

MEDITO

a logic-based meta-diagnosis tool

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1. Can we trust model-based diagnosis?
2. A theory of meta-diagnosis
3. Some diagnostic system's potential abnormalities
4. MEDITO: a logic-based meta-diagnosis tool
5. Meta-diagnosing an Airbus Landing Gear Extraction and Retraction System (LGERS)
6. Conclusions

Can we trust model-based diagnosis (MBD)?

Model-based diagnosis

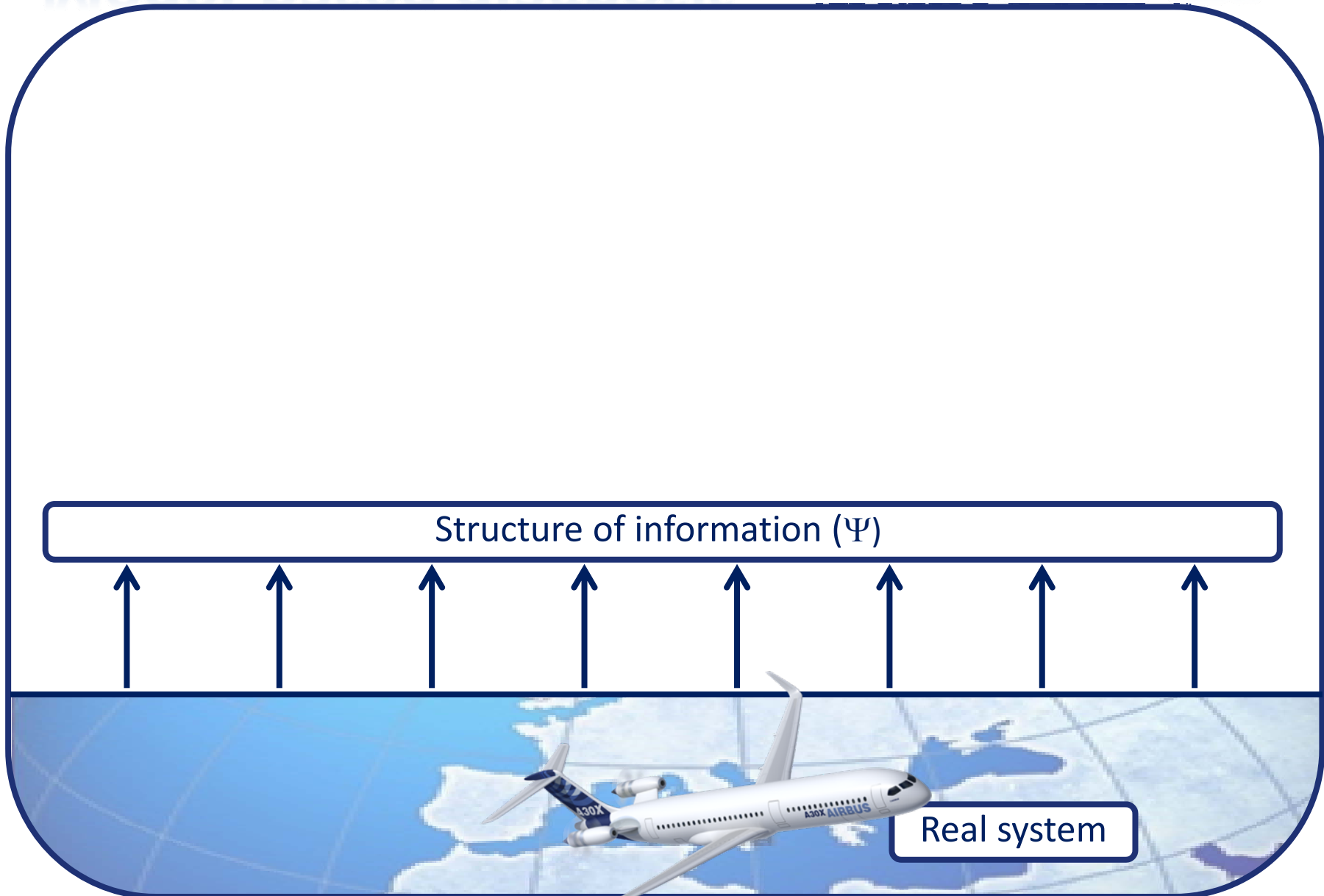
(Reiter, 1987)

(de Kleer & Williams, 1987)

Model-based diagnosis

(Reiter, 1987)

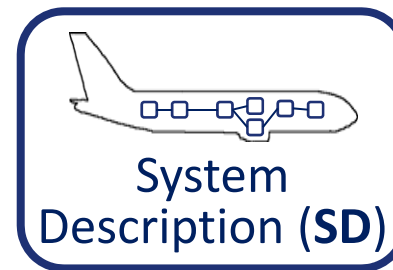
(de Kleer & Williams, 1987)



Model-based diagnosis

(Reiter, 1987)

(de Kleer & Williams, 1987)



Structure of information (Ψ)

Definition (Believed System) A believed system is a pair $(DS, COMPS)$ where:

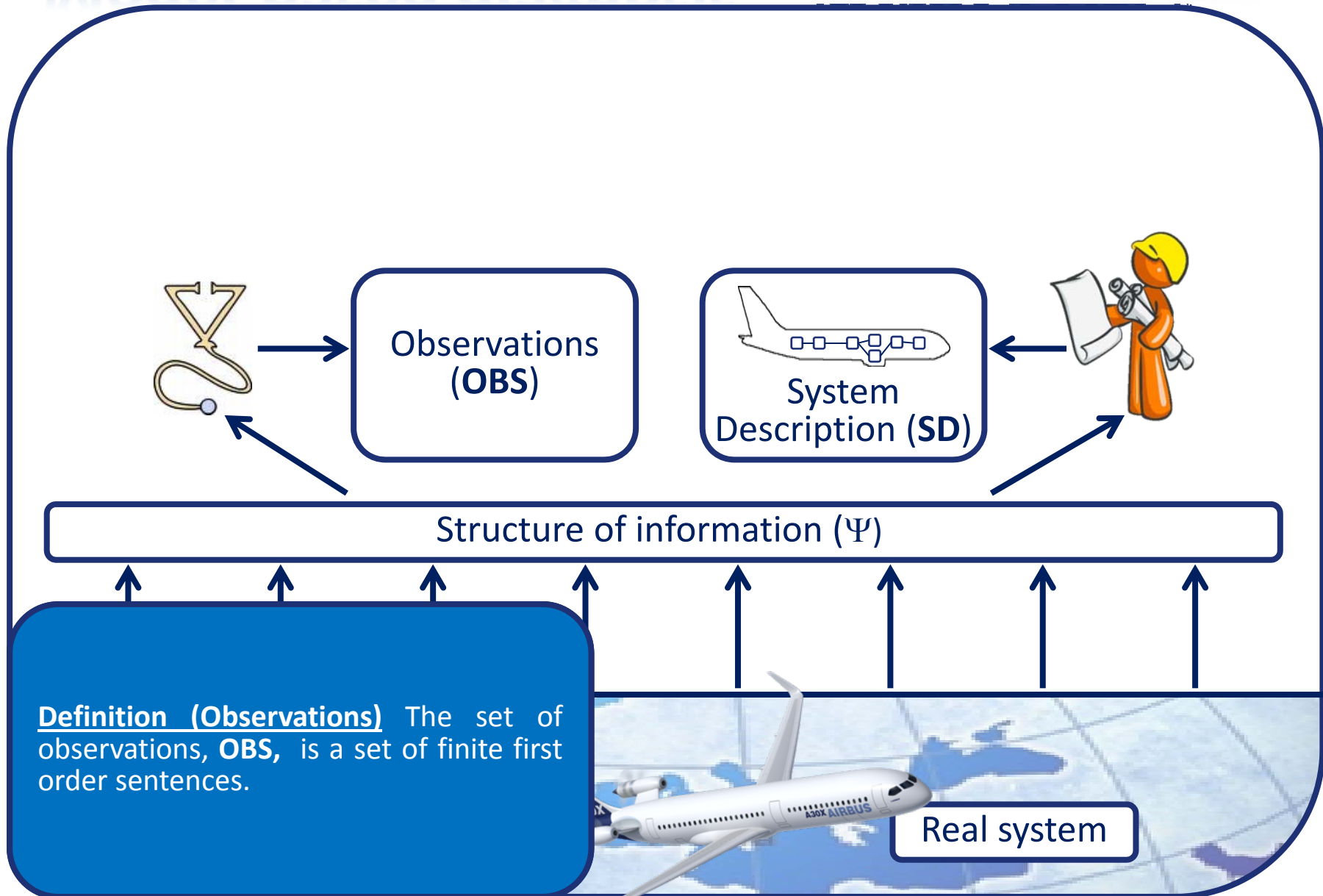
1. **SD**, the system description is a set of first order sentences.
2. **COMPS**, is a finite set of constants representing the real-world system physical units to diagnose.



