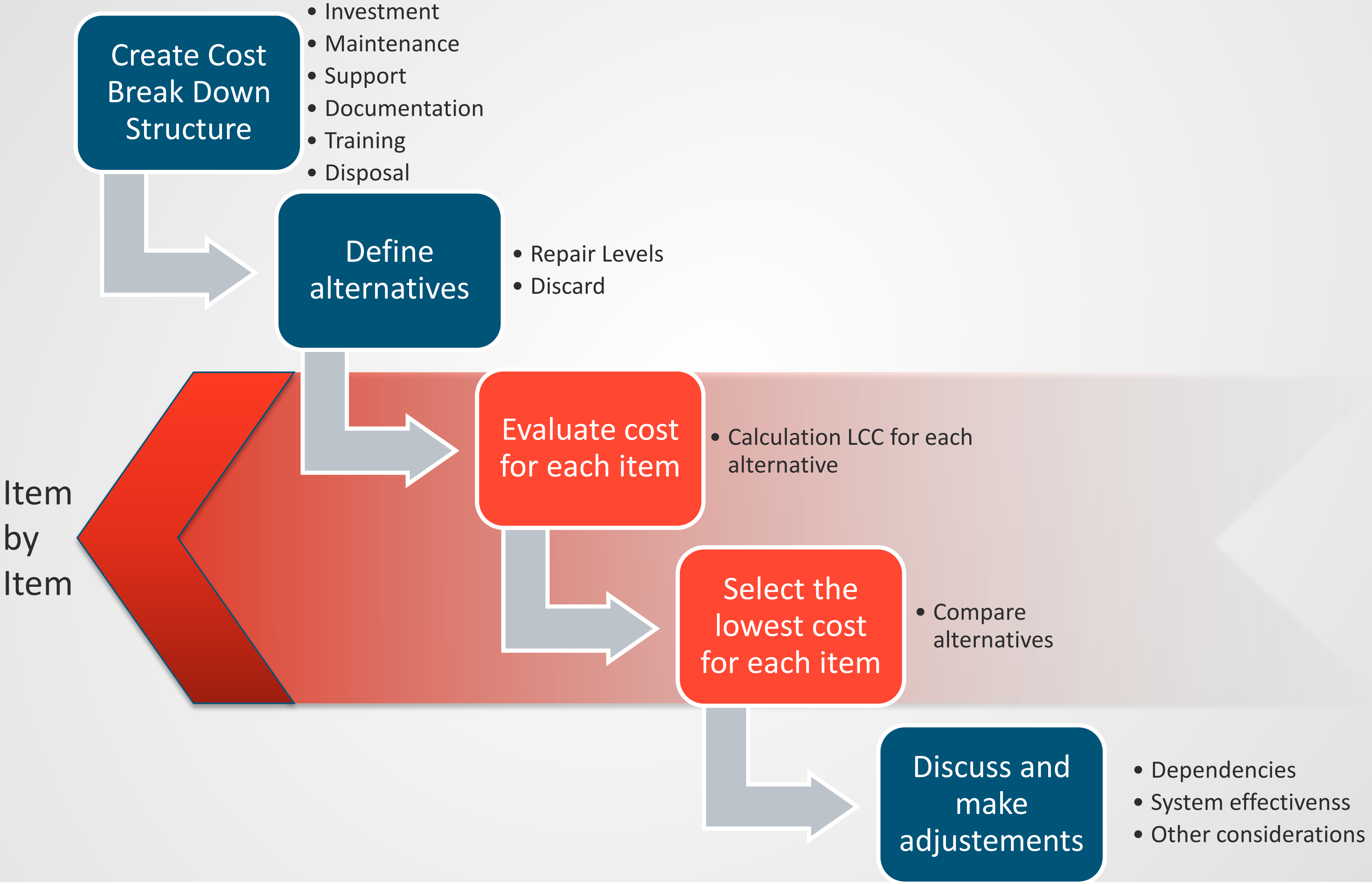
- Traditional LORA – *Level of repair analysis* – is a method which focus on each item to decide at what level in the organization the item should be repaired or if it should be discarded from a cost perspective.
- Traditional LORA was developed for symmetrical organizations at a time when calculation power was low.
- The design decision made in the Systems and Logistics Engineering processes aims to produce a system with high operational capability at a low cost
- Traditional analytic methods are too simplified and fail to handle the strong dependencies between the maintenance locations and investments in spares and resources as well as asymmetries in the support organization
- Traditional analysis does not take the overall system availability or mission effectiveness into consideration and does not optimize for cost effectiveness.
- By combining modern spare parts optimization methods with maintenance capability analysis cost effective decisions can be reached quickly and accurately at a lower total Life Cycle Cost and higher system availability than with traditional methods.

SYSTEMS AND LOGISTICS ENGINEERING

THE BASICS – ALL IN ONE PICTURE



Traditional analysis procedure



Changing world

- Non-symmetrical organizations
- Organizations that are changing quickly
- Operations and deployments that are changing quickly
- More complex technical system
- Fast technological development
- More contractor logistics and maintenance
- Better Algorithms
- Faster Calculations

Need for more capable, faster and flexible methods.

Traditional LORA Scope

Type of analysis	Criteria	Scope of Analysis
Item-By-Item evaluation	Total Cost over Lifetime (LCC)	Repair or Discard Level of Repair How to repair

