Hochschule für Angewandte Wissenschaften Hamburg
*Hamburg University of Applied Sciences*

AERO – AIRCRAFT DESIGN AND SYSTEMS GROUP

# THE PROCESS CHAIN FOR AIRCRAFT CABIN CONVERSION

# Identification and Optimization Algorithms


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# Contributions to the Optimization Methodology for Aircraft Cabin Conversion

## Publications Written and Presented so far:

1. NIŢĂ, Mihaela; SCHOLZ, Dieter: The Process Chain to a Certified Cabin Design and Conversion. In: *DGLR: Deutscher Luft- und Raumfahrtkongress 2009 : Tagungsband - Ausgewählte Manuskripte* (DLRK, Aachen, 01.-04. September 2009). - ISBN: 978-3-932182-63-4
2. NIŢĂ, Mihaela; SCHOLZ, Dieter: Business Opportunities in Aircraft Cabin Conversion and Refurbishing. In: CURRAN, Richard (Ed.): *ATOS 2010 Book of Abstracts (1st International Air Transport and Operations Symposium, TU Delft, 14-15 April 2010)*. Amsterdam : IOS Press, 2010, p. 34. - ISBN: 978-90-5623-082-1. Paper No 2010-331. Full paper download: http://CARISMA.ProfScholz.de
3. NIŢĂ, Mihaela; SCHOLZ, Dieter: Process Chain Analysis and Tools for Cabin Design and Redesign Activities. In ICAS: *International Council of the Aeronautical Sciences : Proceedings* (ICAS, Nice, 19-24 September 2010). – ISBN:978-0-956-5333-0-2
4. SCHOLZ, Dieter; NIŢĂ, Mihaela: Preliminary Sizing of Large Propeller Driven Aeroplanes. In: *Czech Aerospace Proceedings,* (2009), No. 2, pp. 41-47. - ISSN: 1211—877X. Download from: http://paper.ProfScholz.de
5. NIŢĂ, Mihaela; SCHOLZ, Dieter: From Preliminary Aircraft Cabin Design to Cabin Optimization. In: *DGLR: Deutscher Luft- und Raumfahrtkongress 2010 : Tagungsband - Ausgewählte Manuskripte* (DLRK, Hamburg, 30. August - 02. September 2010). - ISBN: 978-3-932073-87-9

Contributions to the Optimization Methodology for Aircraft Cabin Conversion

Design and

Contributions to the Optimization Methodology for Aircraft Cabin Conversion

## Purpose and Structure of Work

1. to present the current picture of aircraft cabin conversion providers:
   - in their relation with the aircraft manufacturer,
   - in their options for improving the business,
   - in their challenges from customers and regulators,
   - in their choices for capability growing
1. to illustrate the regulatory frame in which the engineering design work needs to be performed.
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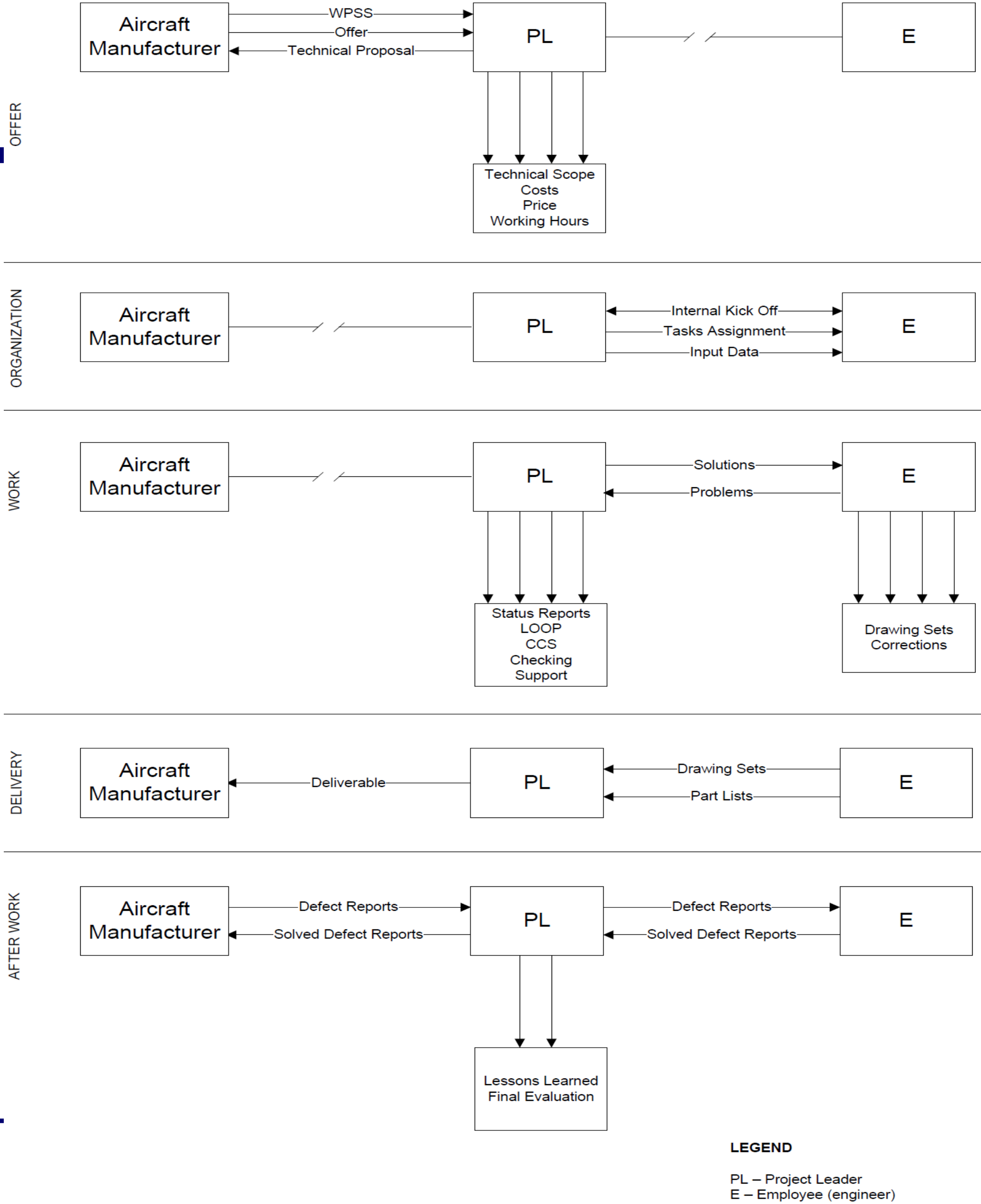
## Aircraft Cabin Conversions Today

- The relation OEM – Subcontractor is changing
- Two alternatives:
  - ✓ make it on the list of main subcontractors
  - ✓ develop the capability to perform designs independent from the aircraft manufacturer
- The deliverable consists of a document:
  - ✓ the title of the document and the aircraft involved,
  - ✓ the design change specifications comprising of installation instructions and drawings,
  - ✓ the requirements and the limitations,
  - ✓ the operational characteristics,
  - ✓ the necessary materials,
  - ✓ the parts lists and kit lists,
  - ✓ warnings and cautions for the workers.