Model-based diagnosis

(Reiter, 1987)

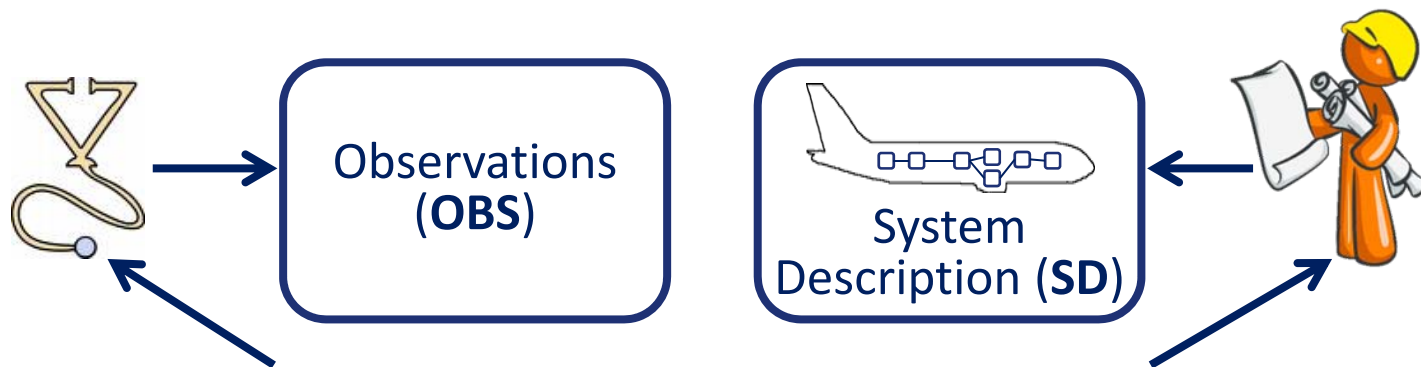
(de Kleer & Williams, 1987)



Model-based diagnosis

(Reiter, 1987)

(de Kleer & Williams, 1987)



Structure of information (Ψ)

Definition (Health state) Let Δ be a set of components considered abnormal. The health state of a believed system, $\sigma(\Delta, \text{COMPS} \setminus \Delta)$, is:

$$\bigwedge_{c \in \Delta} Ab(c) \bigwedge_{c \in (\text{COMPS} \setminus \Delta)} \neg Ab(c)$$