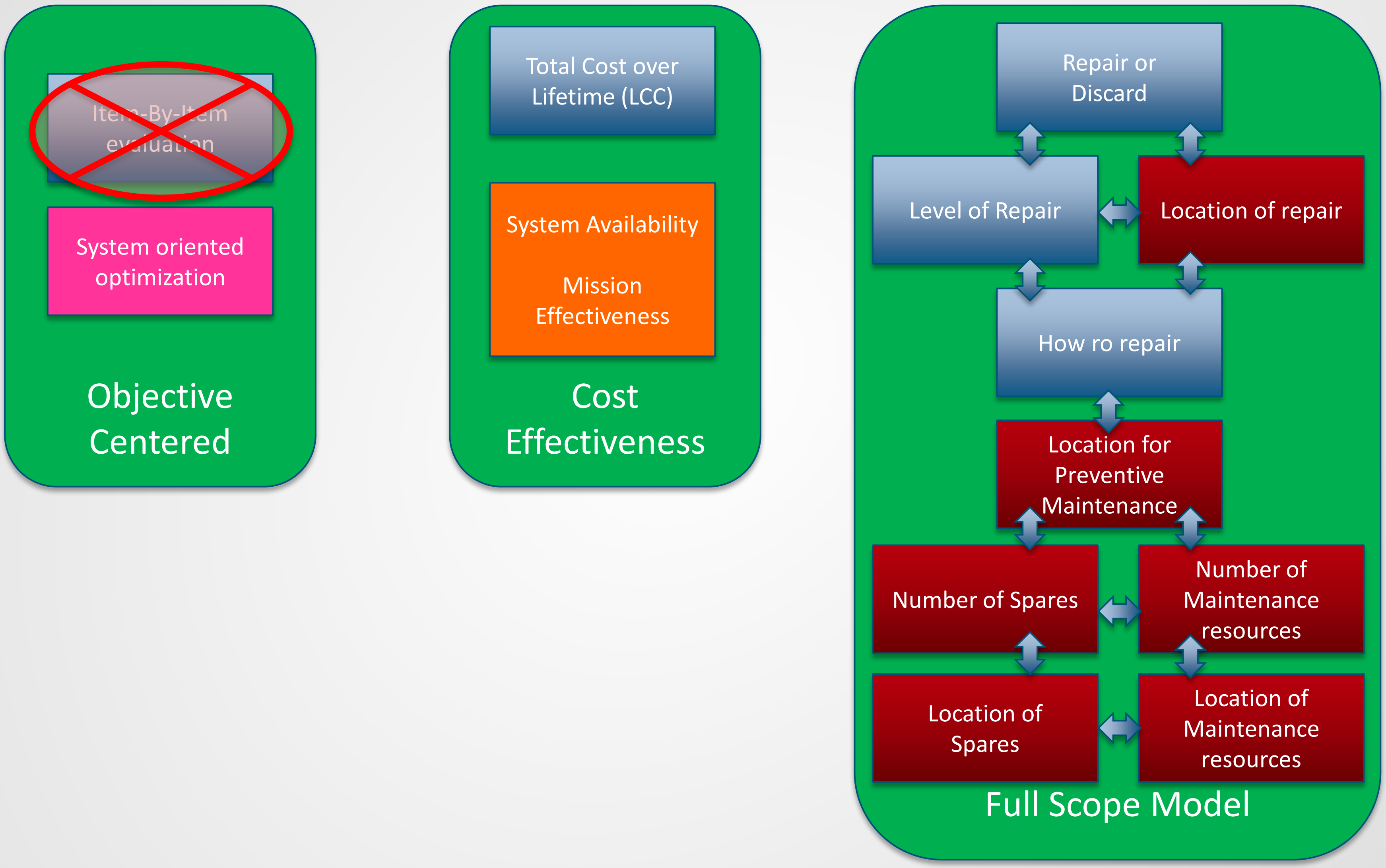
Traditional LORA

Lowest cost for each individual item, a low total cost, no understanding of mission impact