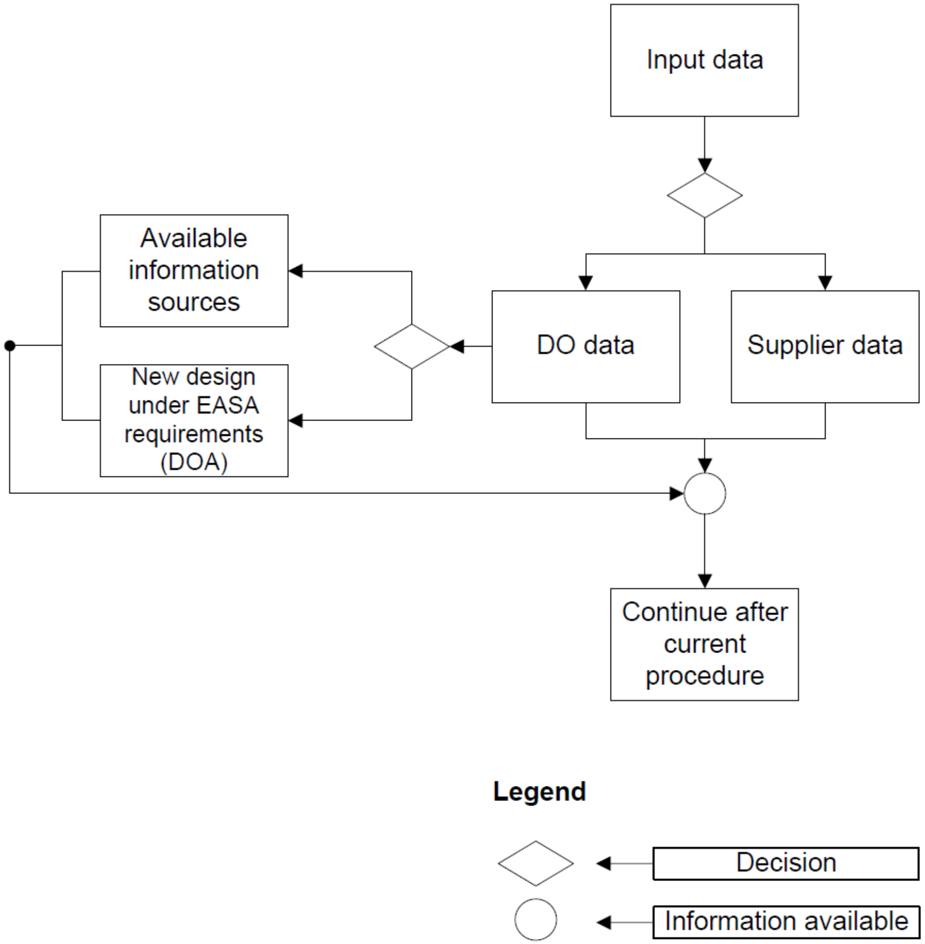
## Case 1

Aircraft Cabin Conversions Today



## Case 2

**Aircraft Cabin Conversions Today**



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## Airworthiness of Aircraft Cabin Conversions

- EASA: Design Organization Approval (DOA)
- type certificate (TC) → type design
- cabin conversion = changes to type design

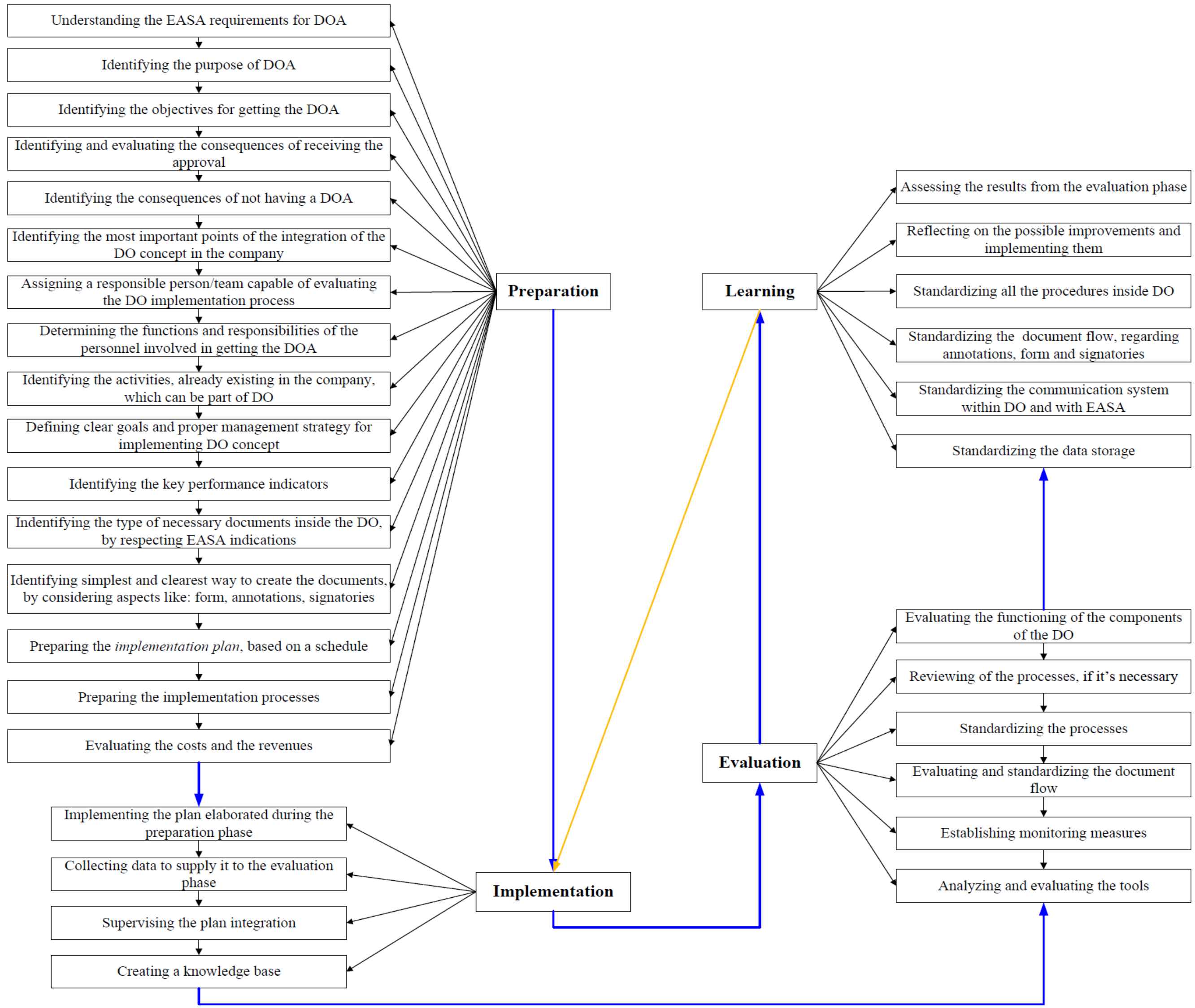
minor | major — STC

- Optimization of cabin conversion design processes is required by EASA

Scope of approval | Specialized personnel | Monitoring system | Design assurance system

# DOA

**Airworthiness of Aircraft Cabin Conversions**



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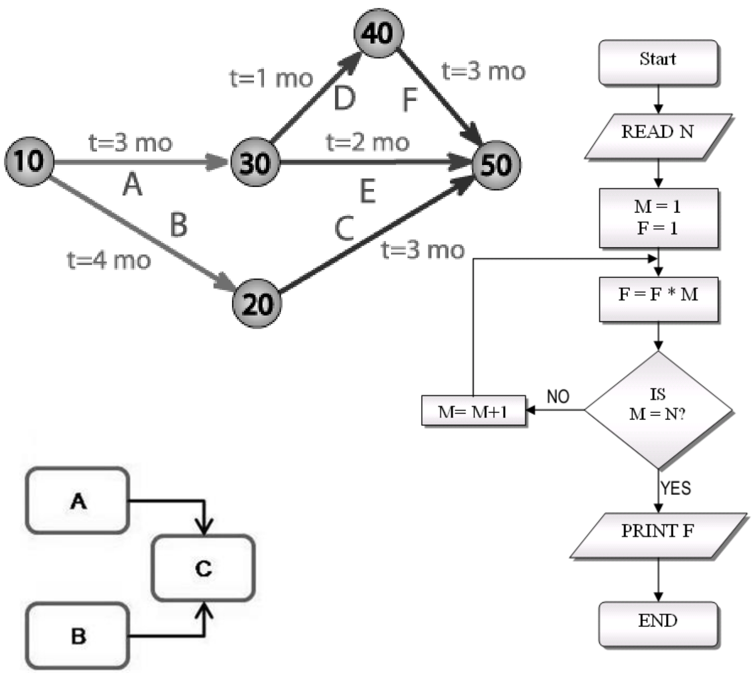
## Process Representation Models

**!** The importance of using process models which allow optimization.

### Flow Charts




### Matrices

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | X | | | | | |
| 2 | | | X | X | X | X | | | |
| 3 | | | | X | | | | X | |
| 4 | | | | | X | | | | |
| 5 | | | | | | | X | | |
| 6 | | | | | | | | | X |
| 7 | | | | | | X | | X | |
| 8 | | | | | | | X | | |
| 9 | | | | | | | X | | |

## Process Representation Models

Dependency and Stucture Modelling Methodology

DSM

Sequential

Parallel

Coupled

| | B | C | A | K | L | J | F | I | E | D | H | G |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | ● | X | | X | | X | | X | | | | X |
| C | | ● | X | X | | X | | X | | | | |
| A | | | ● | | X | | | | | | X | |
| K | | | | ● | X | X | | | X | | X | X |
| L | | | | | ● | X | X | | | X | | |
| J | | | | | X | ● | | X | | | | |
| F | | | | | | | ● | X | X | X | | |
| I | | | | | X | | X | ● | | | X | |
| E | | | | | | | | | ● | X | | |
| D | | | | | | | | | | ● | X | |
| H | | | | | | | | | X | | ● | |
| G | | | | | | | | | | | | ● |

## Process Representation Models

### DSM for Cabin Conversion

- Complexity:
  > identifying the elements of the system
  > identifying the relations between them