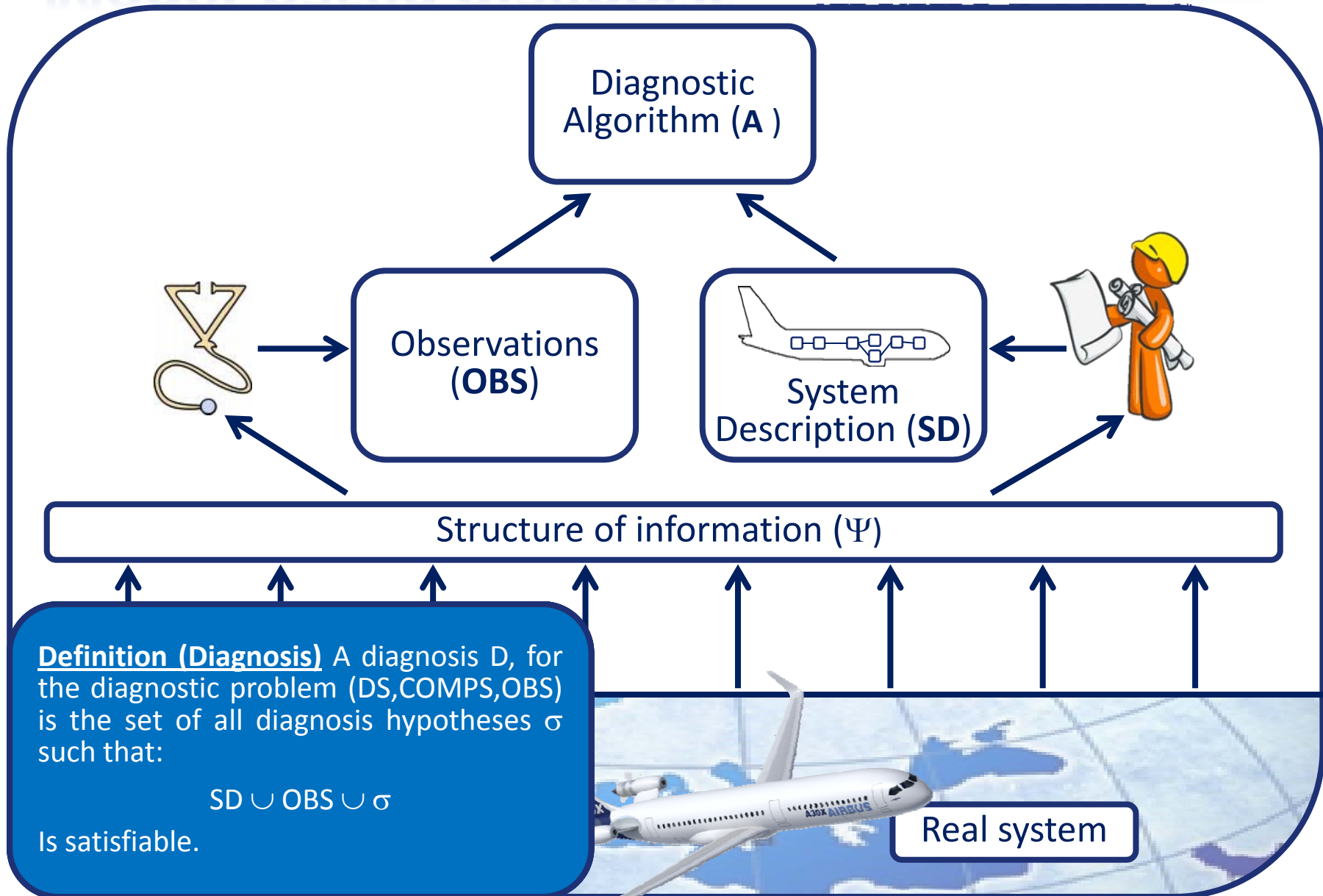


Real system

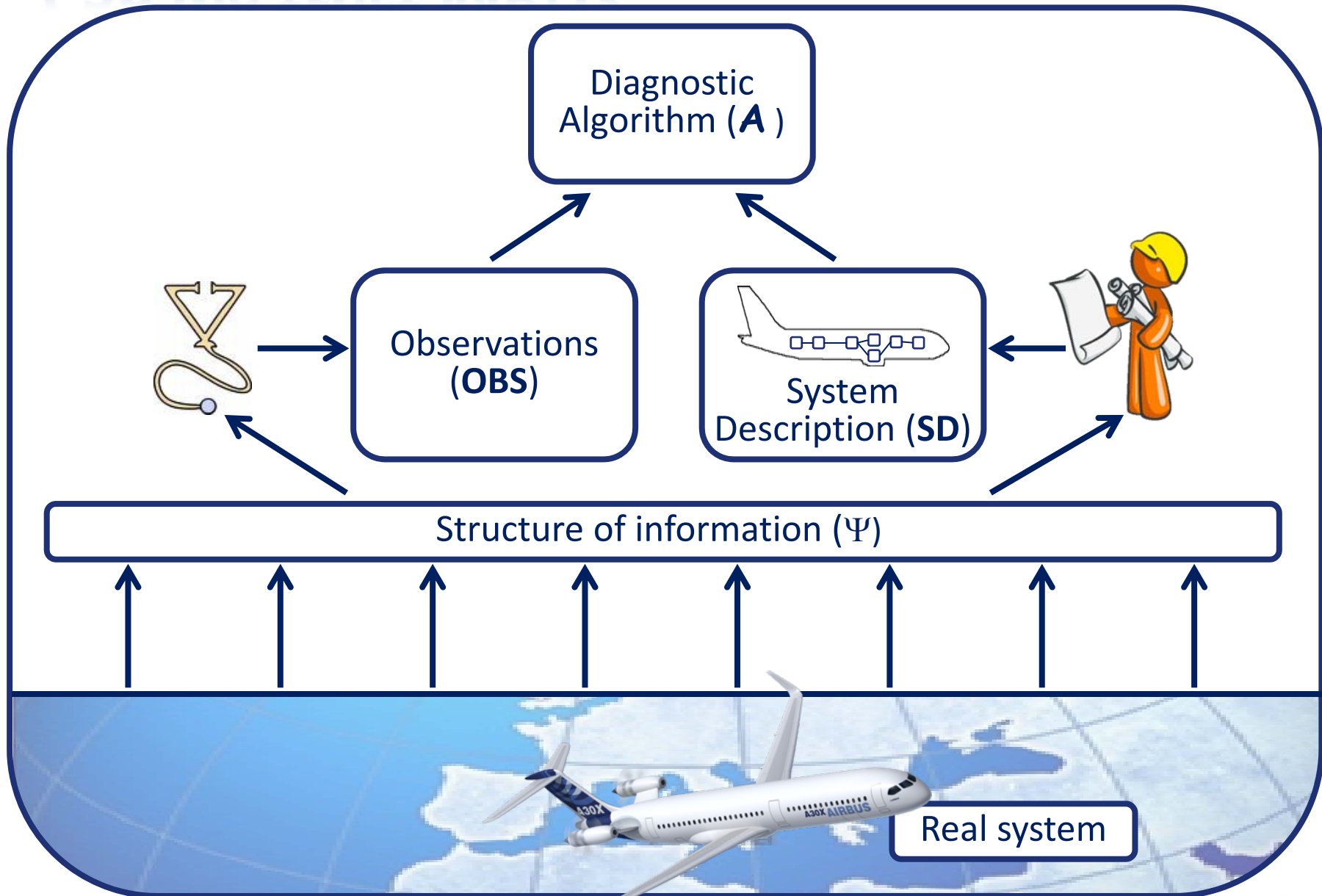
Model-based diagnosis

(Reiter, 1987)

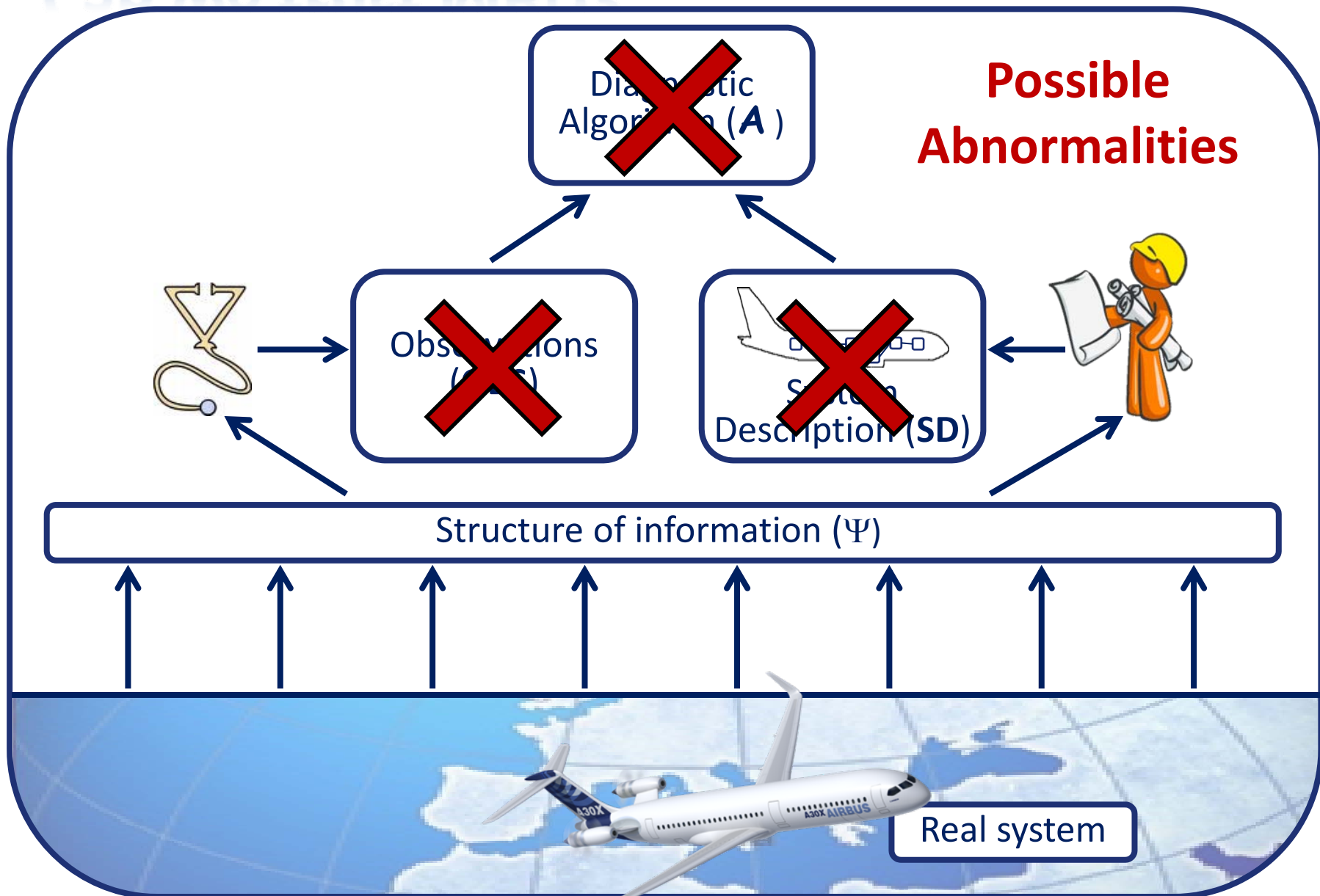
(de Kleer & Williams, 1987)