Traditional Analysis

Important aspects are missing

Type of analysis | Criteria | Scope of Analysis

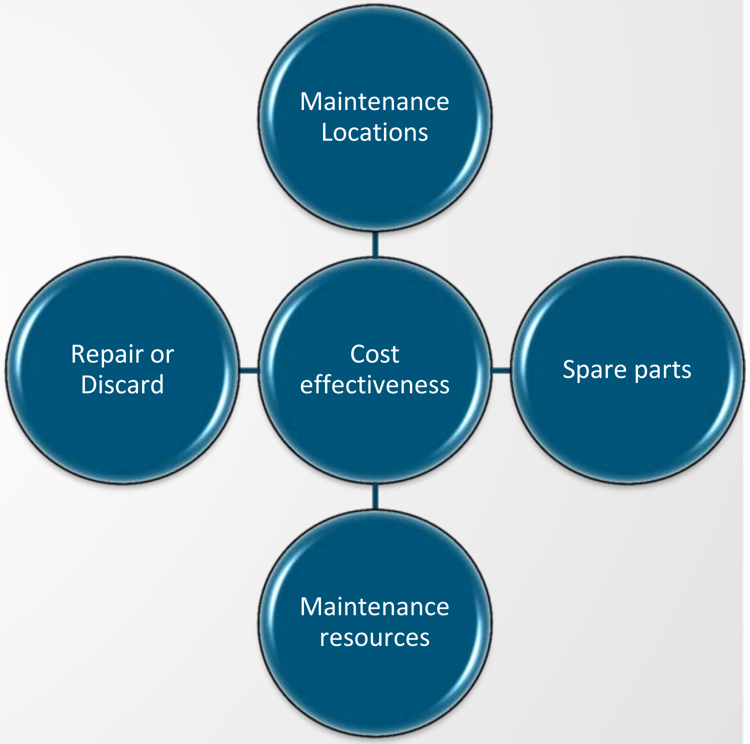


Maintenance Concept Optimization

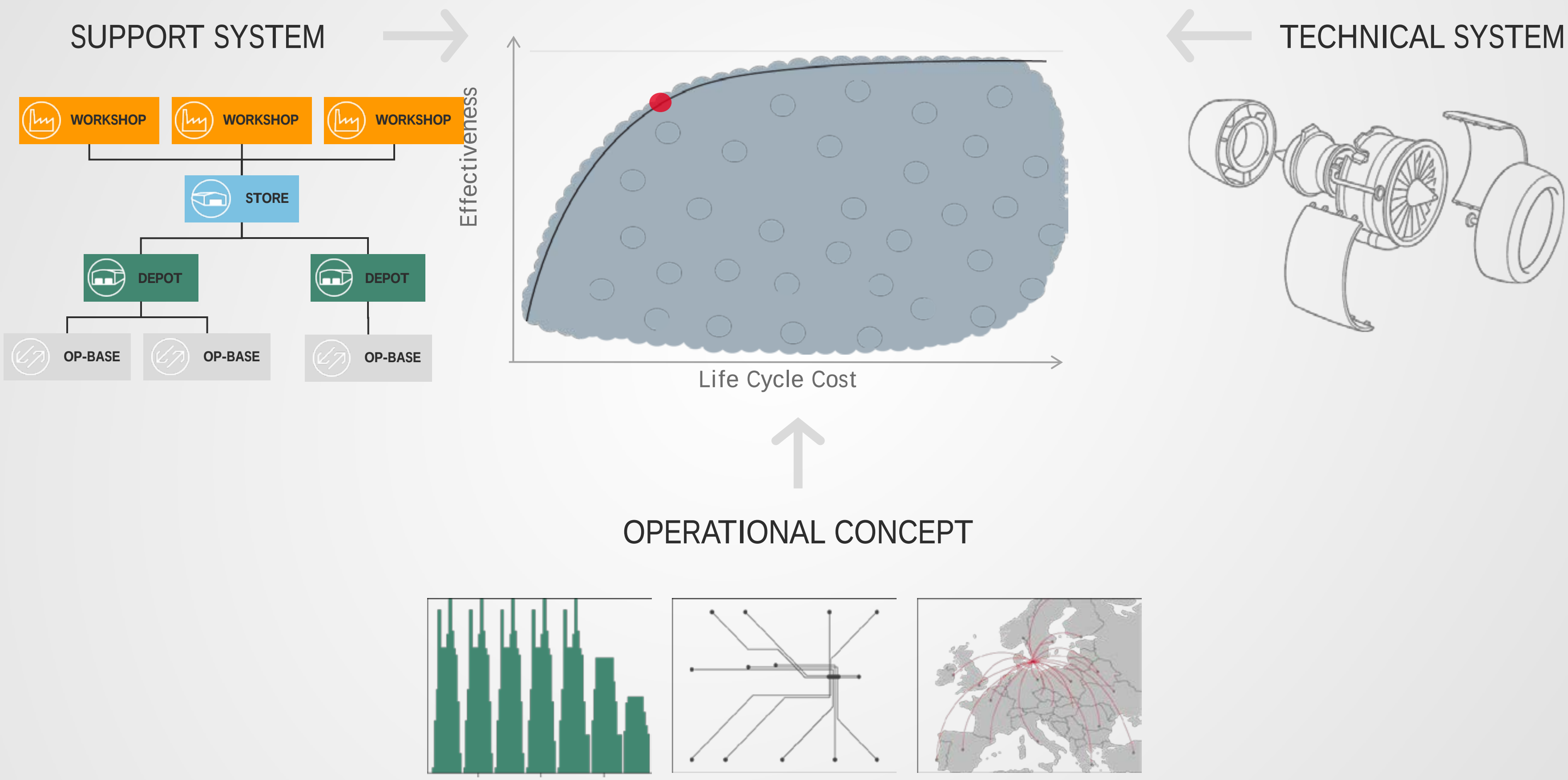
- **Full Scope Model** that handles
  - Non symmetrical organizations
  - Complex support strategies
  - Preventive maintenance
  - Spare parts
  - Resources (Tools, technicians etc)
- **System Cost Effectiveness** as objective function
  - Cost-Effectiveness for the system
- **Optimize** instead of just evaluating
- Simultaneous calculations to handle dependencies

Achieving Maintenance Concept Optimization

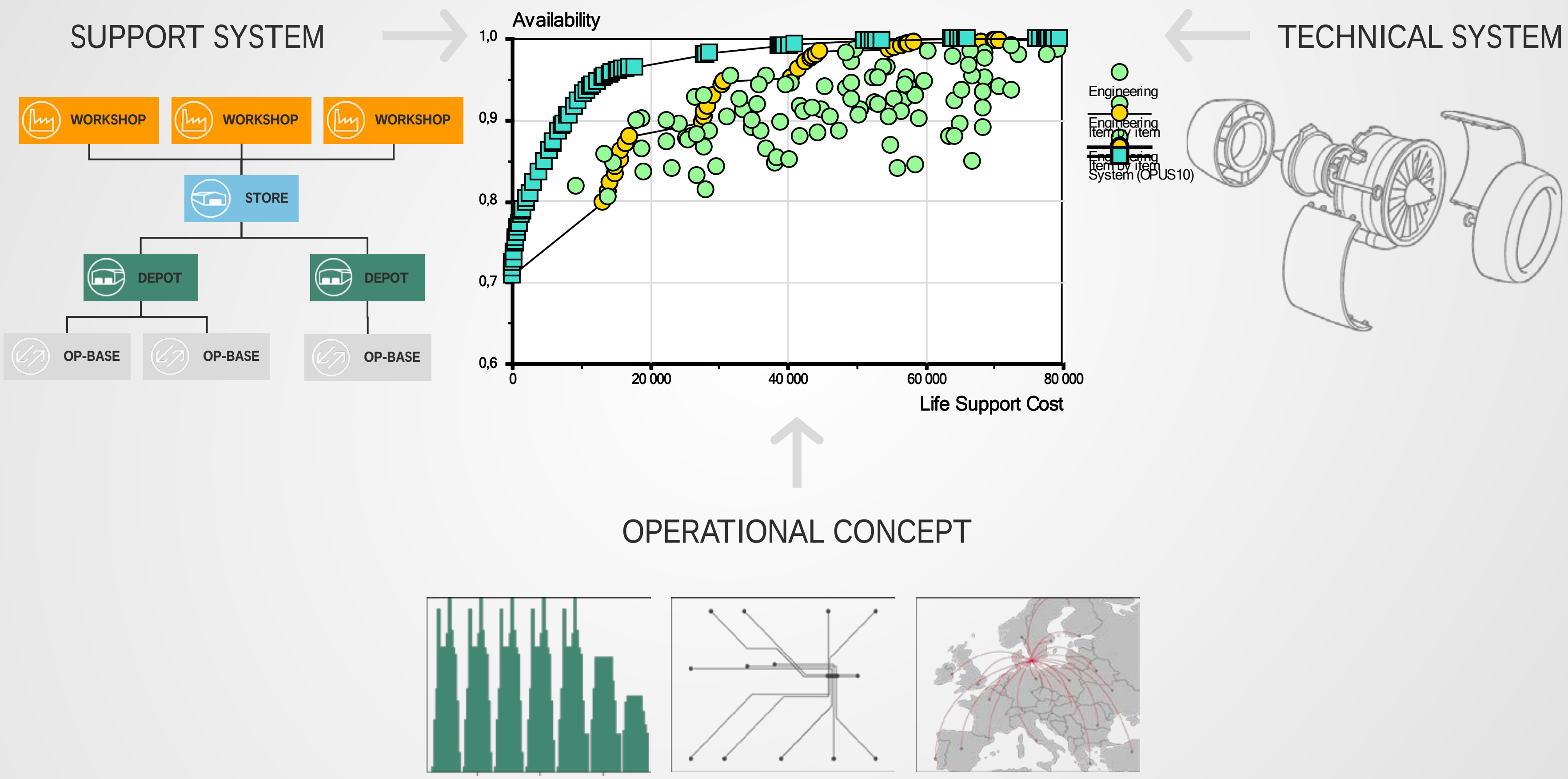
- Use modern methods for evaluating system performance
  - Spares optimization and support system analysis
- Expand the models to handle different maintenance concepts
- Simultaneous optimization of maintenance locations, maintenance resources, spare parts and repair/discard decisions