- Types:
  > Fine Matrix – representation of all processes and relations
  > Coarse Matrix – representation of the main phases
  > Hierarchical Matrix – combination between the first two

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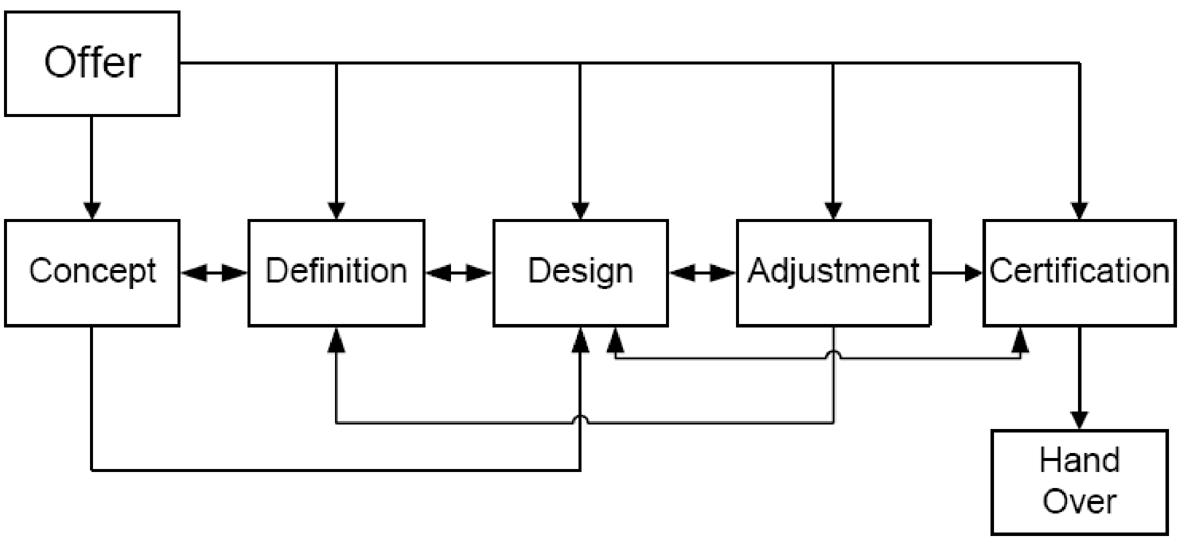
**IDENTIFICATION AND OPTIMIZATION ALGORITHMS**

## Process Representation Models

Coarse

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Offer | 1 | 1 | | | | | | |
| Concept | 2 | 1 | 2 | 1 | | | | |
| Definition | 3 | 1 | 1 | 3 | 1 | | | |
| Design | 4 | 1 | 1 | 1 | 4 | | 1 | |
| Adjustment | 5 | 1 | 1 | 1 | 1 | 5 | 1 | 1 |
| Certification | 6 | 1 | 1 | 1 | 1 | | 6 | |
| Handover | 7 | 1 | 1 | 1 | 1 | | 1 | 7 |



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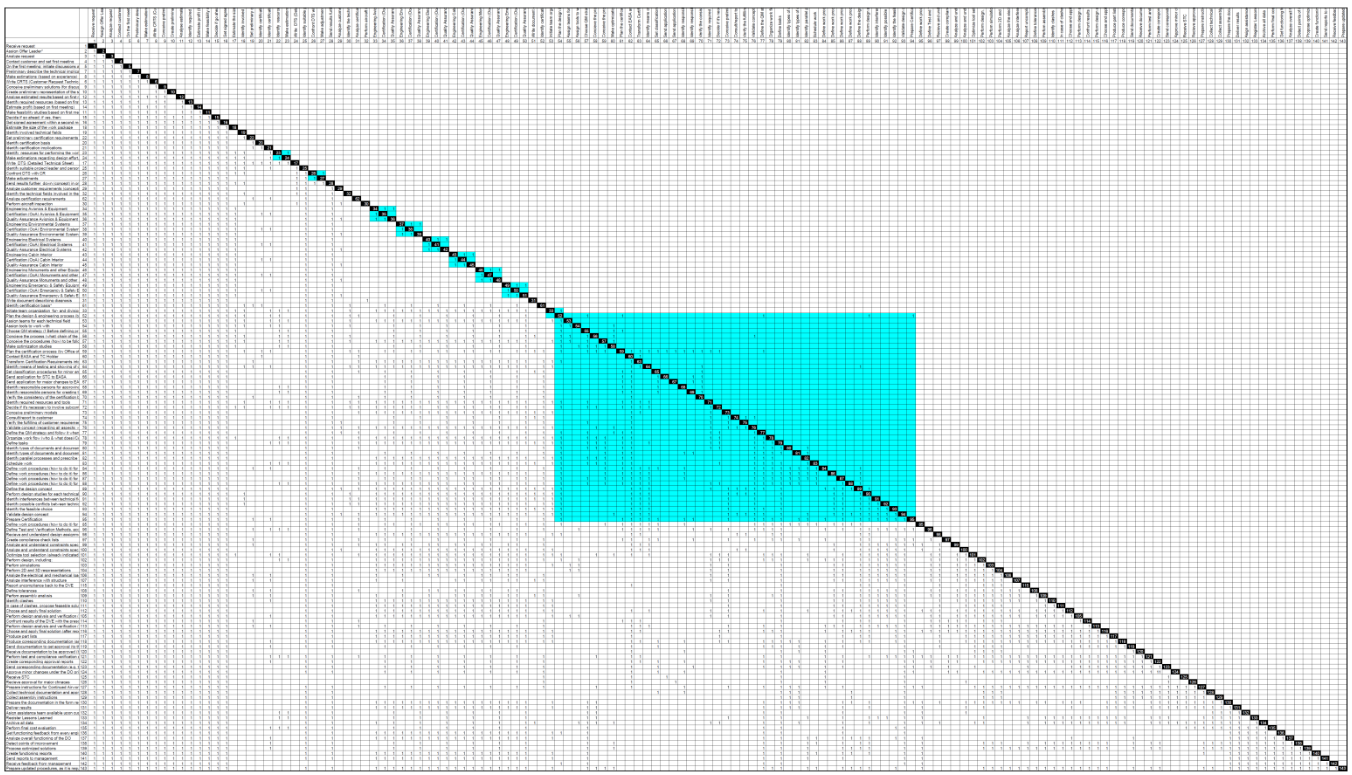
# Process Representation Models

