Recent developments in MDO system formulation

KADMOS and CMDOWS

van Gent, Imco; La Rocca, Gianfranco

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Recent developments for MDO system formulation: KADMOS and CMDOWS

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Gianfranco La Rocca, Assistant professor, TU Delft

Topic 2: MDO Concepts, Methods and Algorithms, 16:20-16:40h

1st European Workshop on MDO for Industrial Applications in Aeronautics – Challenges and Expectations

24-25 October 2017

DLR Braunschweig, Germany

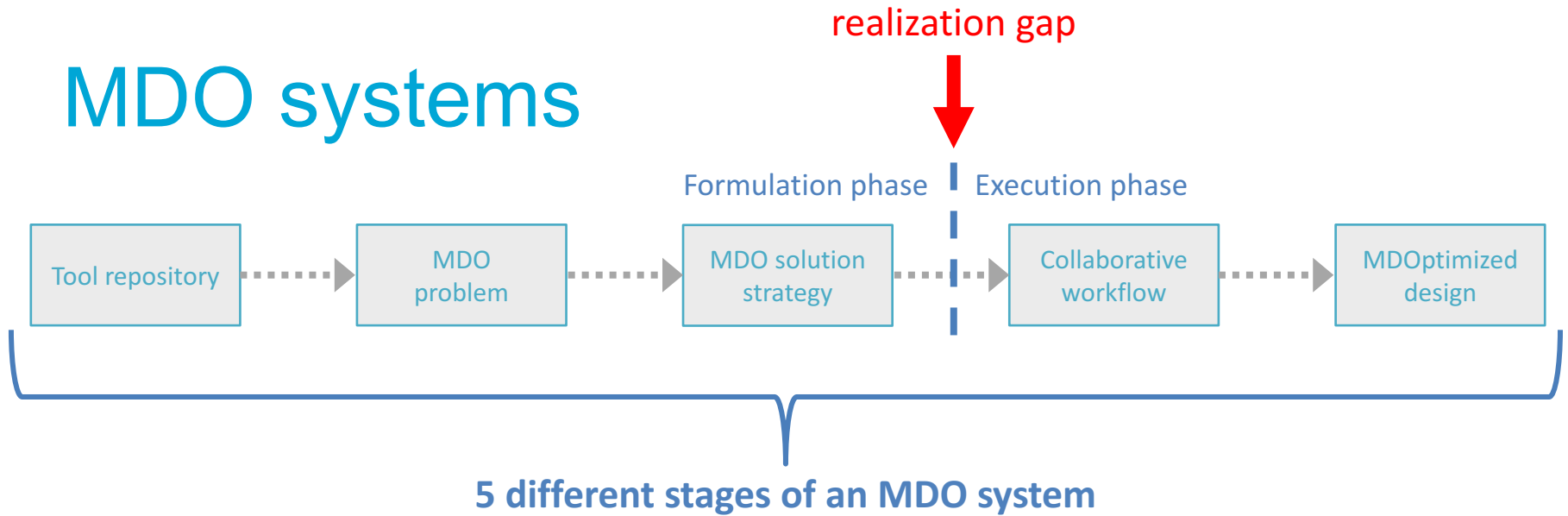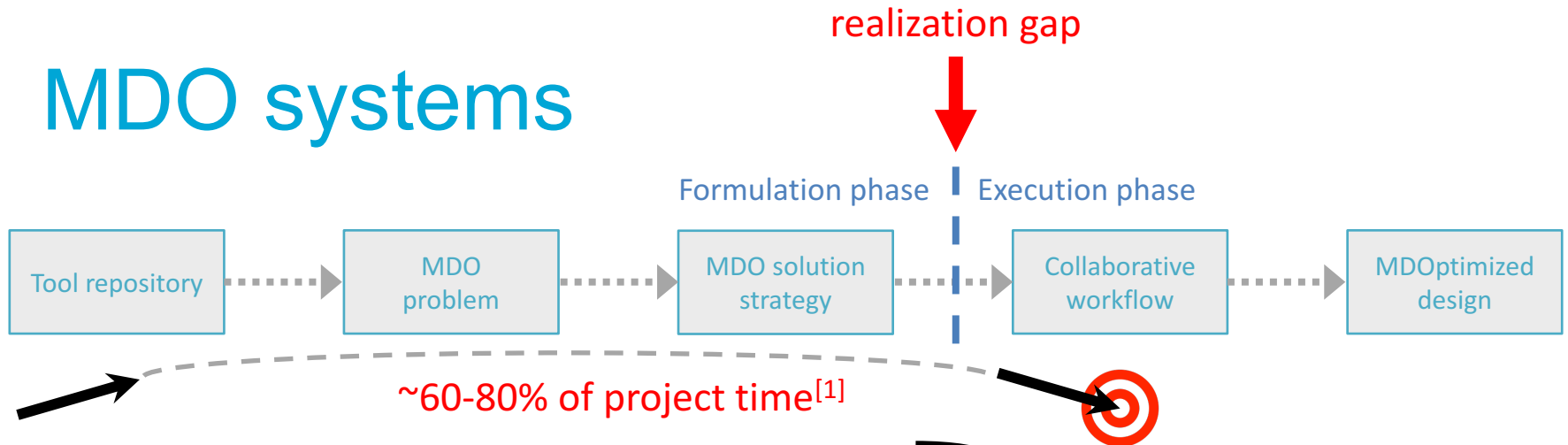AGILE

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MDO systems

MDO systems

realization gap

Formulation phase | Execution phase

| Tool repository | MDO problem | MDO solution strategy | Collaborative workflow | MDOptimized design |

5 different stages of an MDO system

MDO systems

realization gap

Formulation phase | Execution phase

Tool repository ┈┈► MDO problem ┈┈► MDO solution strategy ┊ Collaborative workflow ┈┈► MDOptimized design