System Cost Effectiveness



System Cost Effectiveness, optimization



Benefits of holistic modeling over traditional analysis methods

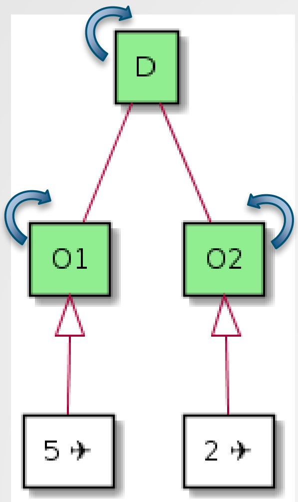
- Higher Availability
- Lower costs
- Flexible non symmetrical support
- Flexible non symmetrical operations
- Handles different configurations for systems
- Accurately describe dependencies
- Faster calculations
- Reusable models
  - Develops throughout the life cycle of the system

Examples

- Small example
  - Demonstrating the effect of not optimizing for system cost – effectiveness
- Large Scale Example
  - Demonstrating the usability of the method in a large scale example

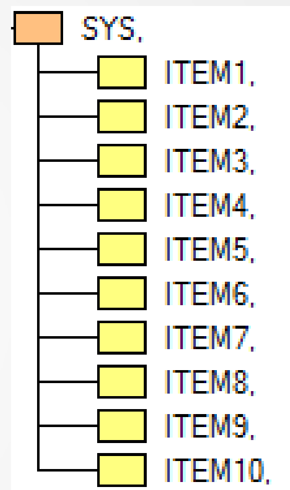
Small example

SUPPORT SYSTEM



- Replace all faulty parts at O-level
- Repair items at any combination of D, O1, O2
  - D
  - O1, O2
  - D, O1
  - D, O2
- Calculate an optimal spare parts assortment
  - 90% availability
- Compare with a calculation when we use a Poisson calculation to set a maximal Risk of Shortage for each part to 10%
- Where should we repair and what will be the stock?