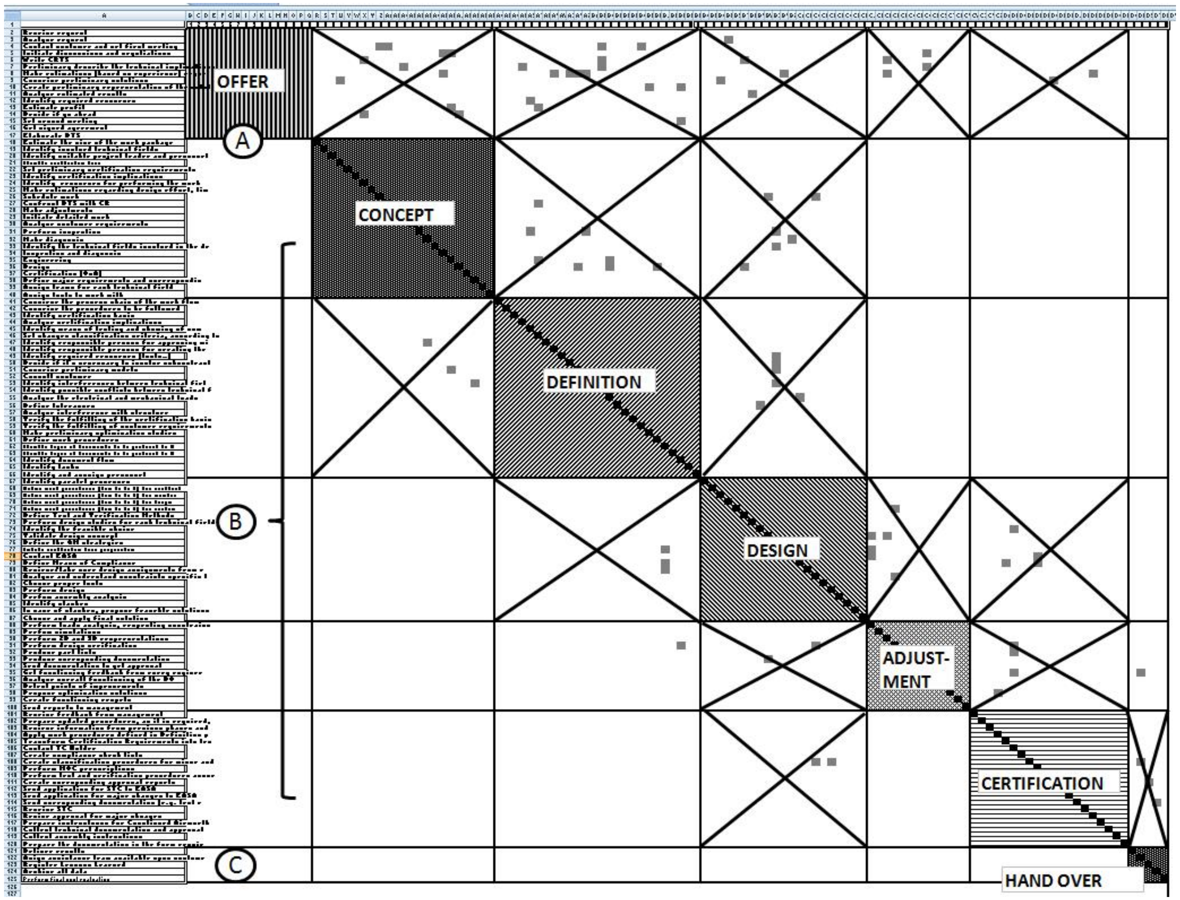
## Fine



# Process Representation Models

Hierarchical

- The hierarchical matrix is based on the fine matrix
- From the hierachical matrix the coarse matrix can be rebuild
- Some relations can be considered small enough so as to be neglected



## Purpose and Structure of Work

1. to present the current picture of aircraft cabin conversion providers:
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## The process chain for cabin design

- The cabin architecture must reflect the requirements for cabin safety and operation
- The cabin architecture needs to integrate a large amount of different systems and components:
  - Cabin communication
  - Entertainment system
  - Air conditioning system
  - Oxygen system
  - Emergency floor path marking
  - Lights
  - Service (galleys)
  - Utilities (lavatories, stowages)
  - Seats (flight attendants and passengers)

## Process Chain Description

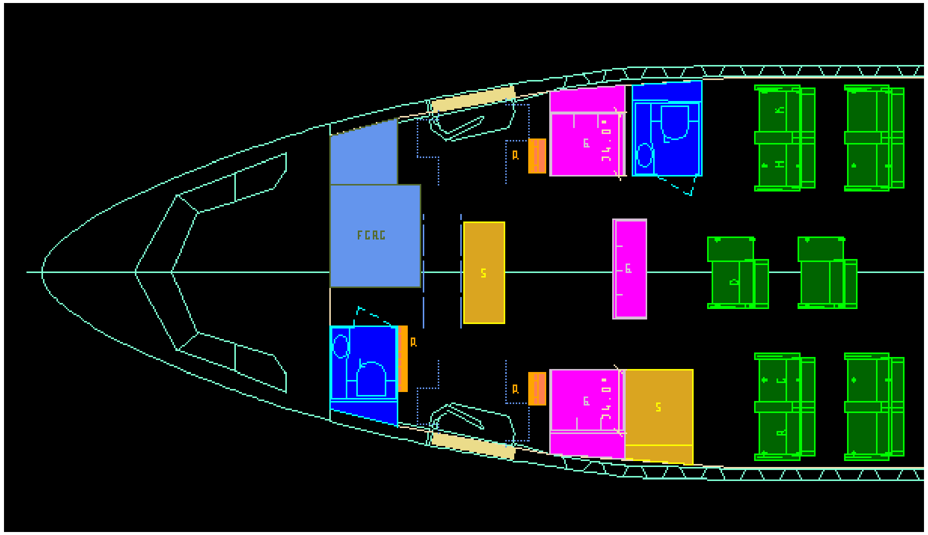
- Process steps:
  1. Creation of a component library
  2. Definition of placement constraints
  3. Generation of an initial architecture
  4. Identification of relevant parameters
  5. Investigation of competing architectures
  6. Post-processing and analysis of the results

1. Optimized physical placement of cabin items.
2. Optimized sizing with respect to regulatory, geometric, volumetric, electric and thermal constraints.
3. Optimized centre of gravity variance and its impact on aerodynamics, mission and operational flight performance.
4. Optimized cabin architecture changes against fuselage sizing process and the impact on mass, range, fuel burn and cost

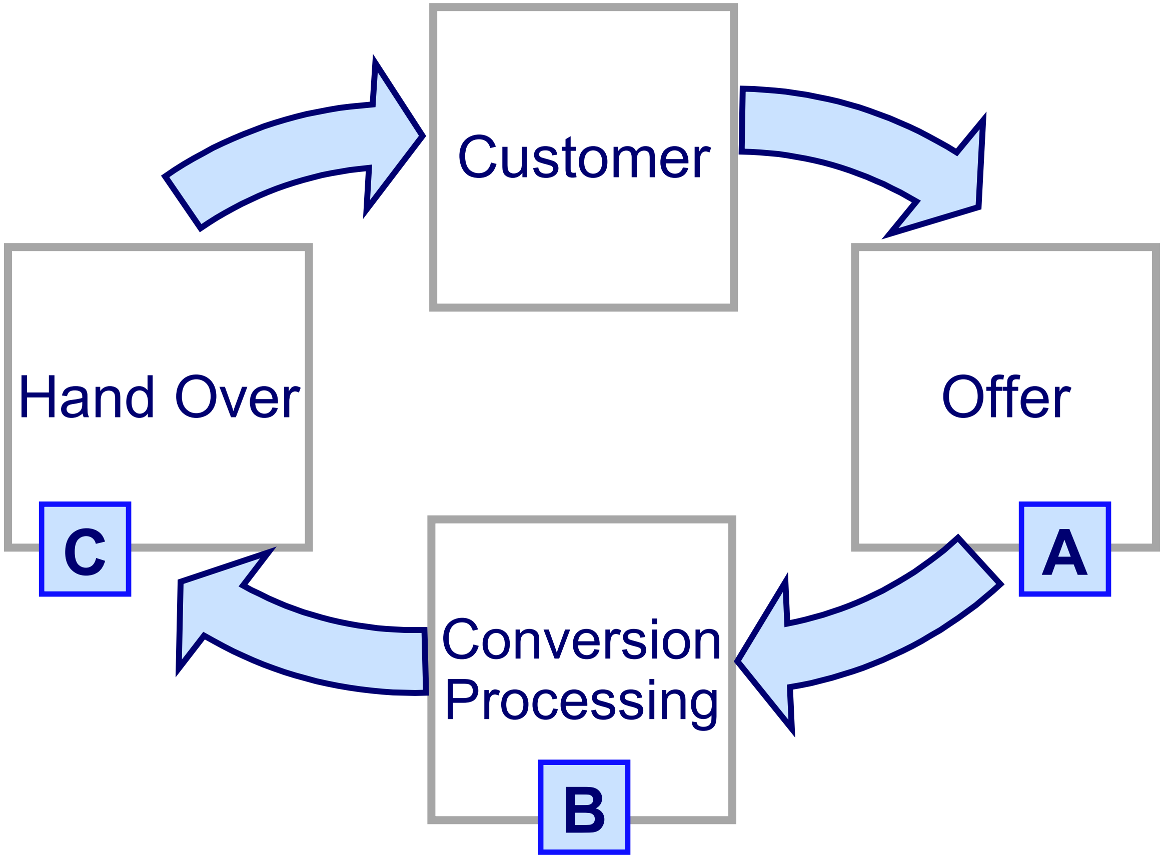
- The input data required when defining the cabin architecture (i.e. an initial Step 0) is a fuselage shape optimized with respect to cabin parameters.