~60-80% of project time[1]
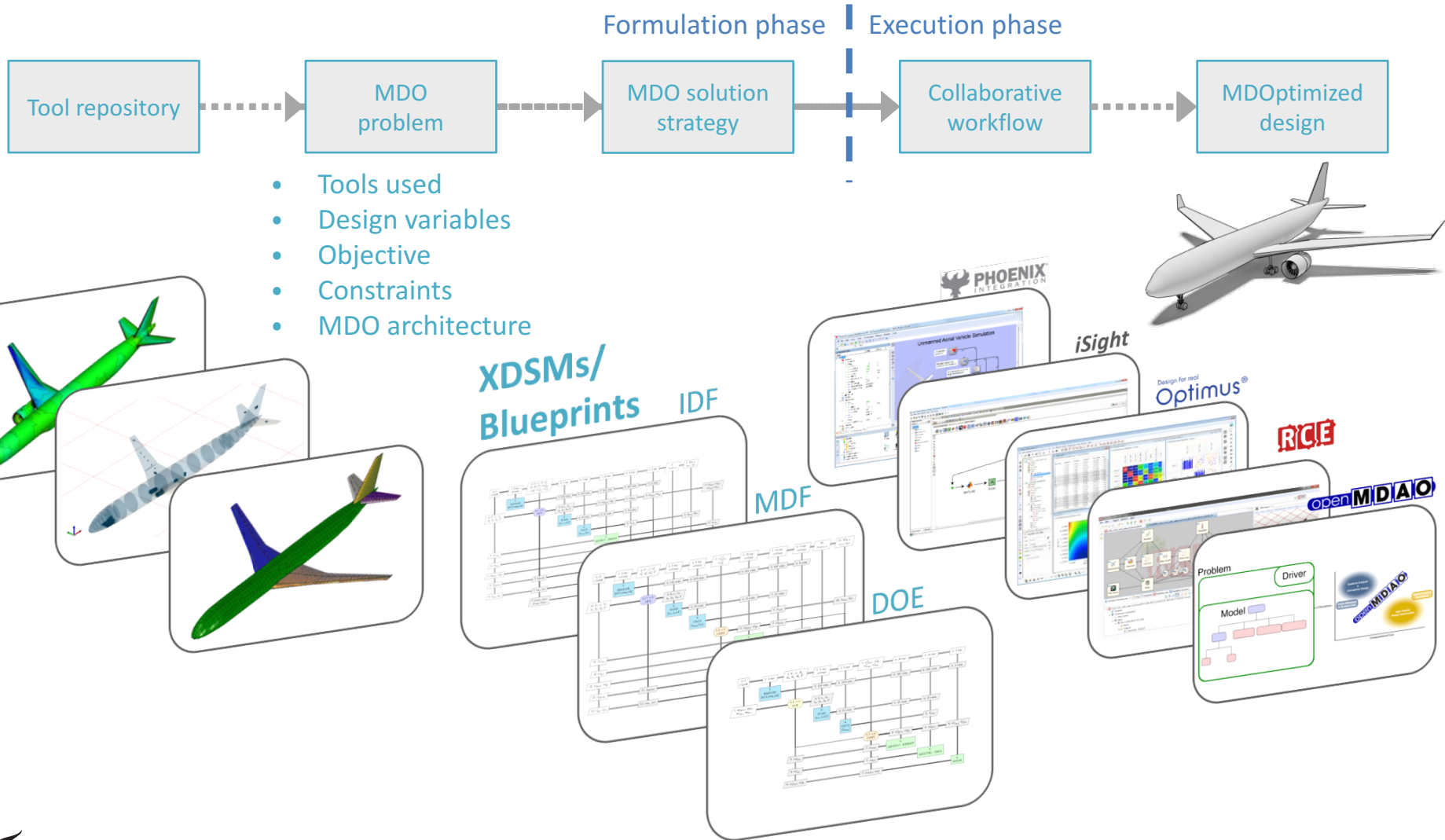
AGILE AIRCRAFT 3RD GENERATION MDO FOR INNOVATIVE COLLABORATION OF HETEROGENEOUS TEAMS OF EXPERTS
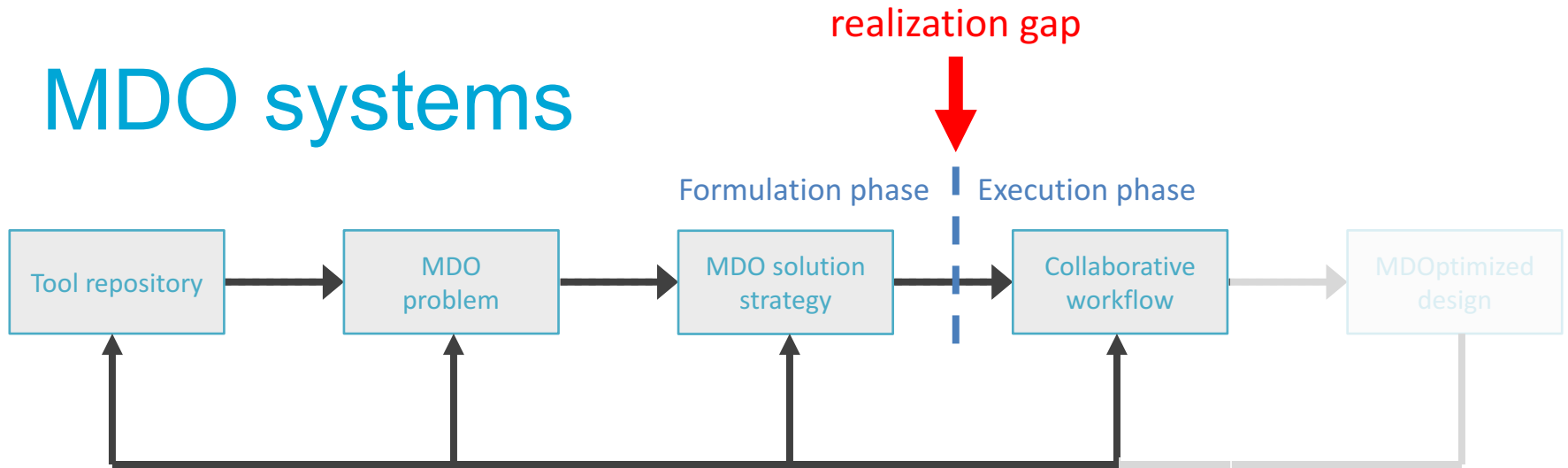
AGILE goal:
40% time reduction to set up collaborative MDO workflow

Collaboration = key!

[1] P.D. Ciampa and B. Nagel. The AGILE Paradigm: the next generation of collaborative MDO. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.