TECHNICAL SYSTEM

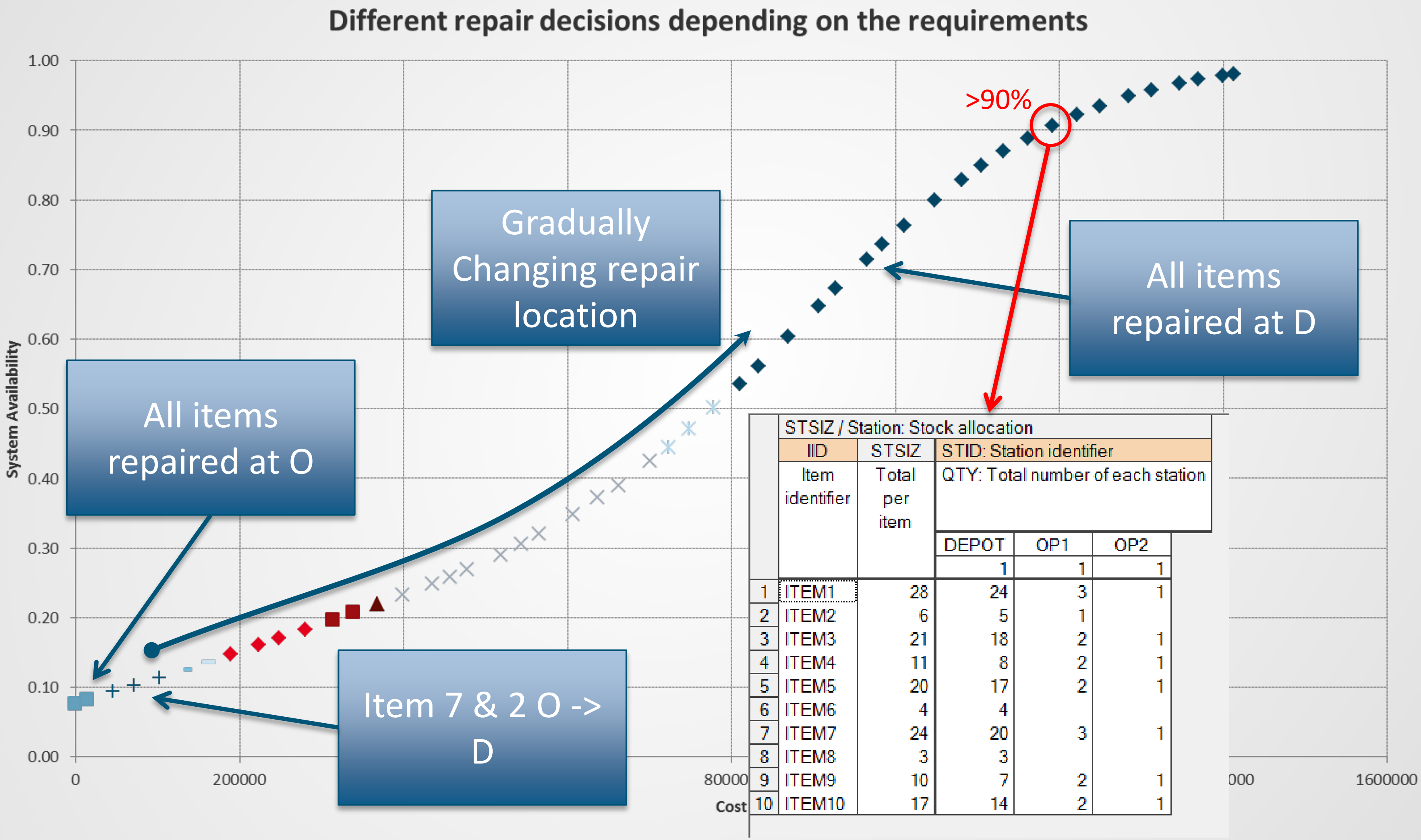


Build model

Run Model (0.38 sec)