## The Knowledge Based Engineering Concept

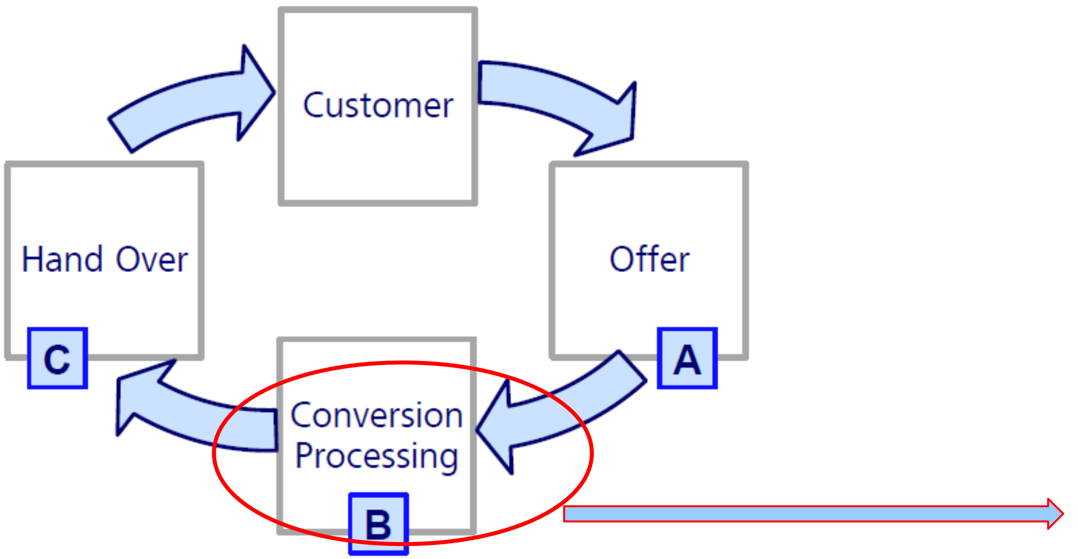
- KBE concept – a viable approach for cabin architecture development.
- KBE aims to capture and reuse product and process multidisciplinary knowledge in an integrated way.
- Example of KBE tool: Pacelab Cabin



## The Process Chain for Cabin Conversion



# Process Chain Description




1) Concept
2) Definition
3) Design
4) Adjustment
5) Certification

## Process Chain Description

A: Offer

- formalization of the customer request
  - conception of the preliminary solutions
- feasibility studies
- go ahead decision
- identification of technical fields
- certification basis
- required resources
- project leader assignment

## Process Chain Descriptionc

B: Conversion Processing

### Concept Phase
- aircraft diagnosis
- organization
- planning D & E process
- planning the certification
- resources & tools
- preliminary models

### Definition Phase
- work breakdown
- work procedures
- document flow
- design concept
- certification preparation
- compliance check lists

### Design Phase
- design constraints analysis
- tools selection
- design
- design verification

### Adjustment Phase
- getting feedback
- detecting points of improvement
- proposing optimized solutions

### Certification Phase
- test & verification
- approval reports
- EASA communication
- continued airworthiness instructions

## Process Chain Description

C: Hand Over

- data collection
- documentation preparation
- delivering results
- providing assistance
- archiving results
- final cost evaluation

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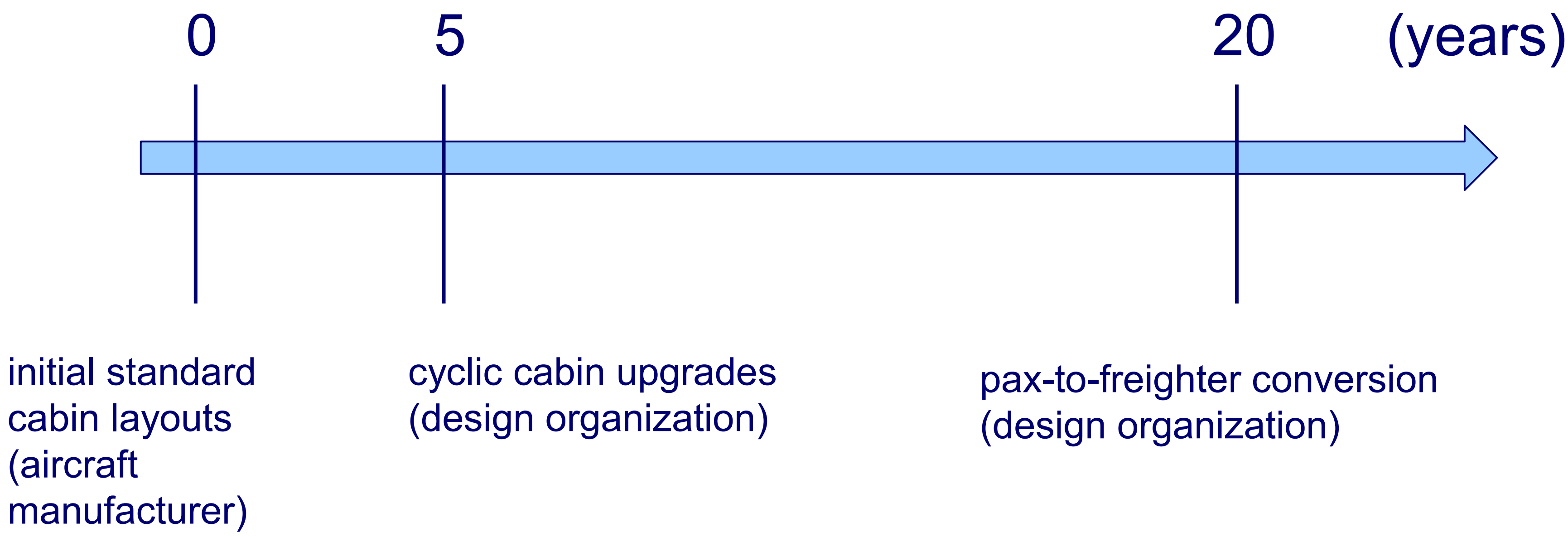
## The Completion Center Concept



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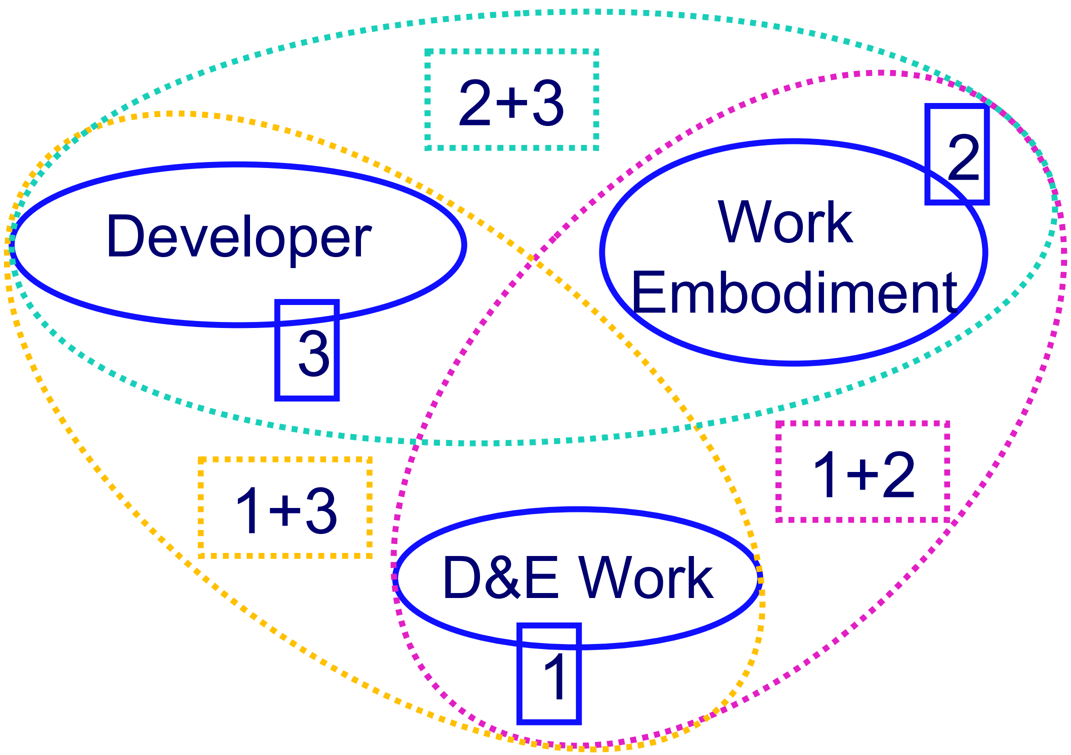

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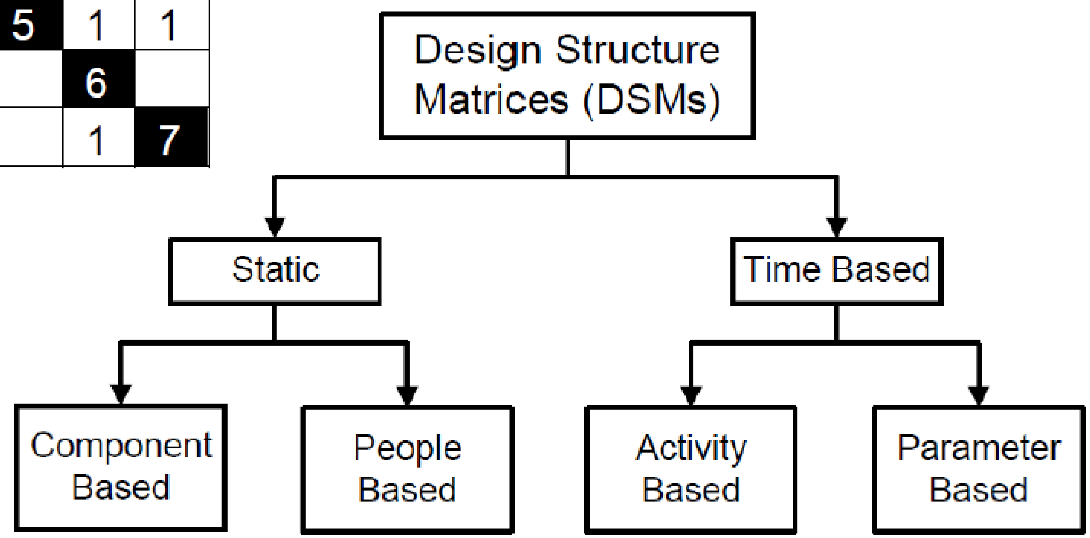
## The DSM Methodology