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MDO systems

realization gap

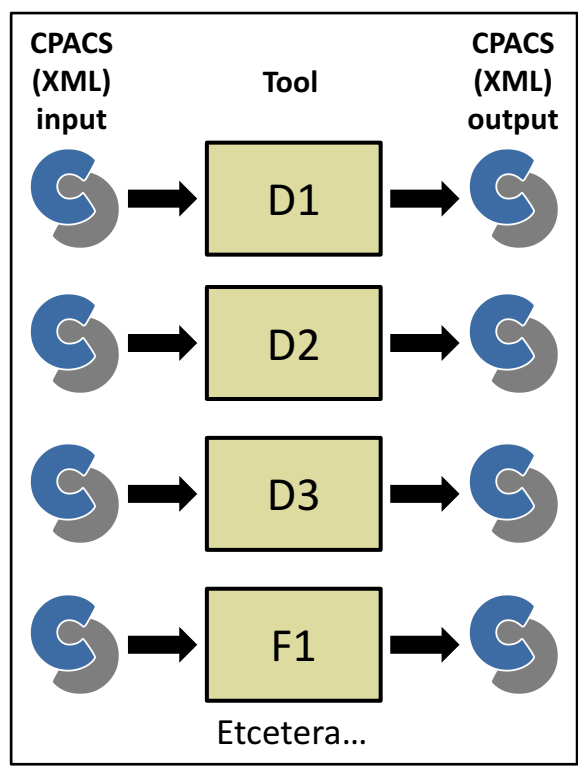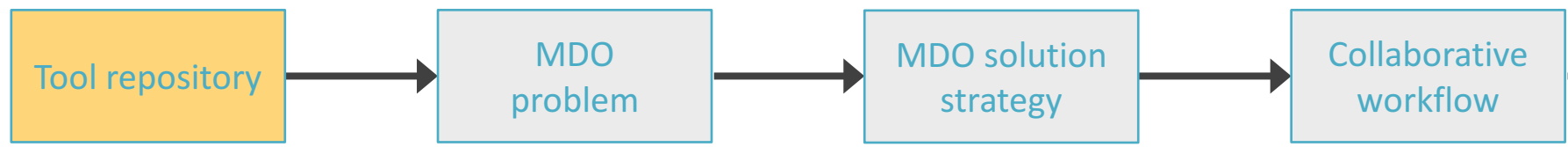| Formulation phase		Execution phase	
Tool repository → MDO problem → MDO solution strategy		Collaborative workflow → MDOptimized design	

FRAMEWORK! FRAMEWORK! FRAMEWORK!

We need to automate the design process

[2] I. van Gent, G. La Rocca, and L.L.M. Veldhuis. Composing MDAO symphonies: graph-based generation and manipulation of large multidisciplinary systems. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.

KADMOS[2]

KADMOS[2]

[2] I. van Gent, G. La Rocca, and L.L.M. Veldhuis. Composing MDAO symphonies: graph-based generation and manipulation of large multidisciplinary systems. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.

Tool repository → MDO problem → MDO solution strategy → Collaborative workflow

KADMOS   **KADMOS**

RCG

Fundamental problem graph (FPG)

🟢 = design variable   🔵 = preprocessing function

🔷 = objective   🟢 = disciplinary analysis

🟠 = constraint   🔴 = function
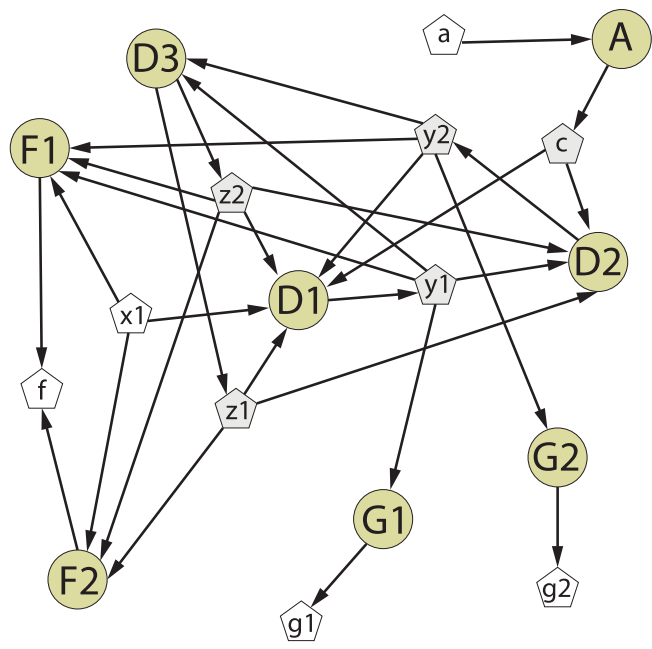
KADMOS[2]

[2] I. van Gent, G. La Rocca, and L.L.M. Veldhuis. Composing MDAO symphonies: graph-based generation and manipulation of large multidisciplinary systems. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.
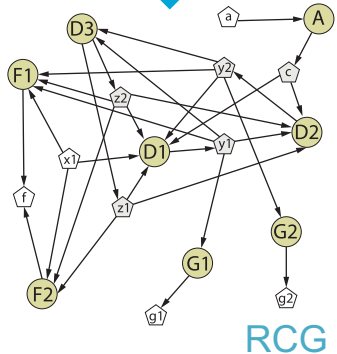

Tool repository — **KADMOS**

MDO problem — **KADMOS**

MDO solution strategy — **KADMOS**

Collaborative workflow

RCG

FPG

MDAO data graph (MDG)

MDAO process graph (MPG)