Review Results

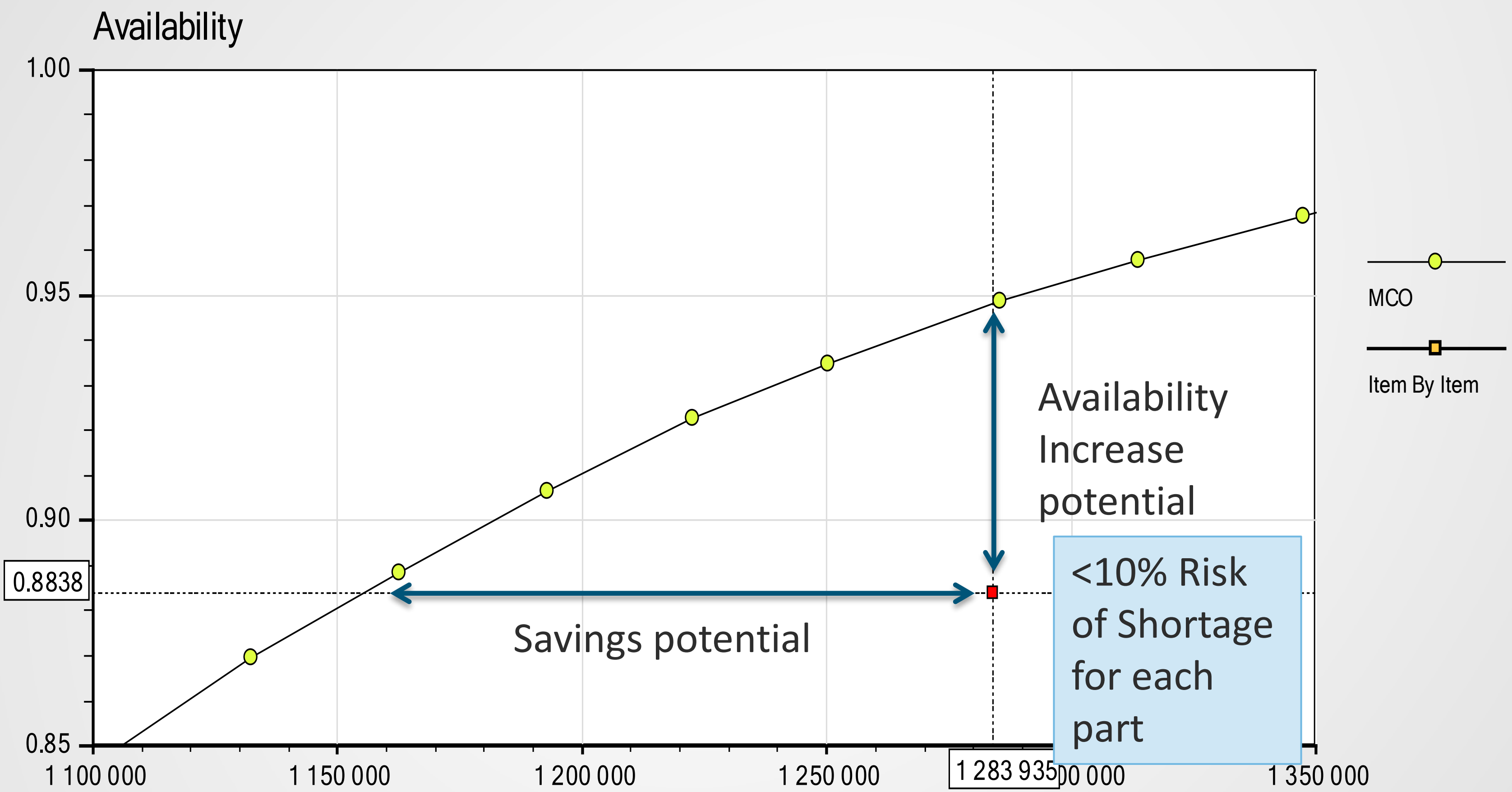
Results of holistic optimization



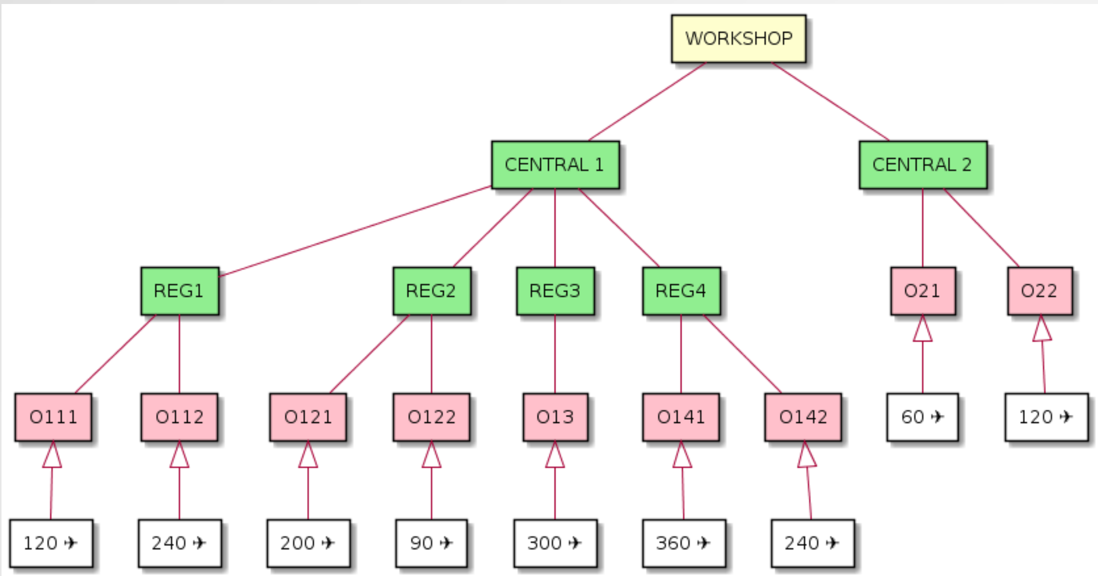
STSIZ / Station: Stock allocation

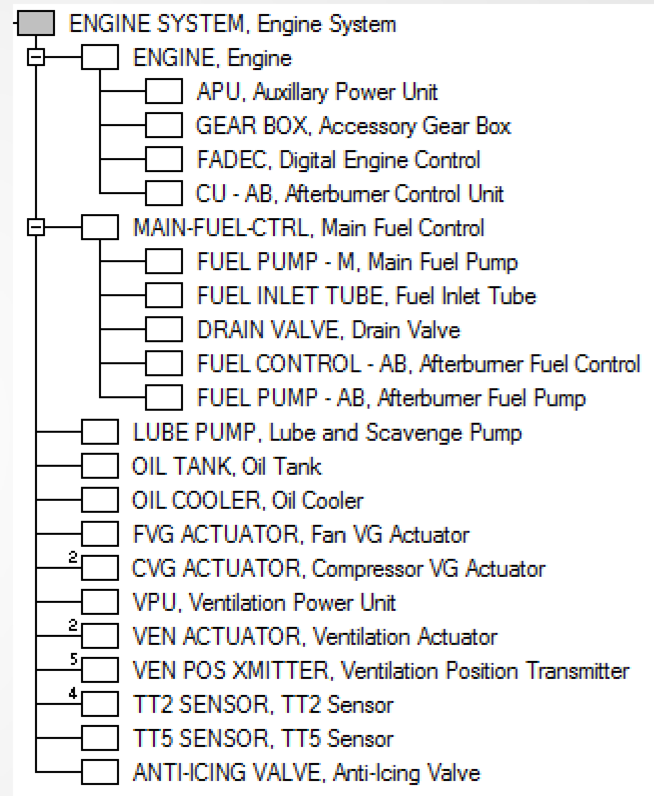
	IID	STSIZ	STID: Station identifier		
	Item identifier	Total per item	QTY: Total number of each station		
			DEPOT	OP1	OP2
			1	1	1
1	ITEM1	28	24	3	1
2	ITEM2	6	5	1	
3	ITEM3	21	18	2	1
4	ITEM4	11	8	2	1
5	ITEM5	20	17	2	1
6	ITEM6	4	4		
7	ITEM7	24	20	3	1
8	ITEM8	3	3		
9	ITEM9	10	7	2	1
10	ITEM10	17	14	2	1

Small Example, Compare Item by Item with holistic



Large Scale Example





- Focus on **Engine System**
  - **ENGINE**
  - **FUEL CONTROL**
  - **OTHER PRIMARY ITEMS**
- 30 years of operation
- 1730 aircraft
- 9 different operational bases
- 2 central / 4 regional depots
- Where and how should we repair the parts?