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Offer | 1 | 1 | | | | | | |
| Concept | 2 | 1 | 2 | 1 | | | | |
| Definition | 3 | 1 | 1 | 3 | 1 | | | |
| Design | 4 | 1 | 1 | 1 | 4 | | 1 | |
| Adjustment | 5 | 1 | 1 | 1 | 1 | 5 | 1 | 1 |
| Certification | 6 | 1 | 1 | 1 | 1 | | 6 | |
| Handover | 7 | 1 | 1 | 1 | 1 | | 1 | 7 |

1. Preparation of questionnaires
2. Gathering and analyzing the results.
3. Implementing the results into the matrix



## Optimization Algorithms

- Partitioning aims to reorder the sequence of the elements in order to obtain a triangular matrix.
- Clustering focuses on identifying groups of items, in the case of time-independent systems.

- The analysis of a great number of processes with the DSM method requires the automation of the optimization.

| | | Offer | Concept | Definition | Design | Certification | Handover | Adjustment |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 6 | 7 | 5 |
| Offer | 1 | 1 | | | | | | |
| Concept | 2 | 1 | 2 | 1 | | | | |
| Definition | 3 | 1 | 1 | 3 | 1 | | | |
| Design | 4 | 1 | 1 | 1 | 4 | 1 | | |
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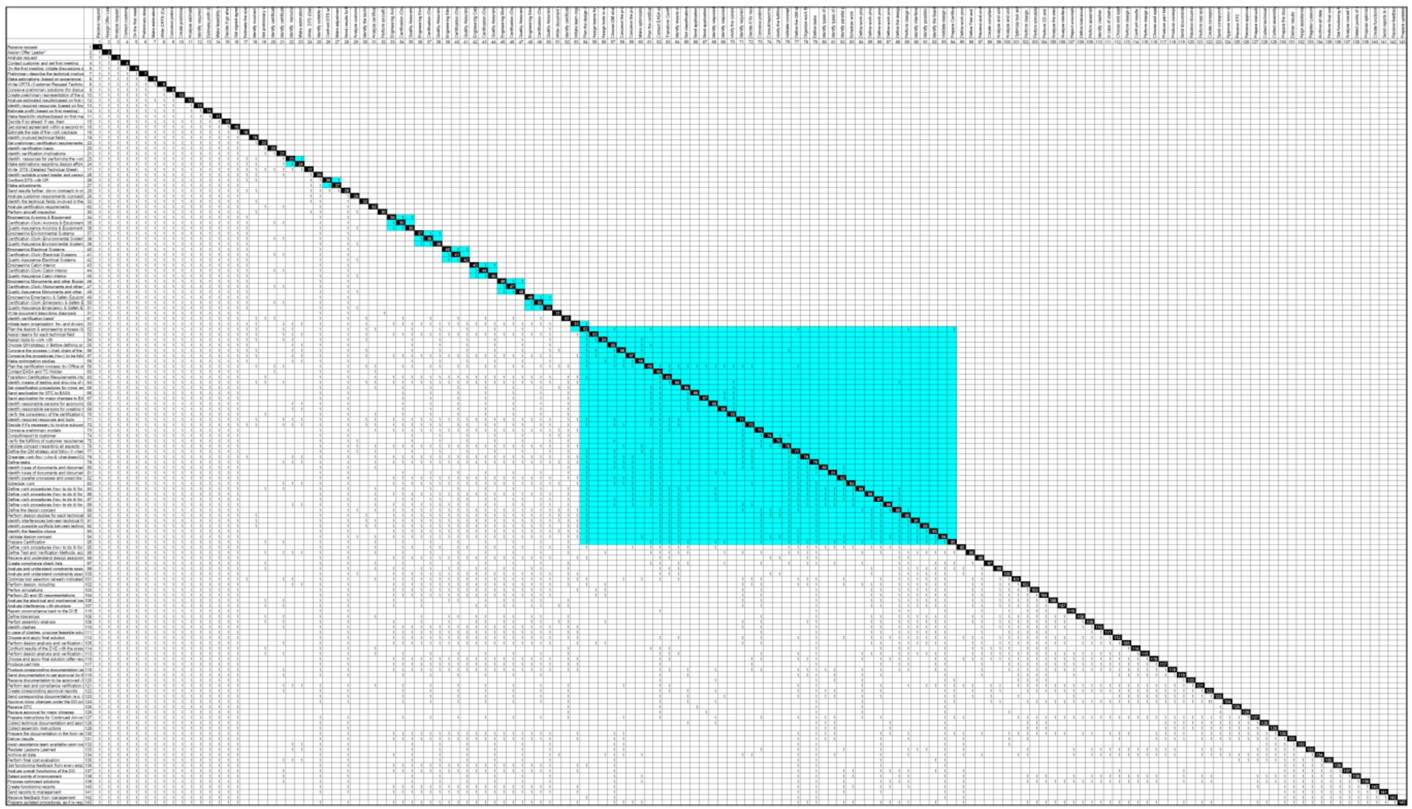
| Handover | 7 | 1 | 1 | 1 | 1 | 1 | 7 | |
| Adjustment | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 5 |

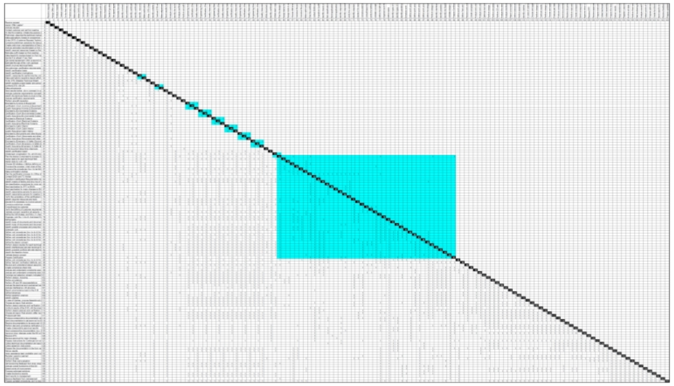
# Analysis of the DSM for the Process Chain for Cabin Conversion

- Partitioning



## Analysis of the DSM for the Process Chain for Cabin Conversion

- Conclusions
  - Definition, Design and Certification phases are coupled (light blue); they create an information cycle which needs iteration, and therefore further optimization.
  - Other small couplings exist between the teams for engineering, certification and quality assurance.
  - A detailed analysis of the matrix and of each of the illustrated dependency allows a better understanding of the results.



## Analysis of the DSM for the Process Chain for Cabin Conversion

### Eigenstructure analysis

- The eigenvalues and eigenvectors determine the nature of the convergence of the design process in a similar way with the aircraft dynamics:
    - the eigenvalues give information about the rate of convergence,
    - the eigenvectors give information about the shape of the natural motion.
- Large magnitude positive eigenvalues give information about the convergence of the system.
- The eigenstructure analysis of the process chain was performed on a Work Transformation Matrix (WTM) under the consideration that the amount of rework is 100%.