CONV = converger

OPT = optimizer

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[2] I. van Gent, G. La Rocca, and L.L.M. Veldhuis. Composing MDAO symphonies: graph-based generation and manipulation of large multidisciplinary systems. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.
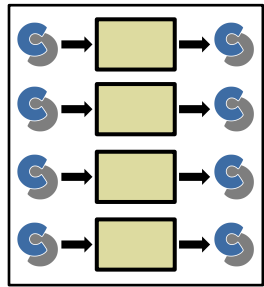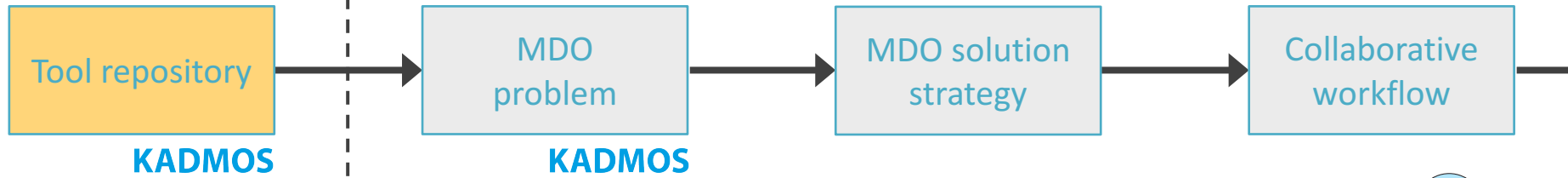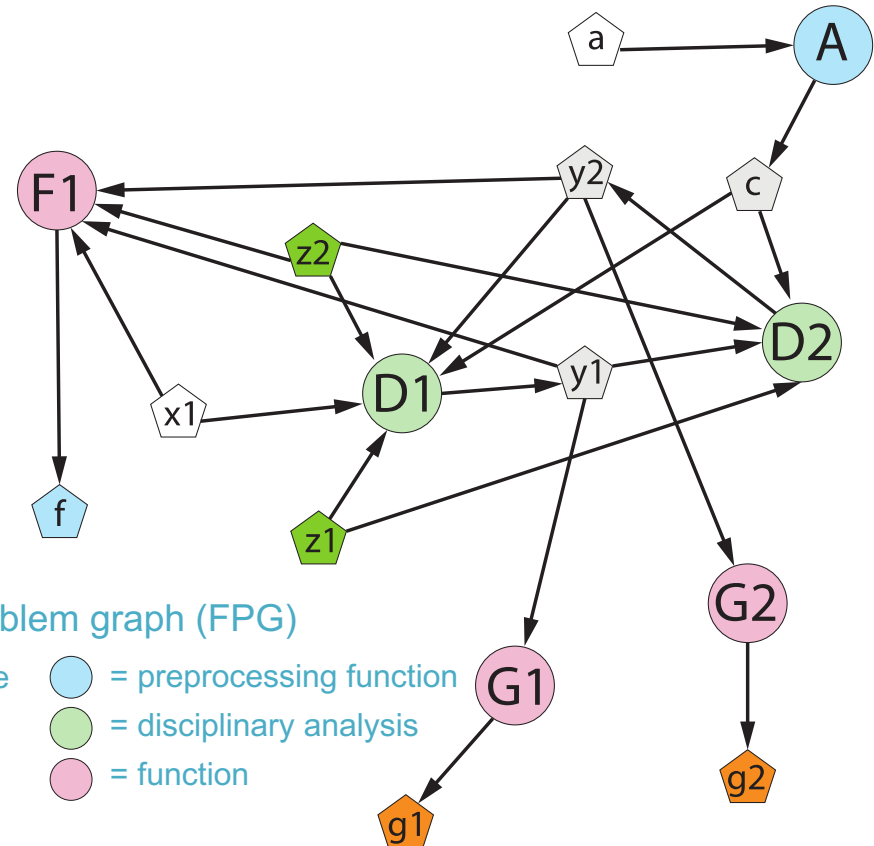
KADMOS[2]

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KADMOS[2]

add tool

Tool repository	MDO problem	MDO solution strategy	Collaborative workflow
KADMOS	**KADMOS**	**KADMOS**	**RCE**

RCG

FPG

MPG

+

MDG

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KADMOS within AGILE[3]