Can we trust MBD?



Can we trust MBD?



Example (Davis, 1984)

A : {A1}, {M3}, {M1,M2}, {A1,M2}

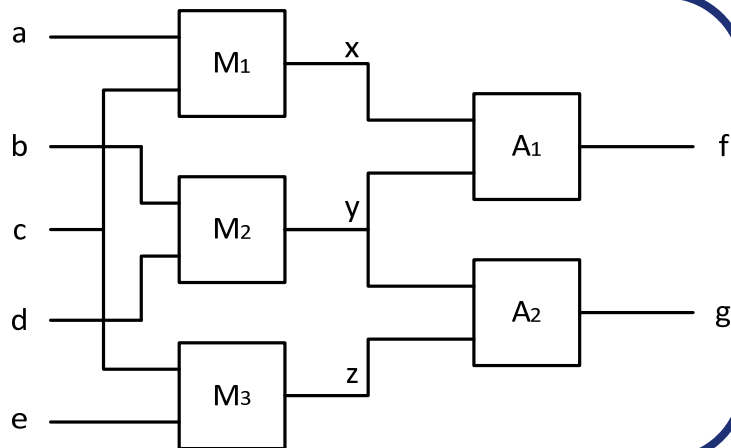
OBS

Ob1: $v(a) = 1 \wedge v(b) = 2 \wedge v(c) = 3 \wedge v(d) = 4 \wedge v(e) = 5 \wedge v(f) = 11 \wedge v(g) = 22$

SD

M1desc: $\neg Ab(M1) \Rightarrow (v(x) = (v(a) + 1) * v(c))$
M2desc: $\neg Ab(M2) \Rightarrow (v(y) = v(b) * v(d))$
M3desc: $\neg Ab(M3) \Rightarrow (v(z) = v(c) * v(e))$
A1desc: $\neg Ab(A1) \Rightarrow (v(f) = v(x) + v(y))$
A2desc: $\neg Ab(A2) \Rightarrow (v(g) = v(y) + v(z))$

Real



A theory of meta-diagnosis

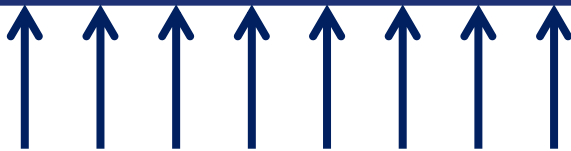
Characterising meta-diagnoses

(Belard, Pencolé &
Combacau, 2011)

Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)

Structure of information (Ψ)



Diagnostic System: (SD, COMPS, OBS, A)

Observations (OBS)

Diagnostic Algorithm (A)



System Description (SD)

Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)

Meta-system
description
(M-SD)



Structure of information (Ψ)

Definition (Meta-System Description)

The meta-system description is a pair (M-SD, M-COMPS) where:

1. M-SD, the meta-system description, is a set of first order sentences.
2. M-COMPS, is a finite set of constants representing the meta-components of the diagnostic system.

Diagnostic System: (SD, COMPS, OBS, A)

Observations
(OBS)

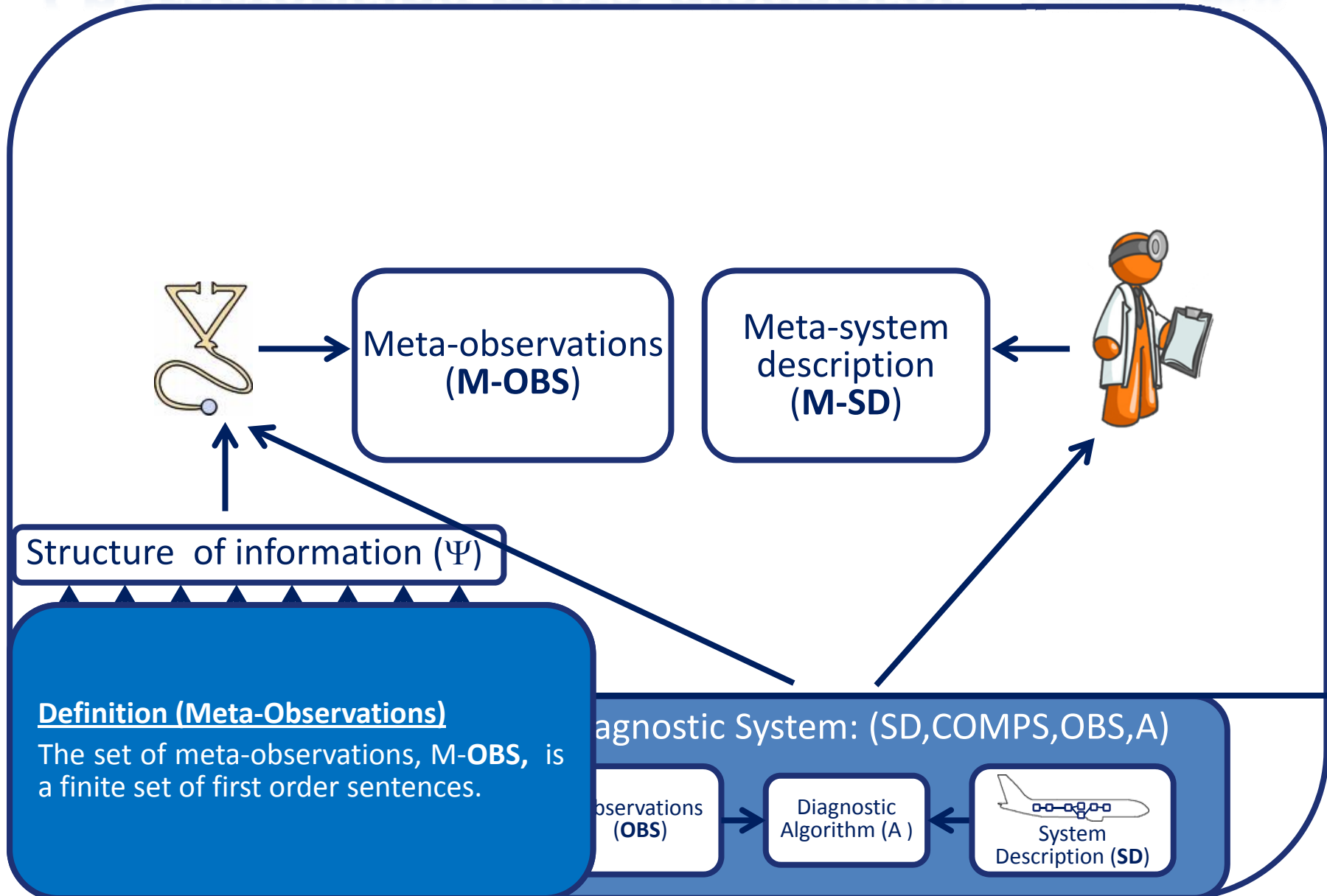
Diagnostic
Algorithm (A)