# Analysis of the DSM for the Process Chain for Cabin Conversion

## Eigenstructure analysis

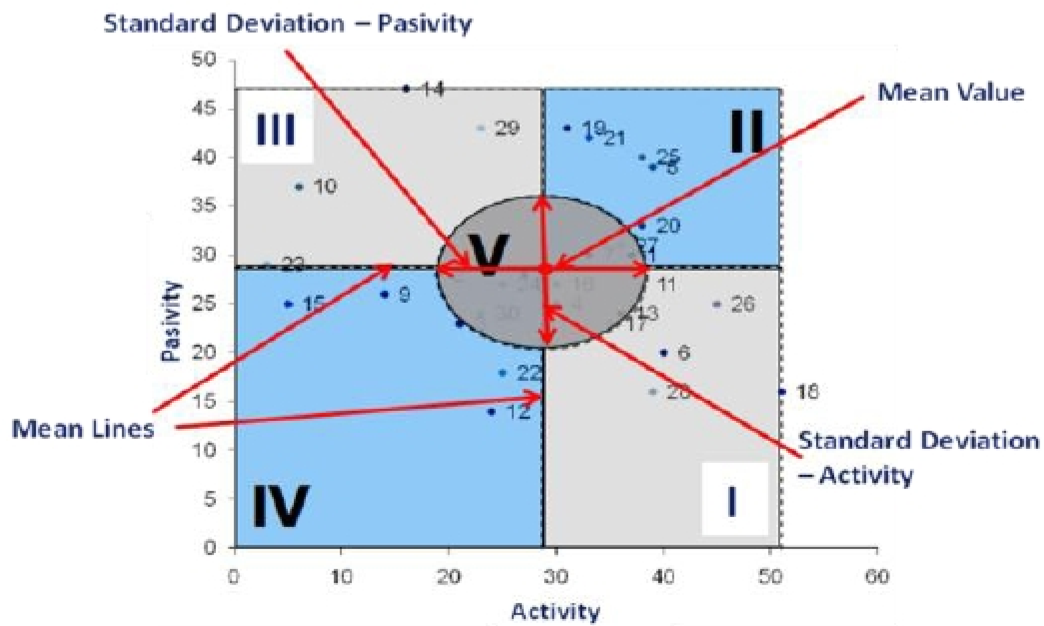
| Process ID | Process Title | Eigenvalue |
|---|---|---|
| 50 | Organizing team for certification | 6.43 |
| 51 | Organizing team for quality assurance | 2.21 |
| 52 | Planning the Design & Engineering process | 2.21 |
| 53 | Assigning Teams for each technical field | 2.31 |
| 106 | Analyzing electrical and mechanical loads | 1.62 |
| 113 | Performing design analysis and verification | 1.62 |
| 121 | Perform test and compliance verification | 1.00 |

## Analysis of the DSM for the Process Chain for Cabin Conversion

### Cross Impact analysis

Pasivity

| Activity | Faktor 1 | Faktor 2 | Faktor 3 | |
|---|---|---|---|---|
| Faktor 1 | | 1 | 3 | Σ |
| Faktor 2 | 0 | | 1 | Σ |
| Faktor 3 | 3 | 0 | | Σ |
| | Σ | Σ | Σ | |



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|---|---|---|---|---|
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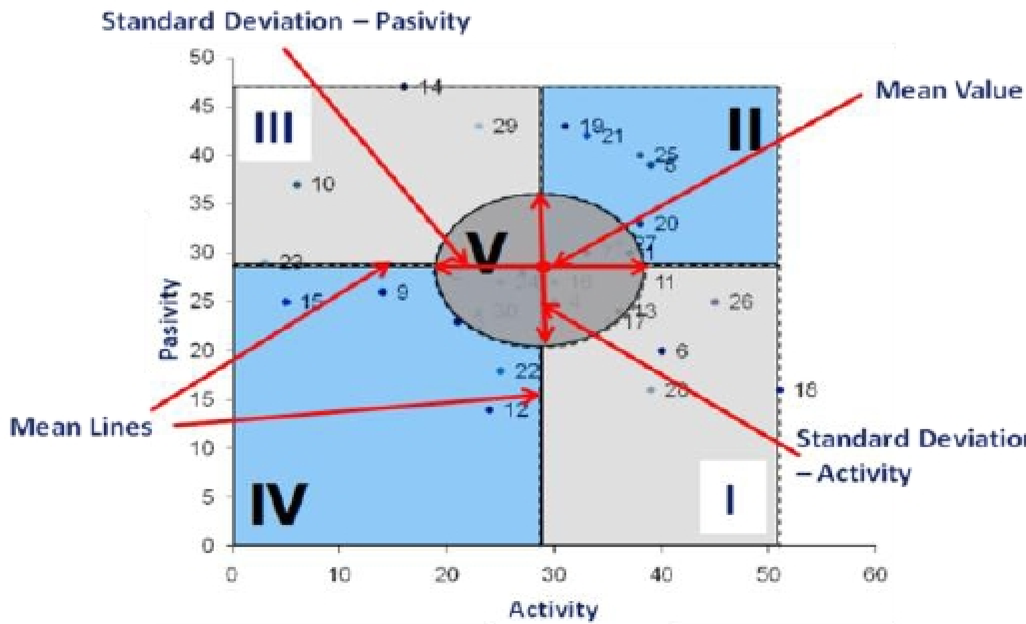
| Faktor 2 | 0 | | 1 | Σ |
| Faktor 3 | 3 | 0 | | Σ |
| | Σ | Σ | Σ | |




Zone I: Reactive Processes

Zone II: Dynamic Processes

Zone III: Impulsive Processes

Zone IV: Low Impact Processes

Zone V: Neutral Processes

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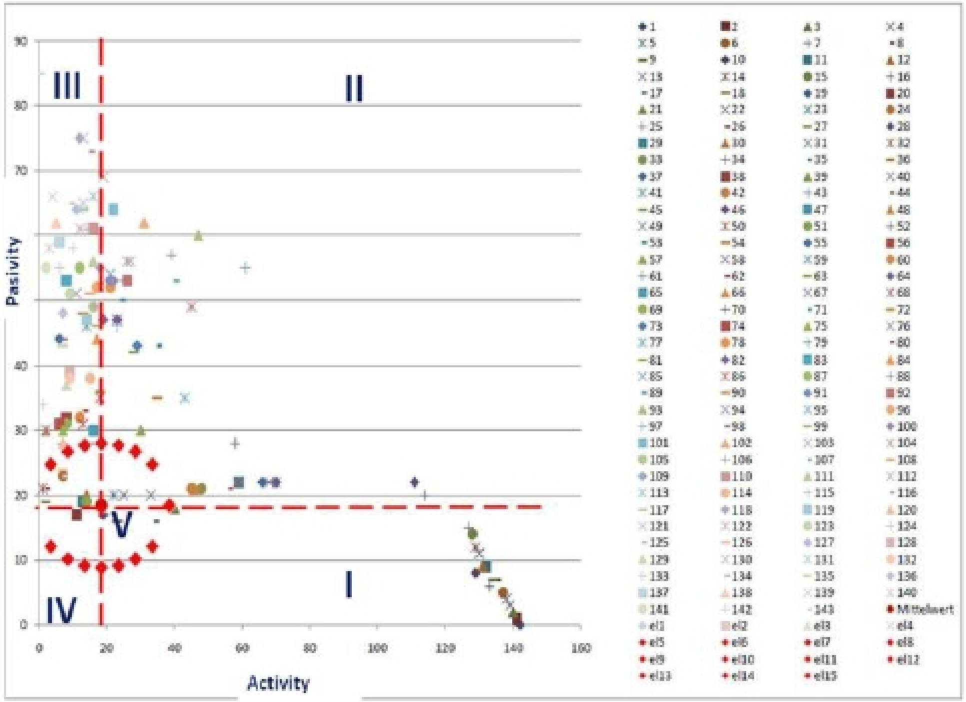
## Cross Impact analysis




| | |
|---|---|
| Zone I | (2) Assign Offer Leader<br>(126) Receive approval for major changes<br>(9) Conceive preliminary solutions for discussing it with the customer (based on the first meeting)<br>(10) Create preliminary representation of the solutions found<br>(12) Identify required resources (based on the first meeting)<br>(14) Make feasibility studies<br>(16) Get signed agreement |
| Zone II | (94) Validate design concept<br>(87) Define work procedures for quality assurance<br>(79) Define tasks (definition phase)<br>(93) Identify feasible choice (when it comes to interferences) (design phase)<br>(73) Conceive preliminary models(concept phase)<br>(61) Identify certification basis (concept phase)<br>(54) Plan the design and engineering process |
| Zone III | (137) Analyze overall functioning of the DO<br>(133) Register Lessons Learned<br>(75) Verify the fulfillment of the customer request<br>(139) Propose optimized solutions (for the functioning of DO)<br>(143) Prepare updated procedures for the functioning of the DO<br>(138) Detect points of improvement (of the DO)<br>(119) Send documentation to EASA (to get approval) |
| Zone IV | (27) Make adjustments of the DTS after confronting it with CR |
| Zone V | (17) Write DTS<br>(18) Estimate the size of the work package<br>(24) Make estimations regarding design effort<br>(30) Perform aircraft inspection<br>(31) Write document describing diagnosis<br>(32) Identify the technical fields involved in the design process (concept phase)<br>(62) Analyze certification requirements (concept phase) |

## Conclusions

- The necessity of optimizing the engineering processes is a key factor in the aeronautical industry.
- A simple matrix approach can aid this process.
- The optimization was performed on a high number of processes, which made the implementation of the algorithms rather difficult.

- The partitioning algorithm delivered the optimal sequence of the basic processes inside the completion center.
- The eigenstructure analysis underlined those processes with the greatest influence on the engineering system.
- The cross impact diagram delivered groups of processes belonging to five spheres: reactive, dynamic, impulsive, low impact and neutral.