Tool repository — **KADMOS**

Tool repository — KE-chain

Tool repository — **SMR**

MDO problem — **KADMOS**

MDO solution strategy — **KADMOS**

Collaborative workflow — RCE

Collaborative workflow — Optimus

Collaborative workflow — openMDAO

Collaborative workflow — PHOENIX INTEGRATION

Visualization package — VISTOMS
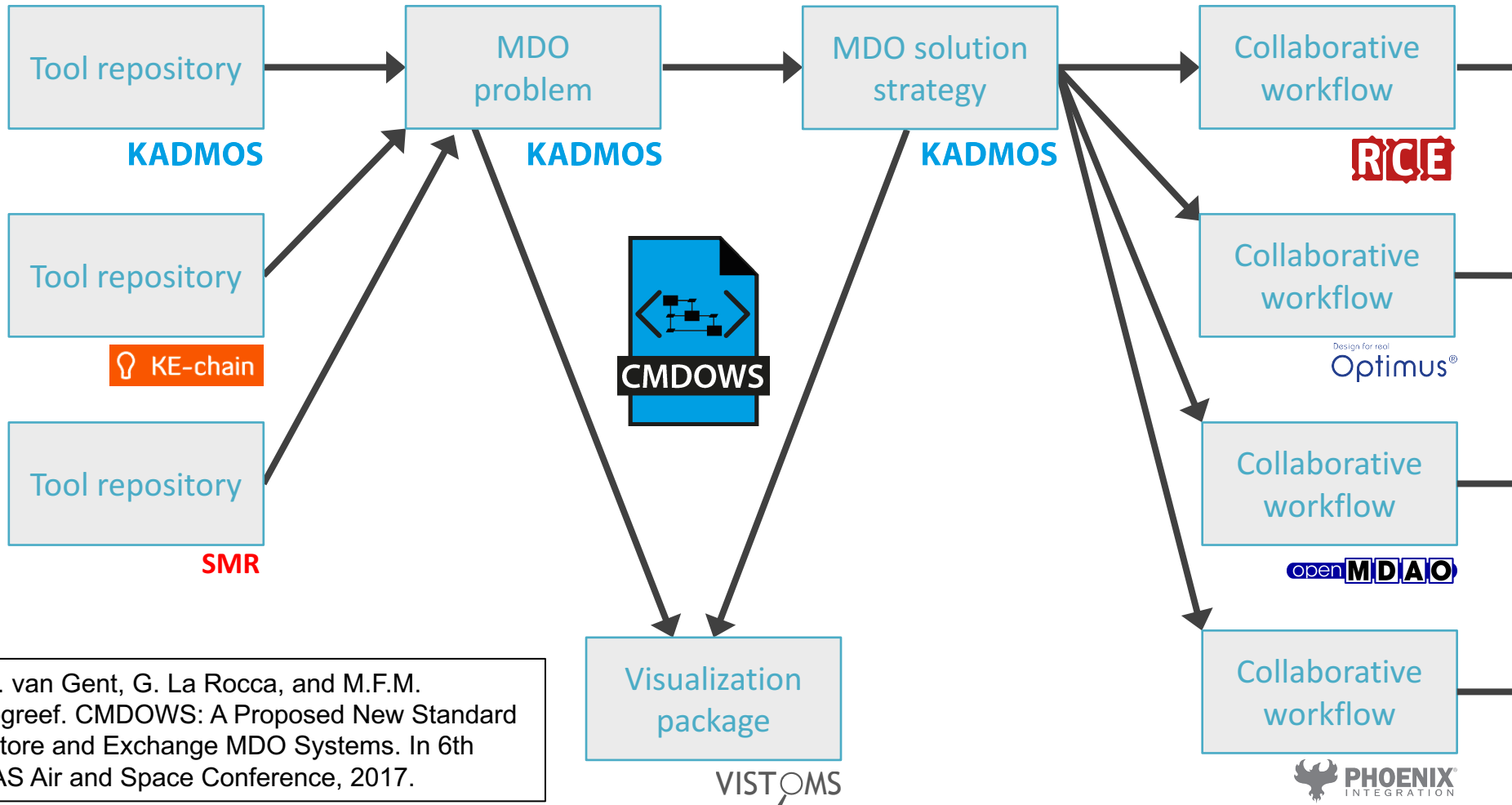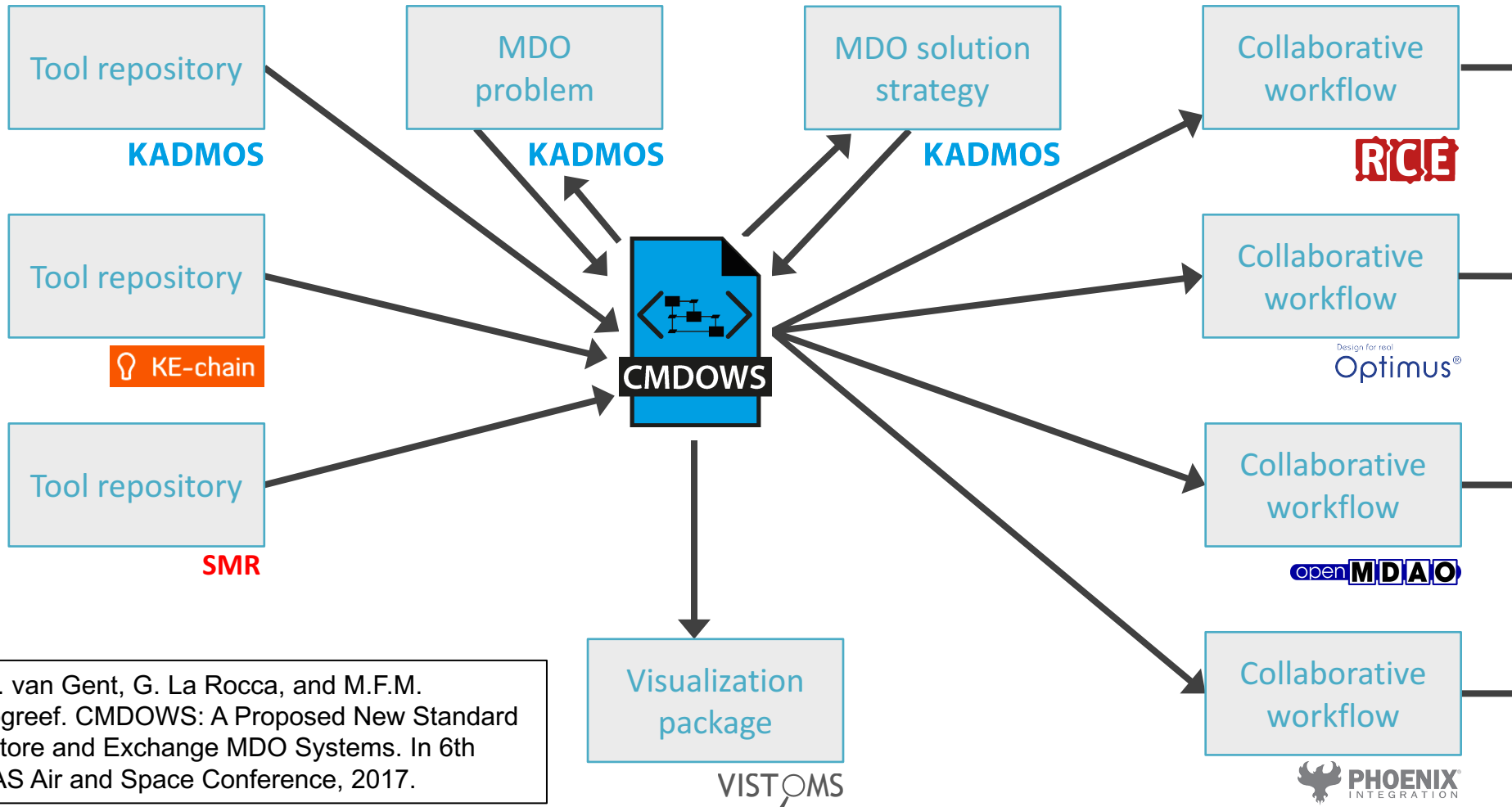
[3] I. van Gent, P.D. Ciampa, B. Aigner, J. Jepsen, G. La Rocca, and E.J. Schut. Knowledge architecture supporting collaborative MDO in the AGILE paradigm. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.

TUDelft   AGILE

CMDOWS[4]

Tool repository — KADMOS

Tool repository — KE-chain

Tool repository — SMR

MDO problem — KADMOS

MDO solution strategy — KADMOS

Collaborative workflow — RCE

Collaborative workflow — Optimus (Design for real)