System
Description (SD)

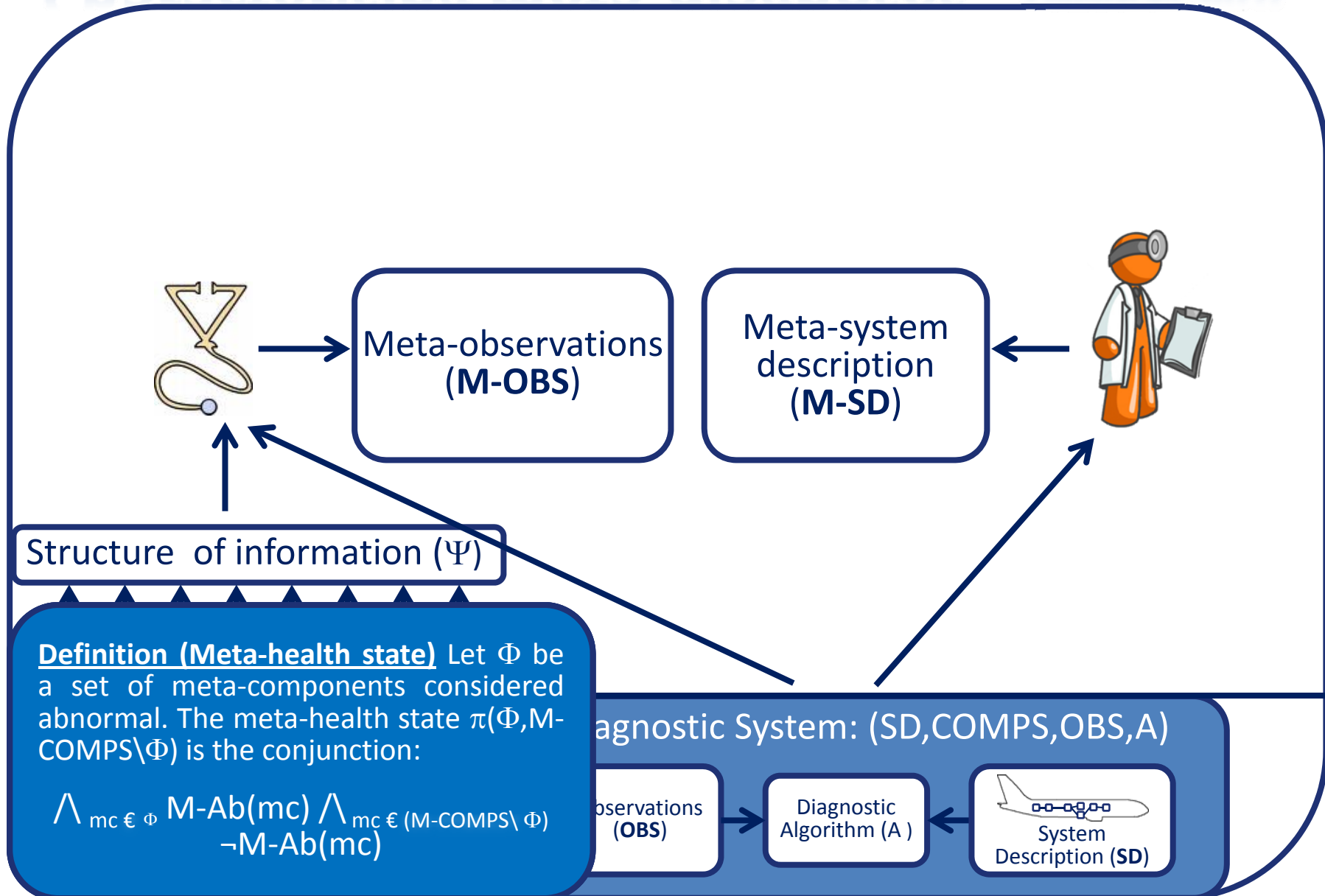
Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)