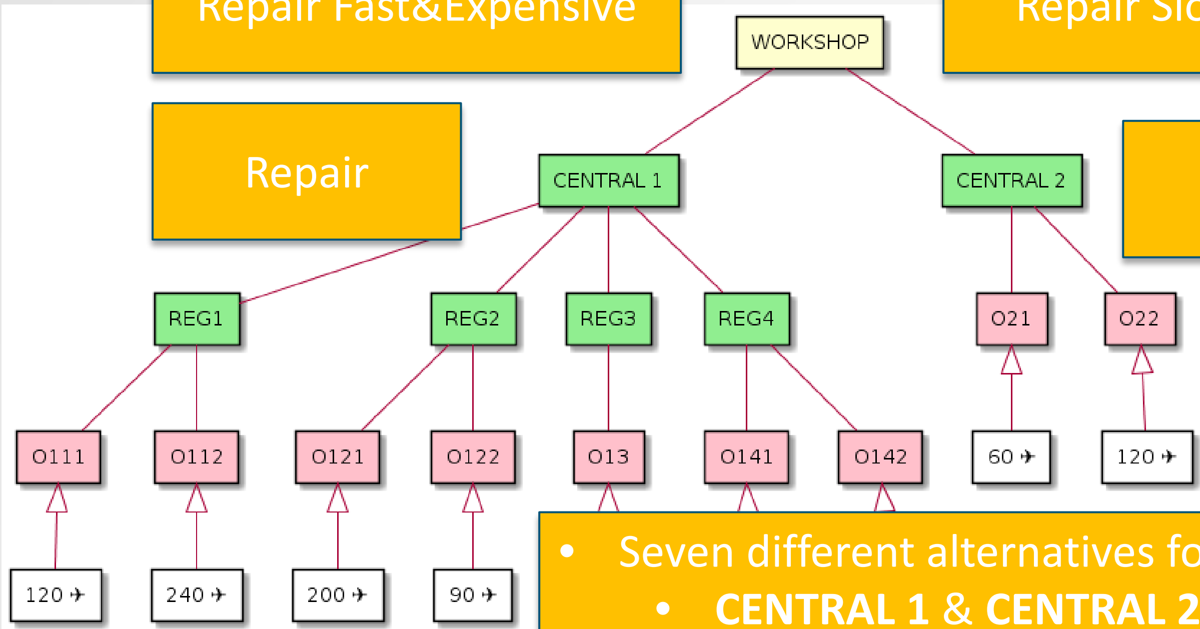
Alternatives - Primary Items Options

Repair Fast&Expensive

Repair Slow&Cheap

Repair

Repair



- Seven different alternatives for repair locations
  - **CENTRAL 1** & **CENTRAL 2**
  - **CENTRAL 1** & Fast @ **WORKSHOP**
  - **CENTRAL 1** & Slow@ **WORKSHOP**
  - **CENTRAL 2** & Fast @ **WORKSHOP**
  - **CENTRAL 2** & Slow@ **WORKSHOP**
  - Fast @ **WORKSHOP**
  - Slow @ **WORKSHOP**

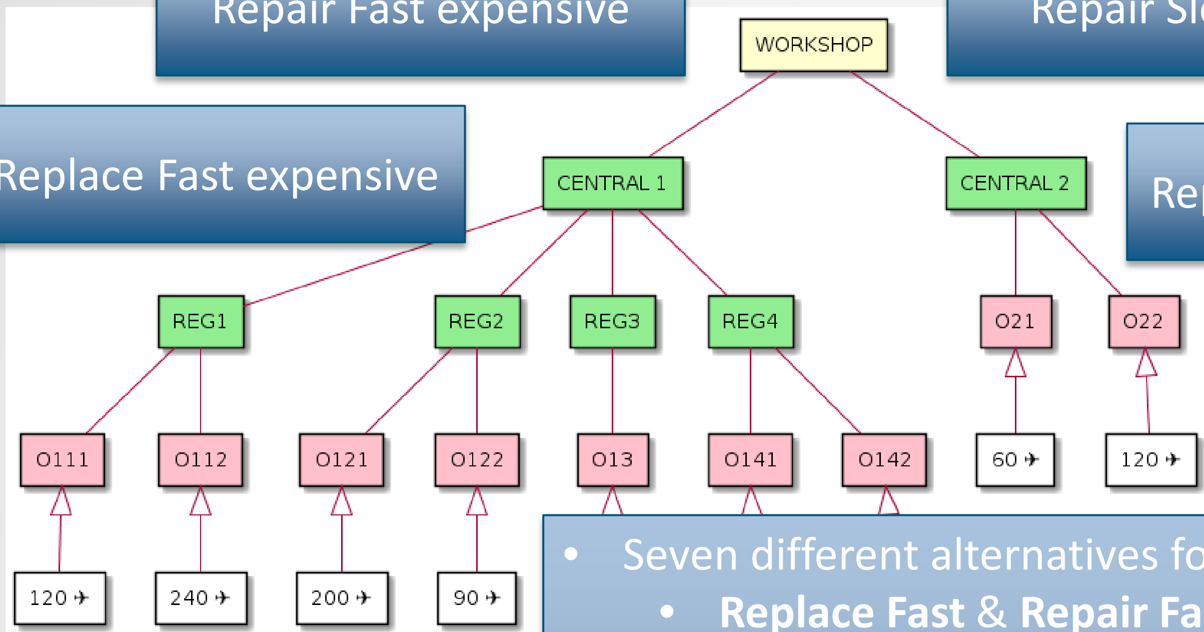
Alternatives - Engine Options

Repair Fast expensive

Repair Slow Cheap

Replace Fast expensive

Replace Slow Cheap



- Seven different alternatives for repair& replace
  - **Replace Fast & Repair Fast**
  - **Replace Fast & Repair Slow**
  - **Replace Slow& Repair Fast**
  - **Replace Slow & Repair Slow**

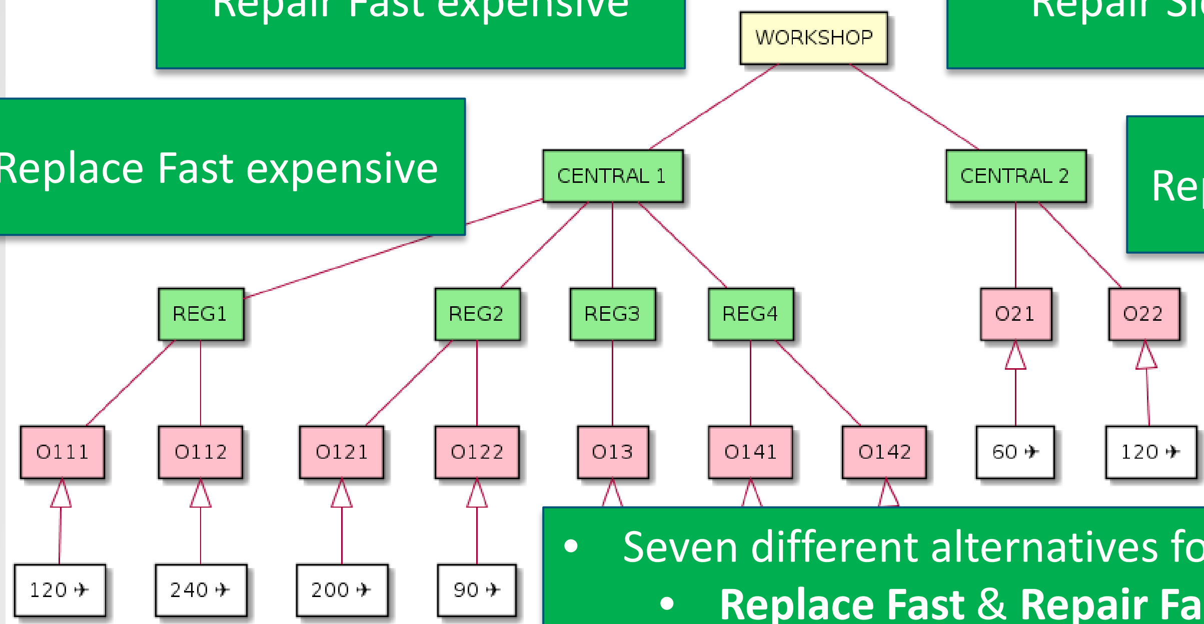
Alternatives - Fuel Control

Repair Fast expensive

Repair Slow Cheap

Replace Fast expensive

Replace Slow Cheap



- Seven different alternatives for repair& replace
  - **Replace Fast & Repair Fast**
  - **Replace Fast & Repair Slow**
  - **Replace Slow& Repair Fast**
  - **Replace Slow & Repair Slow**