Collaborative workflow — openMDAO

Collaborative workflow — PHOENIX INTEGRATION

CMDOWS

Visualization package — VISTOMS

[4] I. van Gent, G. La Rocca, and M.F.M. Hoogreef. CMDOWS: A Proposed New Standard to Store and Exchange MDO Systems. In 6th CEAS Air and Space Conference, 2017.
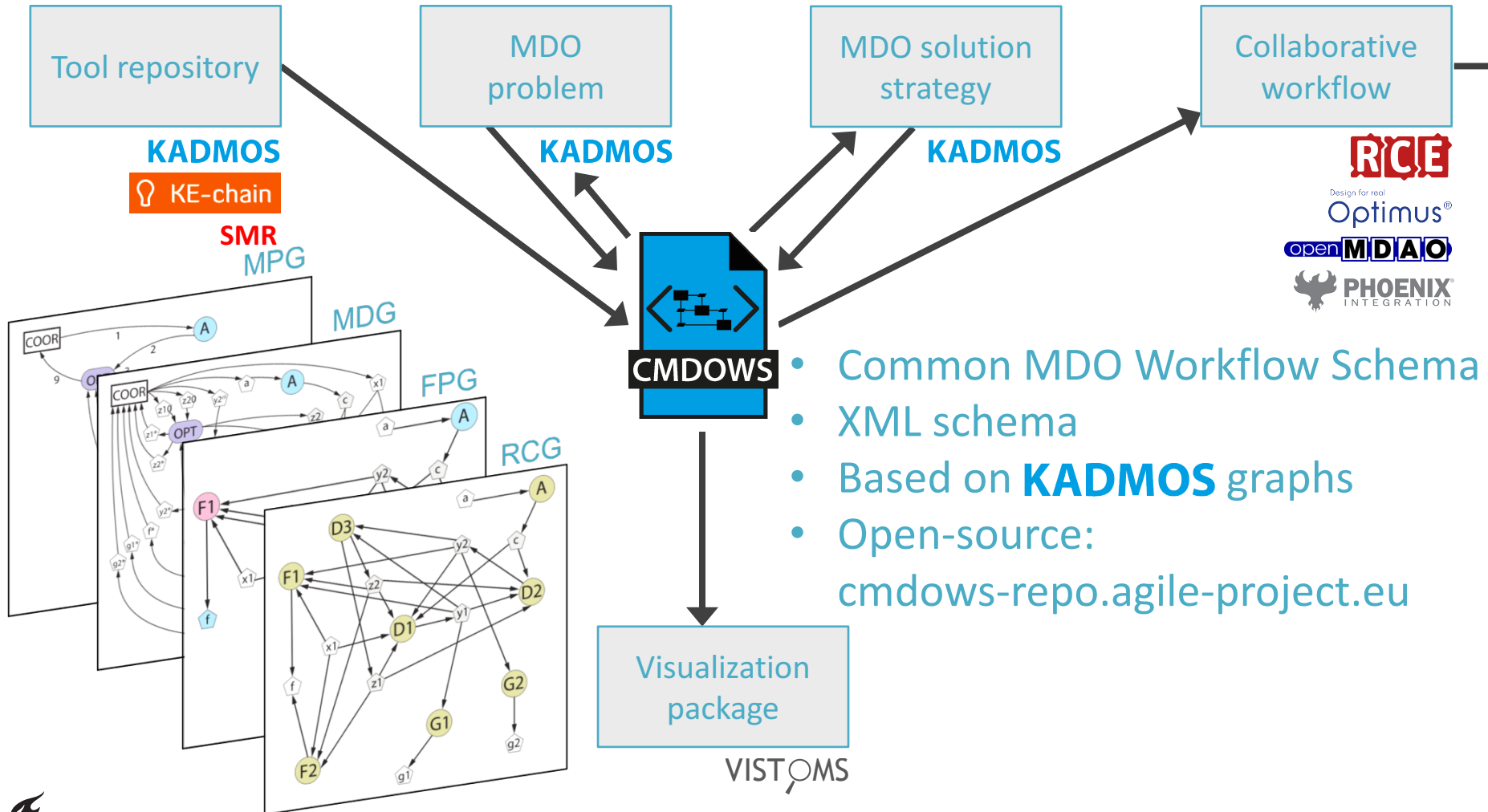
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CMDOWS[4]

[4] I. van Gent, G. La Rocca, and M.F.M. Hoogreef. CMDOWS: A Proposed New Standard to Store and Exchange MDO Systems. In 6th CEAS Air and Space Conference, 2017.

CMDOWS[4]

Tool repository	MDO problem	MDO solution strategy	Collaborative workflow

KADMOS

KE-chain

SMR

MPG

MDG

FPG

RCG

KADMOS

KADMOS

RCE

Design for real
Optimus®

open**MDAO**

PHOENIX
INTEGRATION

CMDOWS

- Common MDO Workflow Schema
- XML schema
- Based on **KADMOS** graphs
- Open-source:
  cmdows-repo.agile-project.eu
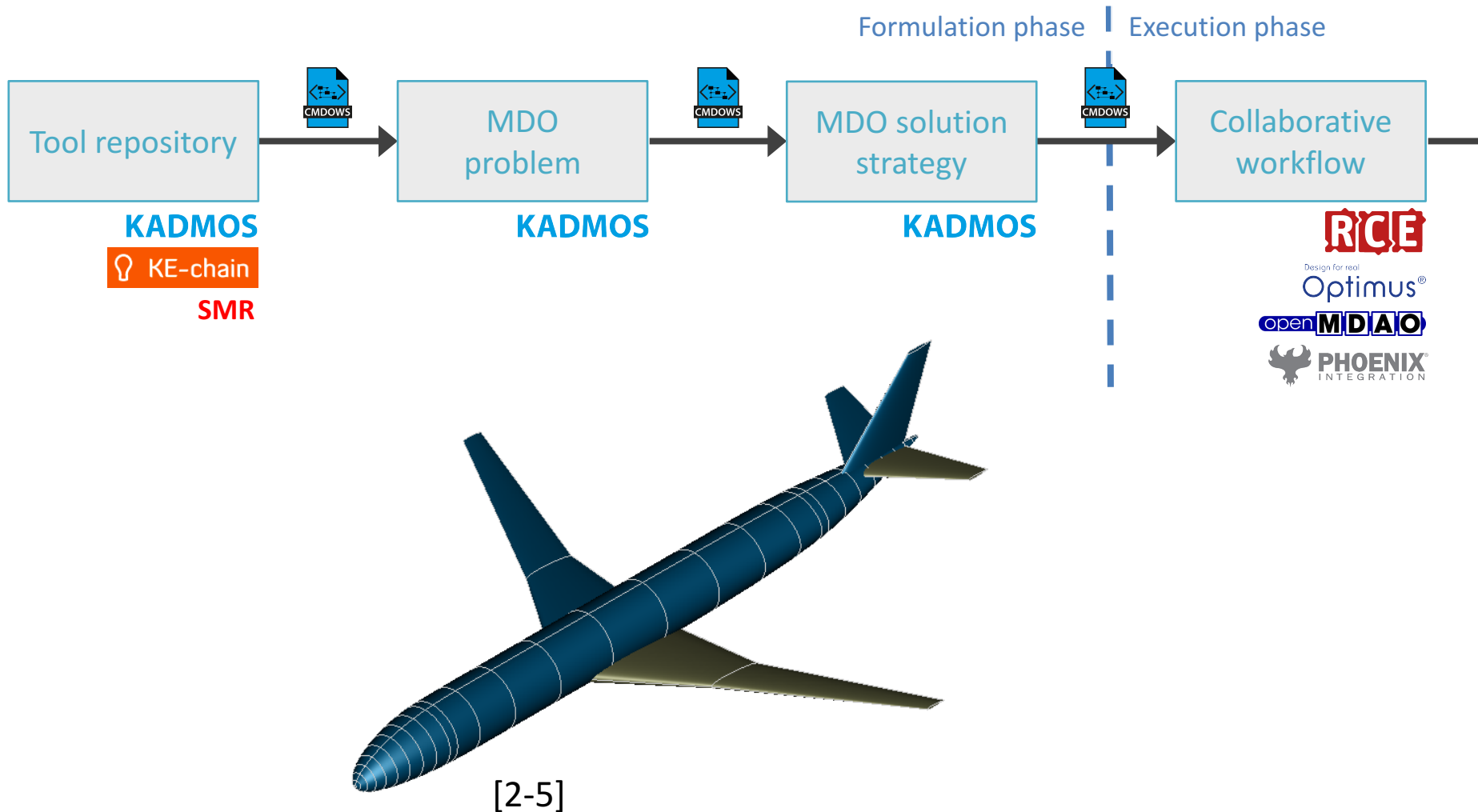
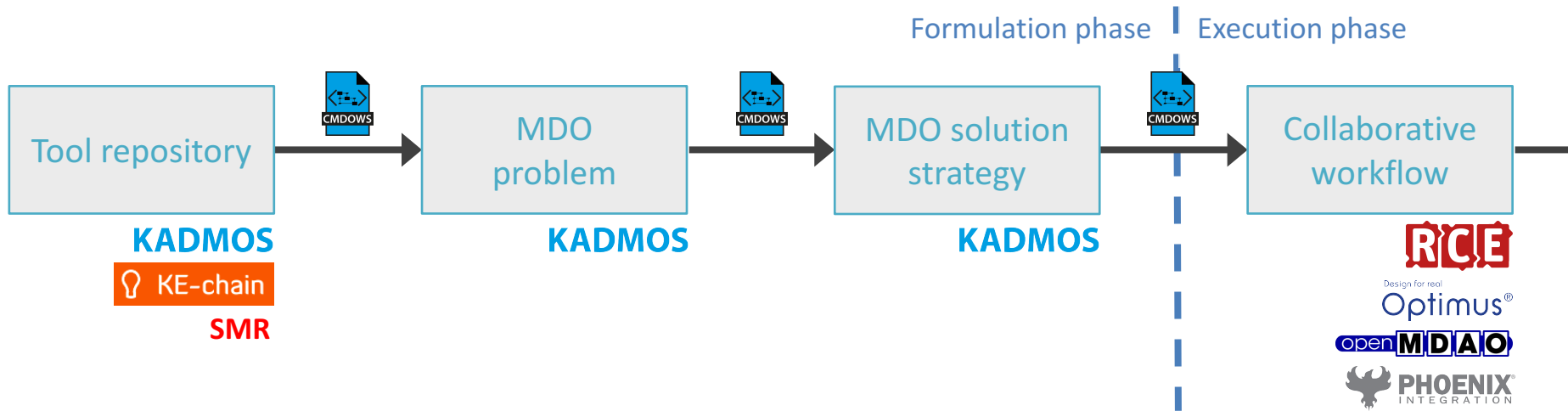Visualization package