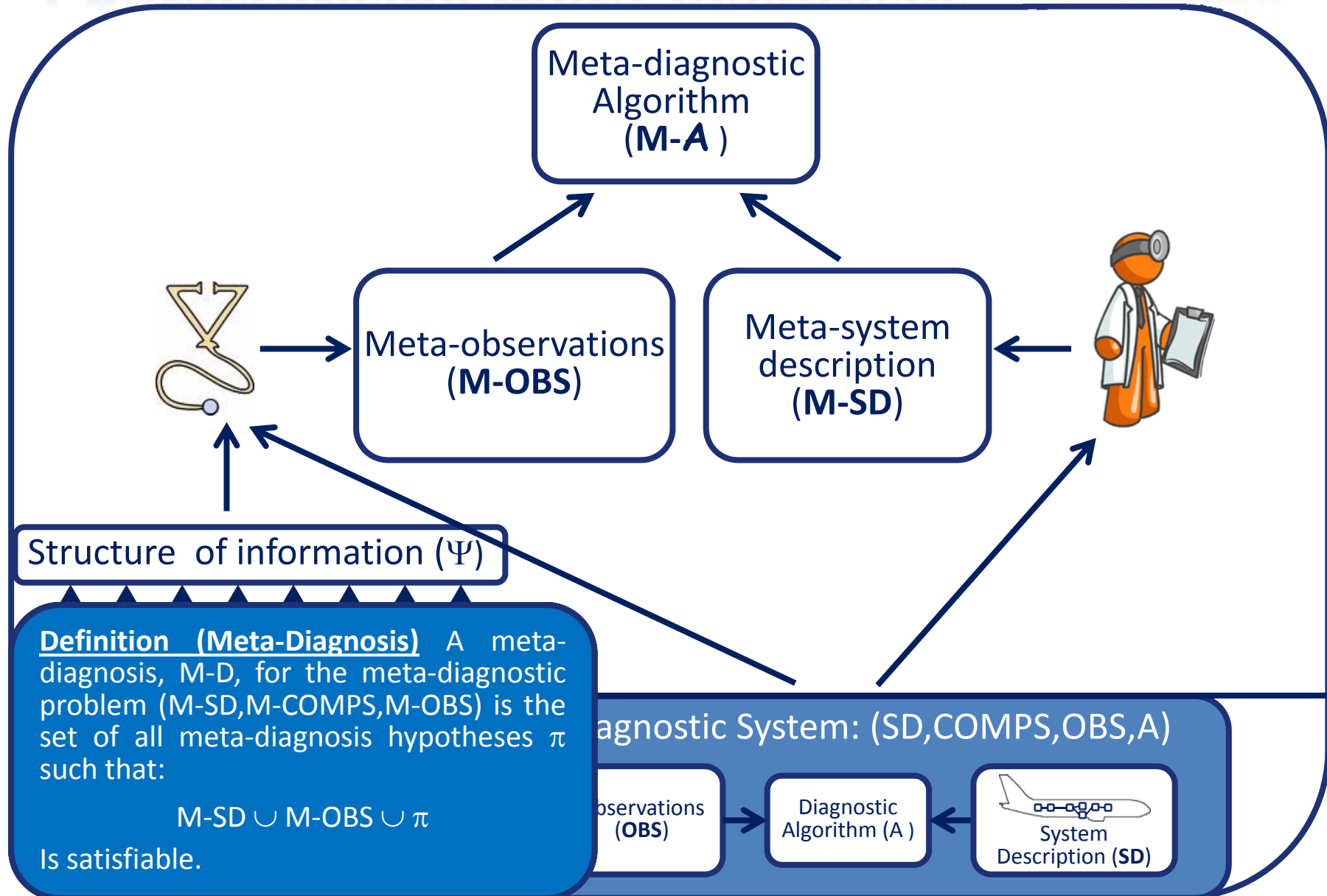
Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)



Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)



Structure of information (Ψ)

Definition (Meta-Diagnosis) A meta-diagnosis, M-D, for the meta-diagnostic problem (M-SD, M-COMPS, M-OBS) is the set of all meta-diagnosis hypotheses π such that:

$$M-SD \cup M-OBS \cup \pi$$

Is satisfiable.

Diagnostic System: (SD, COMPS, OBS, A)

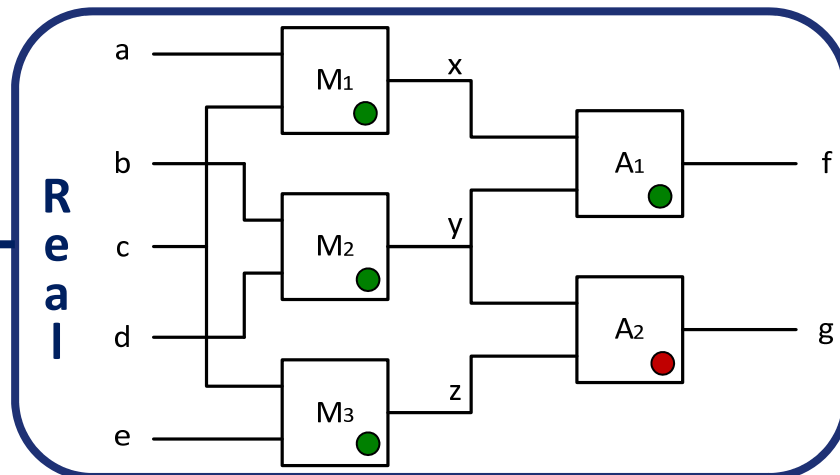


Example (continued)

M-A: {M1desc}, {M2desc}, {A1desc}

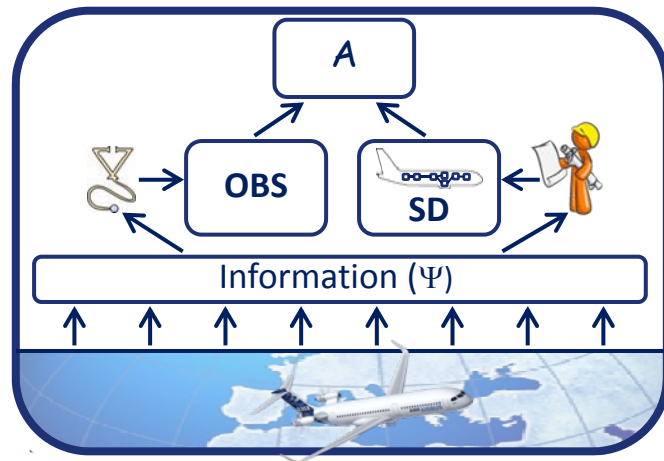
M $v(a)=1 \wedge v(b)=2 \wedge v(c)=3 \wedge v(d)=4$
- $\wedge v(e)=5 \wedge v(f)=11 \wedge v(g)=22$
O
B $\neg Ab(M1) \wedge \neg Ab(M2) \wedge \neg Ab(M3) \wedge$
S $\neg Ab(A1) \wedge Ab(A2)$

-M-Ab(M1desc) $\Rightarrow [\neg Ab(M1) \Rightarrow (v(x)=(v(a)+1)*v(c))]$
M **-M-Ab(M2desc)** $\Rightarrow [\neg Ab(M2) \Rightarrow (v(y) = v(b) * v(d))]$
-
S **-M-Ab(M3desc)** $\Rightarrow [\neg Ab(M3) \Rightarrow (v(z) = v(c) * v(e))]$
D **-M-Ab(A1desc)** $\Rightarrow [\neg Ab(A1) \Rightarrow (v(f) = v(x) + v(y))]$
-M-Ab(A2desc) $\Rightarrow [\neg Ab(A2) \Rightarrow (v(g) = v(y) + v(z))]$

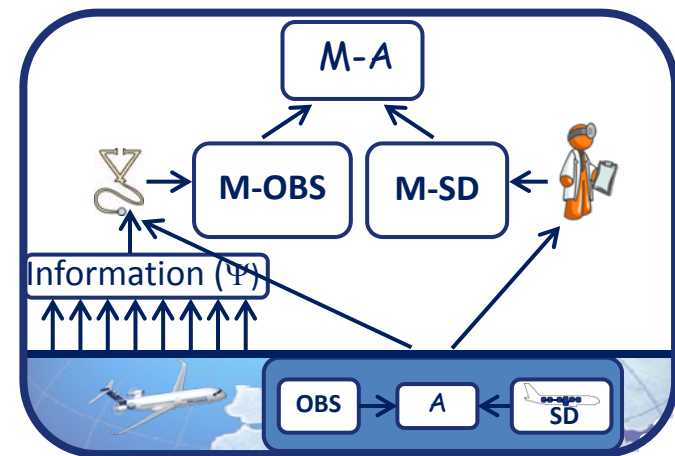


Syntax and semantics

Diagnosis



Meta-Diagnosis



Diagnosis and Meta-Diagnosis are semantically different, but syntactically the same. Therefore, diagnostic-world techniques, algorithms and tools can be directly used in meta-diagnosis.