## Outlook

- Conducting such an analysis on smaller DSMs characterizing a smaller subsystem, comprising of one or several phases.
- Expressing the rework load for each process fractionally. WTM is especially suitable for reconversion tasks, as it allows the estimation of how much work is required for the rest of the cabin items if one item is being replaced / reconverted. It also allows the calculation of the total time or the partial times for performing the cabin conversions
- Cross Impact Analysis on smaller DSMs in order to identify especially those tasks which poorly influence the system. Such tasks may be further coupled or ignored.

Continuing the work in cabin design optimization by contributing to the development of a tool called PreSTo (Preliminary Sinzig Tool) for preliminarily designing aircraft. I am responsible for the design optimization module.

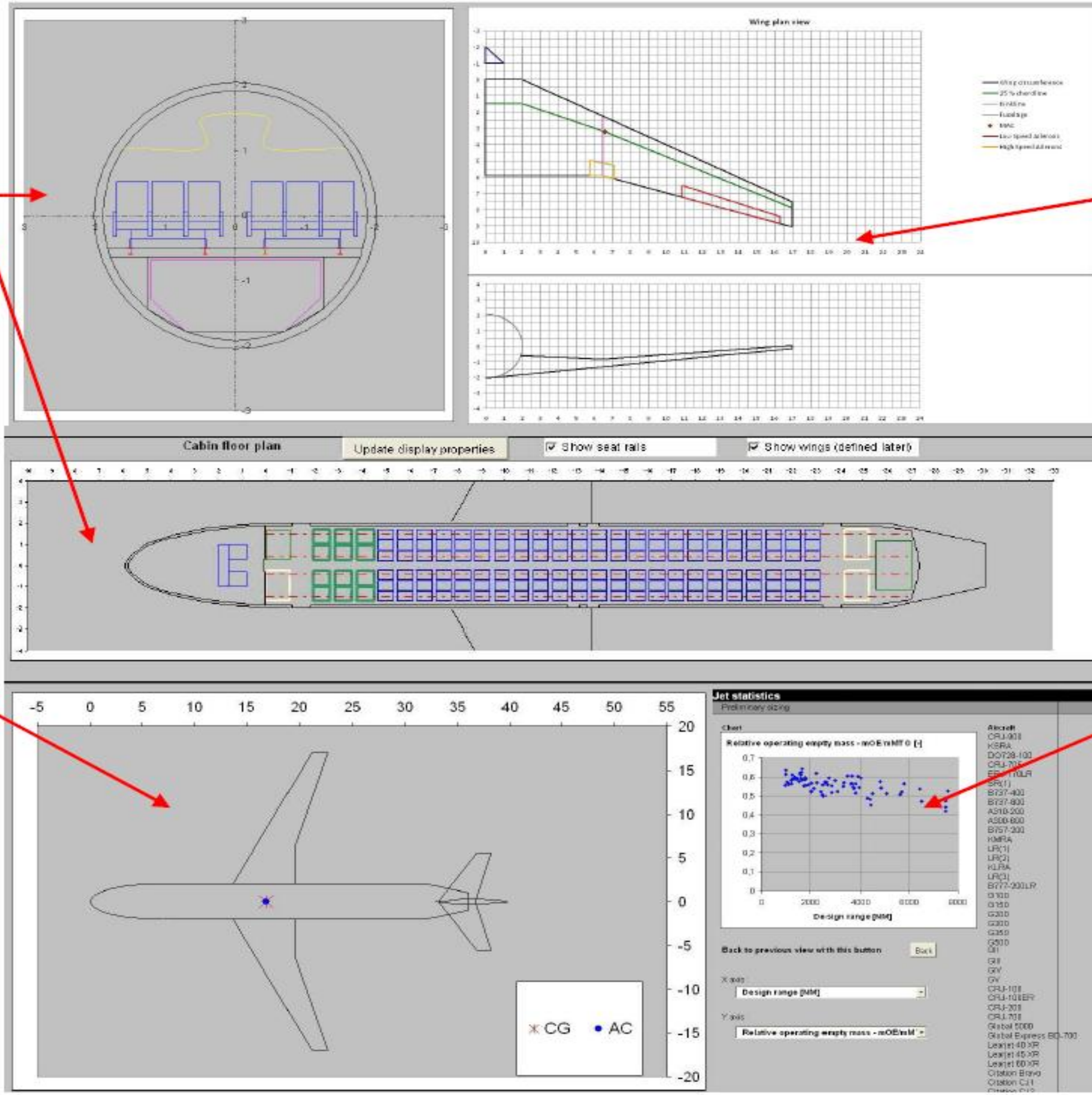
## PreSTo

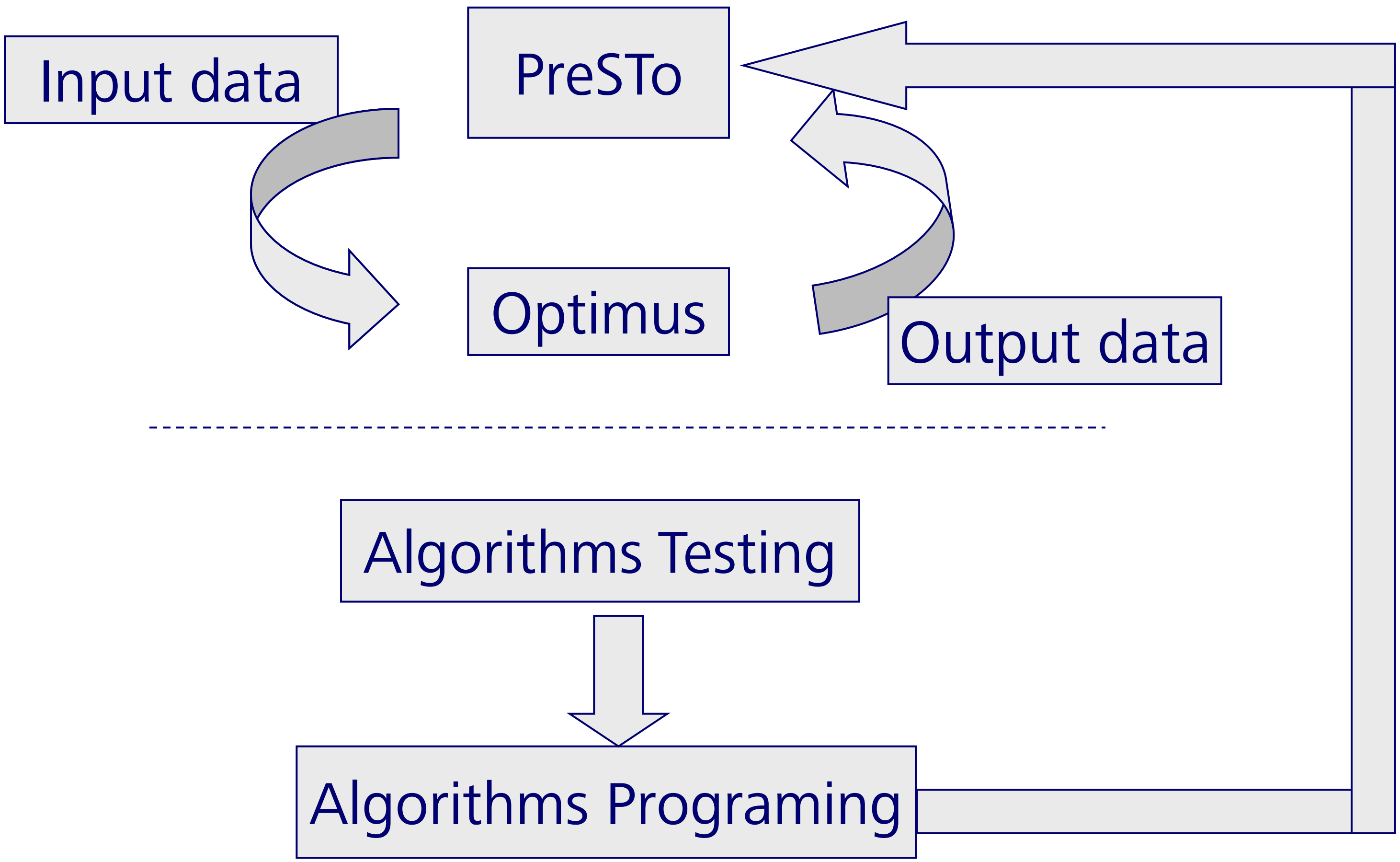
Cabin design

Wing design

Center of gravity

Available statistics




Input data
PreSTo
Optimus
Output data
Algorithms Testing
Algorithms Programing

# Întrebări? ... şi mai ales Sugestii?

# Questions? ... and especially Suggestions?

Contact: Mihaela.Nita@HAW-Hamburg.de

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*Hamburg University of Applied Sciences*