VIST MS

TUDelft AGILE

Conclusion
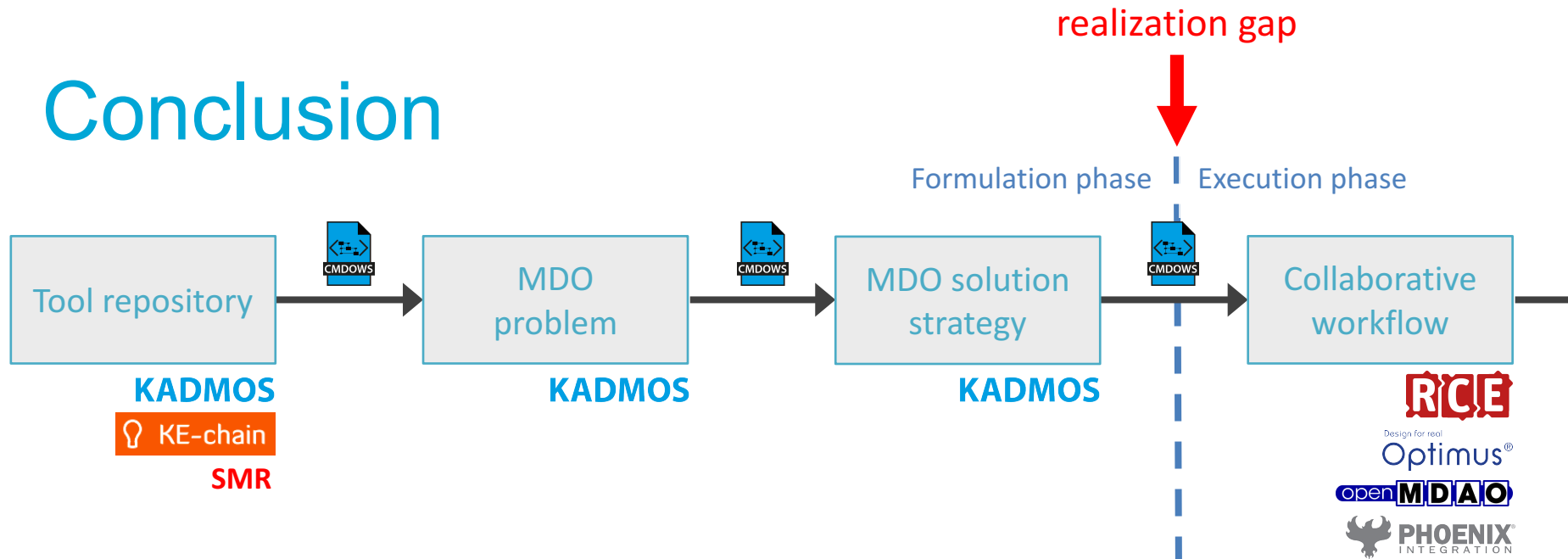
In collaborative MDO with a large, heterogeneous team (industrial setting):

I. We need a separate, **dedicated system to support the formulation** of our MDO solution strategy before we move to the execution phase.

II. We need an open-source, central data schema to **enable the storage and exchange of our MDO system** at different stages of the formulation phase.
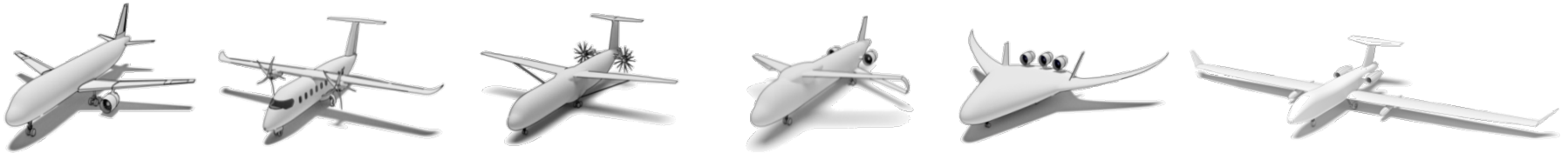
Conclusion

Formulation phase | Execution phase

Tool repository → MDO problem → MDO solution strategy → Collaborative workflow

CMDOWS

KADMOS
KADMOS
KADMOS

KE-chain

SMR

RCE
Design for real
Optimus®
open**MDAO**
PHOENIX INTEGRATION

[2-5]

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[5] I. van Gent, R. Lombardi, G. La Rocca, and R. d'Ippolito. A fully automated chain from MDAO problem formulation to workflow execution. In EUROGEN 2017, 2017.