Some diagnostic systems' potential abnormalities

Some SD, OBS and D properties

(Belard, Pencolé & Combacau, 2010)

of observations (Tarski, 1936)

Definition (Truth): Let Ω be the set of all structures and $\Psi \in \Omega$ the structure of raw information about the reality. The observations OBS are an ontological truth iff'

$$\exists s \in \text{Mod}(\text{OBS}) \exists t \in \Omega: (s \subseteq t) \wedge (t \leftrightarrow \Psi).$$

of observations (Tarski, 1936)

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of system description (Tarski, 1936)

Definition (truth): Let Ω be the set of all structures and $\Psi \in \Omega$ the structure of raw information about the reality. A believed system is an ontological truth iff, for all ontologically true OBS,

$$\exists s \in \text{Mod}(\text{OBSUSD}) \exists t \in \Omega: (s \subseteq t) \wedge (t \leftrightarrow \Psi).$$

of observations (Tarski, 1936)

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of diagnoses

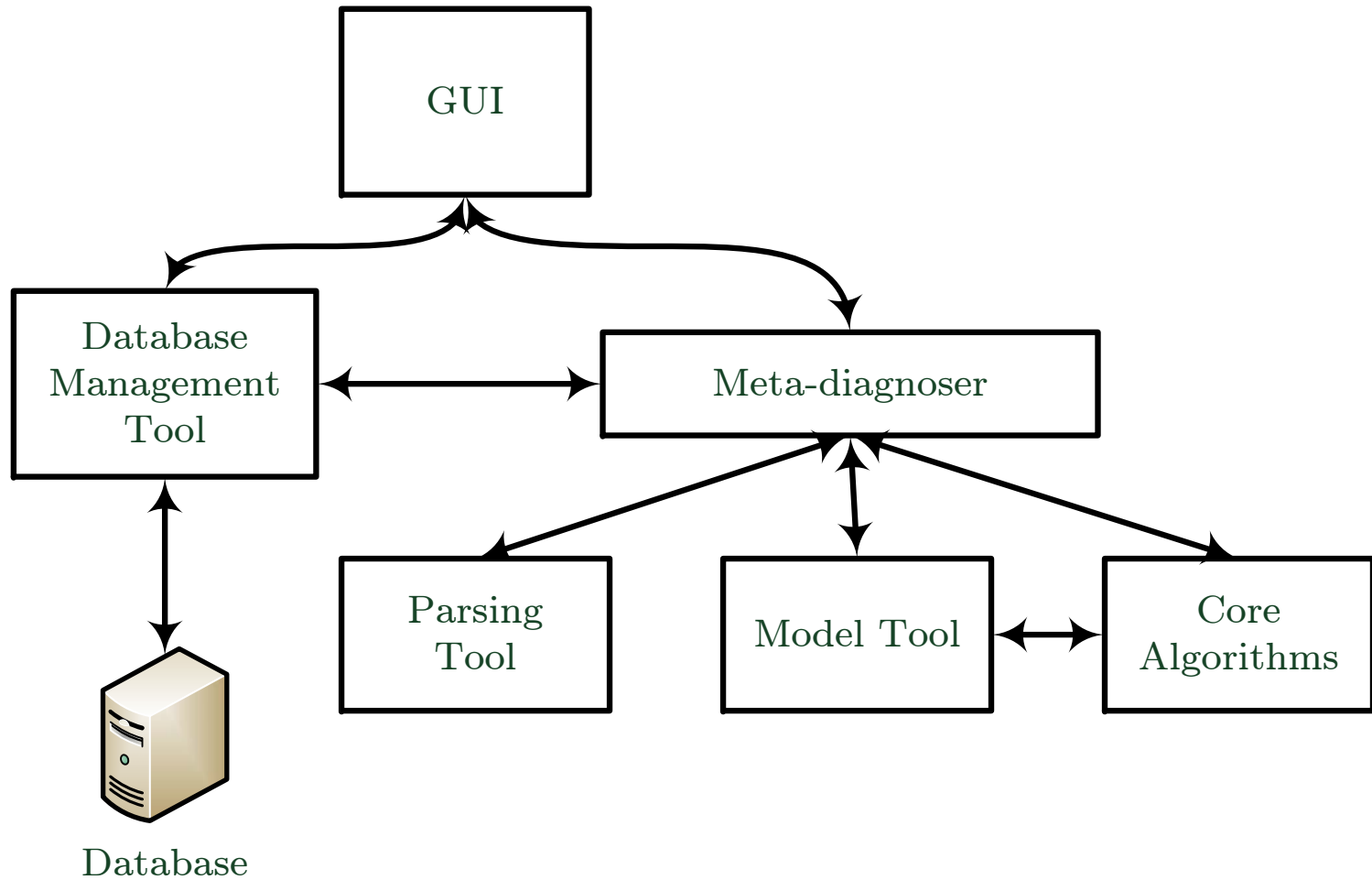
Definition (validity): Let σ_{real} be the believed system health state such that for every $c \in \text{COMPS}$, if c is the image of $r \in R$, 1) if r is normal, $\sigma_{\text{real}} \Rightarrow \neg \text{Ab}(c)$, and 2) if r is abnormal $\sigma_{\text{real}} \Rightarrow \text{Ab}(c)$.

A diagnosis, D , is valid iff $\sigma_{\text{real}} \in D$.

Theorem: If (SD,COMPS) is an ontologically true believed system, then for every diagnostic problem (SD, COMPS,OBS) with ontologically true observations, every diagnosis D is valid.