Alternatives

- A total of 112 alternative strategies
  - 7 *4 *4
- 4 strategies are cost effective

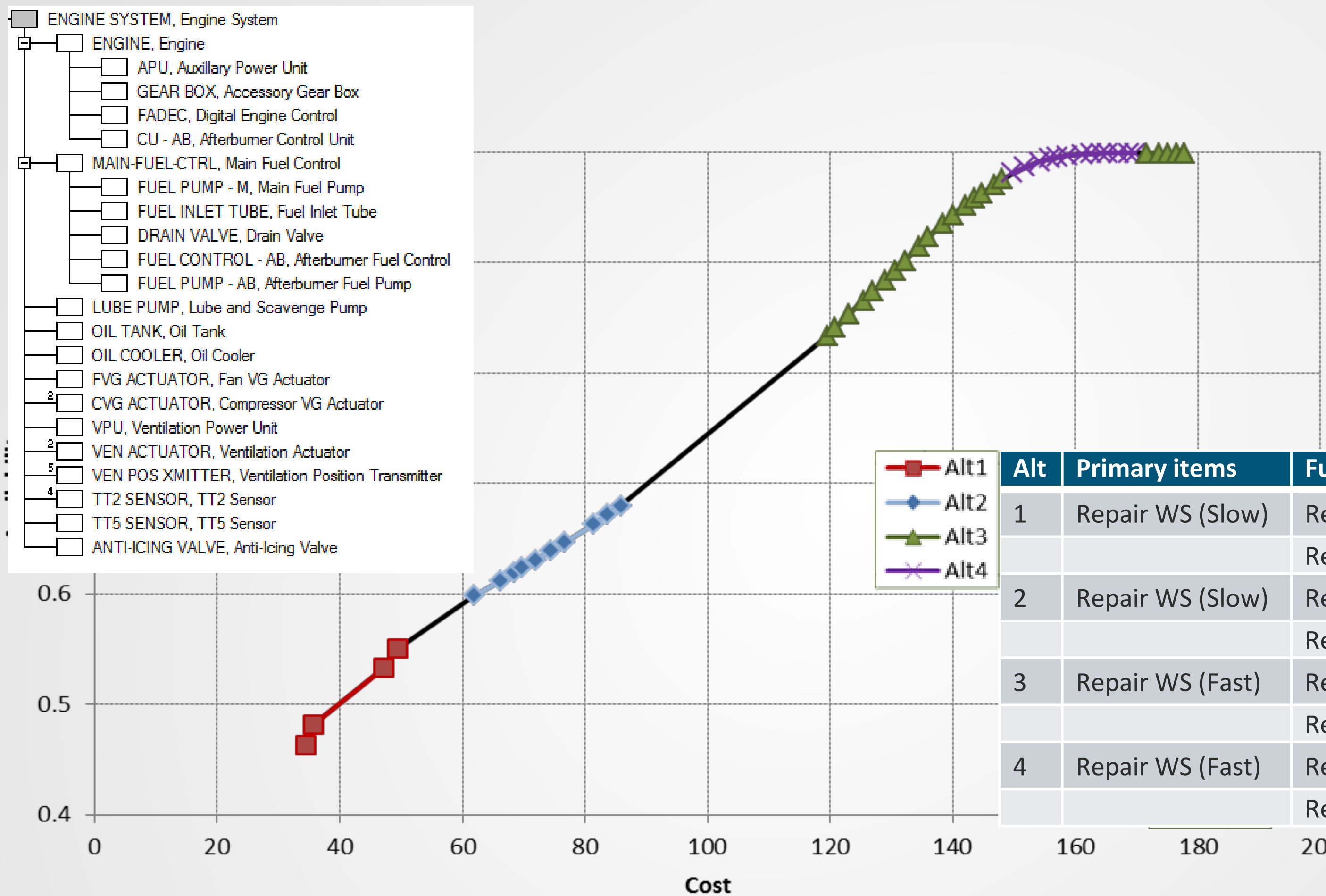
Alternative	Primary items	Fuel ctrl	Engine
1	Repair WS (Slow)	Repair (Slow)	Repair (Slow)
		Removal(Slow)	Removal(Slow)
2	Repair WS (Slow)	Repair (Slow)	Repair (Fast)
		Removal(Slow)	Removal(Slow)
3	Repair WS (Fast)	Repair (Slow)	Repair (Fast)
		Removal(Slow)	Removal(Slow)
4	Repair WS (Fast)	Repair (Slow)	Repair (Fast)
		Removal(Slow)	Removal(Fast)

Build model

Run Model (1.41 sec)

Review Results

Different strategies at different budget



Alt	Primary items	Fuel ctrl	Engine
1	Repair WS (Slow)	Repair (Slow)	Repair (Slow)
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2	Repair WS (Slow)	Repair (Slow)	Repair (Fast)
		Removal(Slow)	Removal(Slow)
3	Repair WS (Fast)	Repair (Slow)	Repair (Fast)
		Removal(Slow)	Removal(Slow)
4	Repair WS (Fast)	Repair (Slow)	Repair (Fast)
		Removal(Slow)	Removal(Fast)

Conclusions

- Holistic Multi-System Optimization is a new approach which takes into account the simultaneous optimization of
  - Stock
  - Resources
  - Maintenance capability
- The method is implemented by taking advantage of the powerful cost-effectiveness evaluator in modern spares optimization/support analysis software
- By not treating the decision variables as dependent the support system designs will be suboptimal
- The new approach is implemented in the Opus® Suite software by Systecon®