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Future work

Formulation phase | Execution phase

Tool repository		MDO problem		MDO solution strategy		Collaborative workflow

CMDOWS → CMDOWS → CMDOWS →

KADMOS

KE-chain

SMR

KADMOS

KADMOS

RCE
Design for real
Optimus®
open MDAO
PHOENIX INTEGRATION

AGILE Configurations

40% time reduction?

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Questions?

Open-source references

KADMOS => https://bitbucket.org/imcovangent/kadmos

 => http://cmdows-repo.agile-project.eu
=> http://cmdows.agile-project.eu

 => http://rcenvironment.de/

 => http://openmdao.org/

 => https://www.agile-project.eu/files/VISTOMS_SellarProblem
=> https://www.agile-project.eu/files/VISTOMS_TUDWingDesign

References

[1] P.D. Ciampa and B. Nagel. The AGILE Paradigm: the next generation of collaborative MDO. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.

[2] I. van Gent, G. La Rocca, and L.L.M. Veldhuis. Composing MDAO symphonies: graph-based generation and manipulation of large multidisciplinary systems. In 18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2017.

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[5] I. van Gent, R. Lombardi, G. La Rocca, and R. d'Ippolito. A fully automated chain from MDAO problem formulation to workflow execution. In EUROGEN 2017, 2017.

Appendix: AGILE Knowledge Architecture
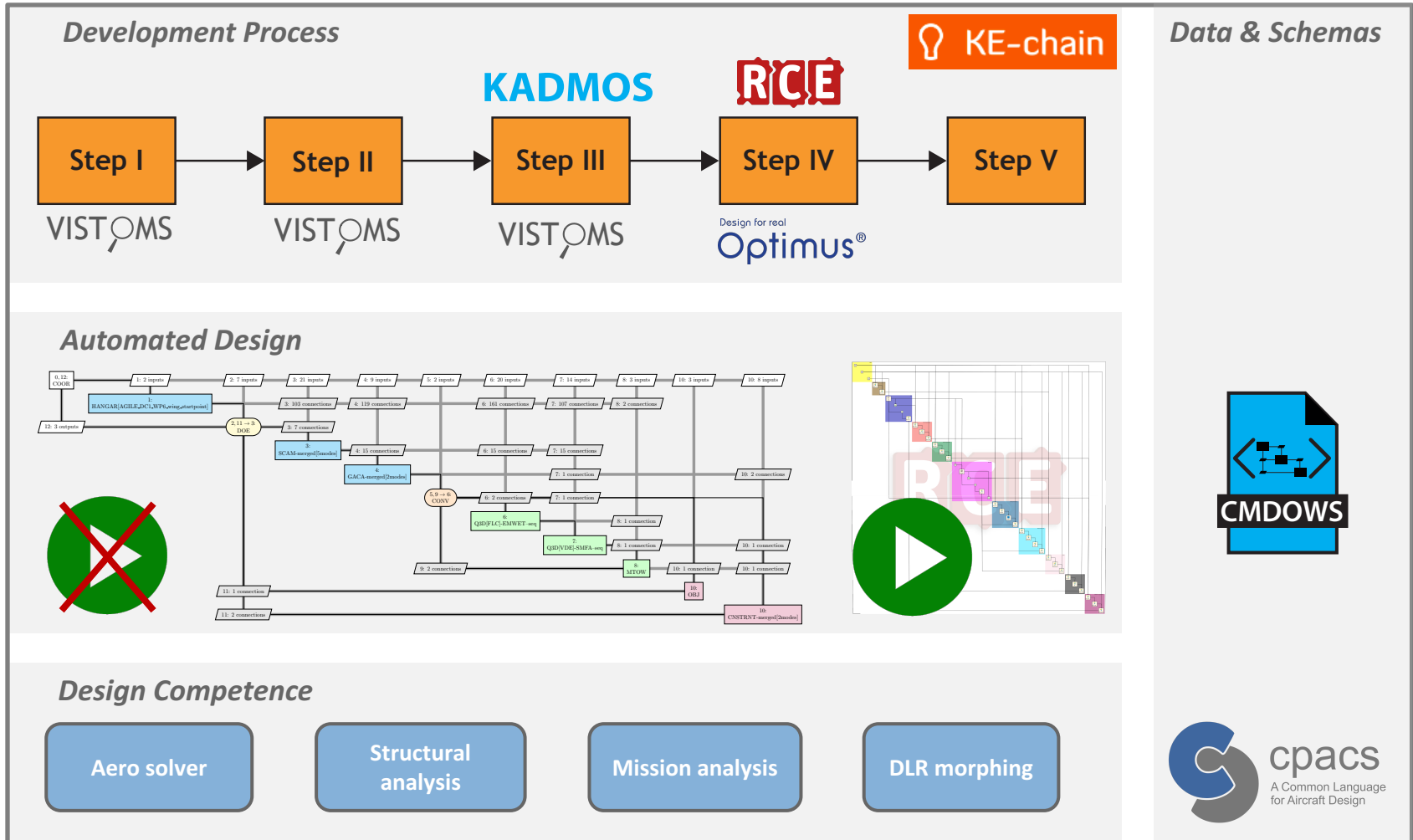
Appendix: Setup time

- Flager and Haymaker, Stanford University:

  MDAO requires more than **double the amount of time** to perform a first design iteration compared to conventional design methods.

- Ciampa and Nagel, DLR (German Aerospace Center):

  60-80% of project time is spent on setting up the first automated design workflow.

- Pate, Gray, and German (Georgia Tech, NASA):

  The **cost and time required** to integrate an MDAO system can easily approach the cost and time requirements of creating any of the discipline analyses themselves.

Appendix: Setup time

Design Method	Relative Time Spent				Iteration Duration		Number of Possible Iterations*
					Initial	Subsequent	
Legacy	8%	32%	50%	10%	6 wks	4 wks	2.5
MDO	26%	18%	8%	48%	14 wks	1.5 hrs	>1,000**

*   assuming a 12 week period
** after process set-up has been completed

Specification
(e.g. determining tasks, staffing, and what information is used and produced)

Execution
(e.g. generating options and running analyses)

Management
(e.g. representing, documenting and coordinating existing information)

Reasoning
(e.g. interpreting results, choosing options)

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