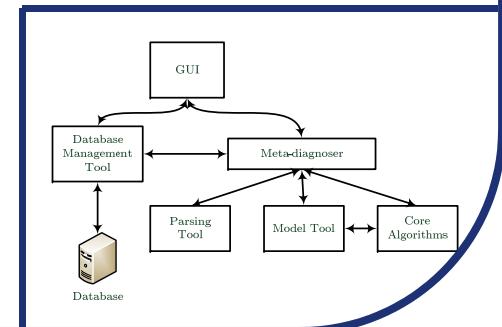
MEDITO: a logic-based meta-diagnosis tool

MEDITO: meta-diagnosis tool architecture



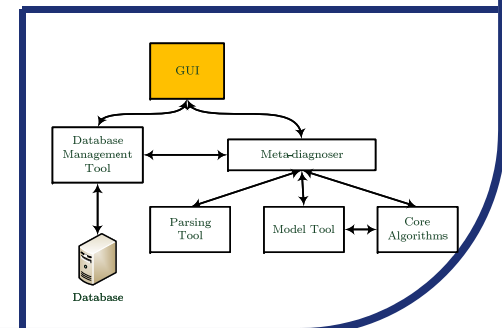
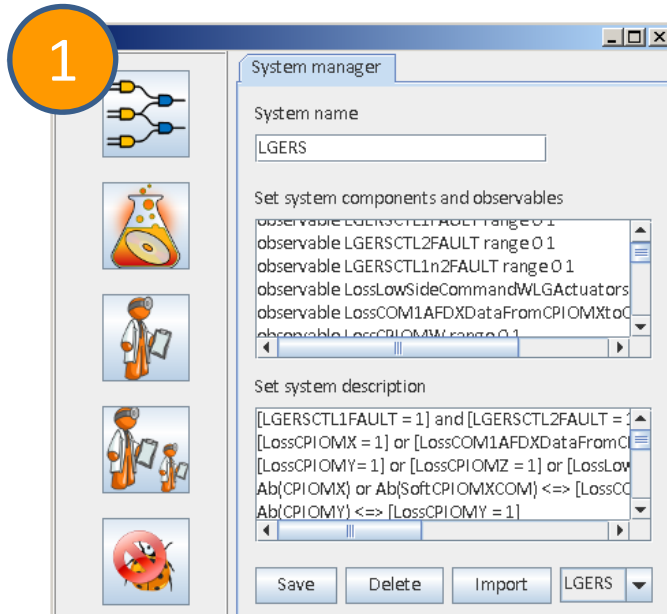
MEDITO: meta-diagnosis tool workflow

Data injection



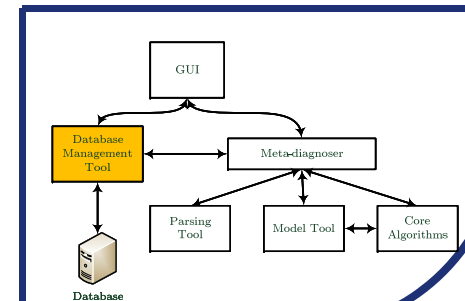
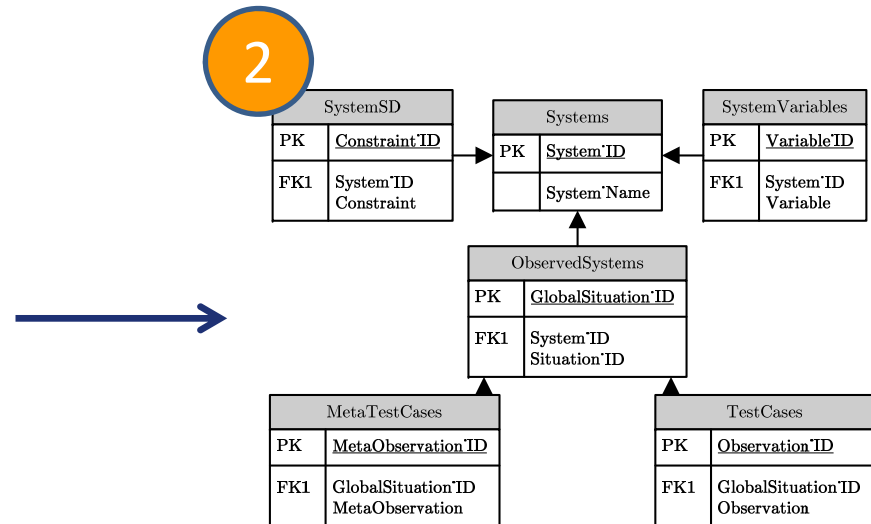
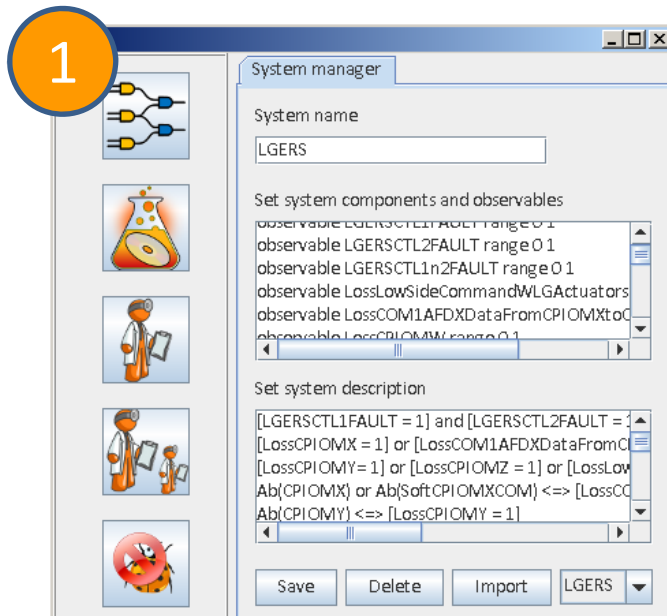
MEDITO: meta-diagnosis tool workflow

Data injection



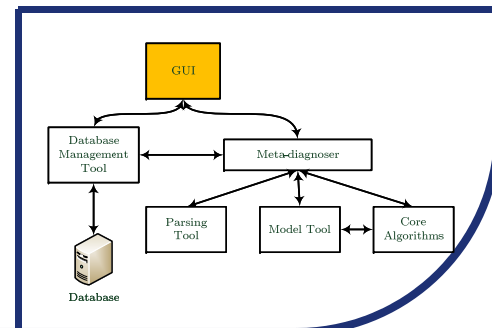
MEDITO: meta-diagnosis tool workflow

Data injection



MEDITO: meta-diagnosis tool workflow

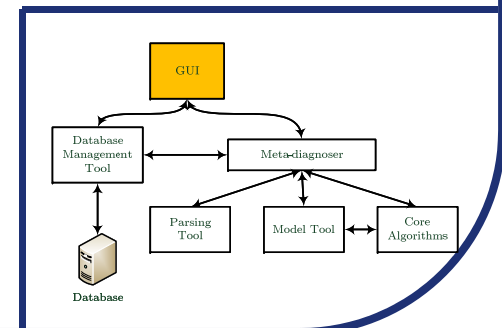
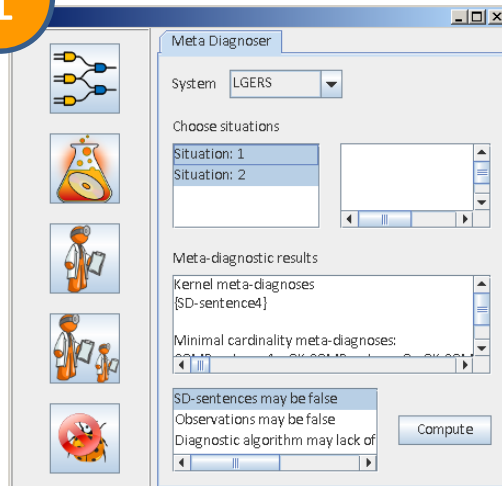
Data exploitation



MEDITO: meta-diagnosis tool workflow

Data exploitation

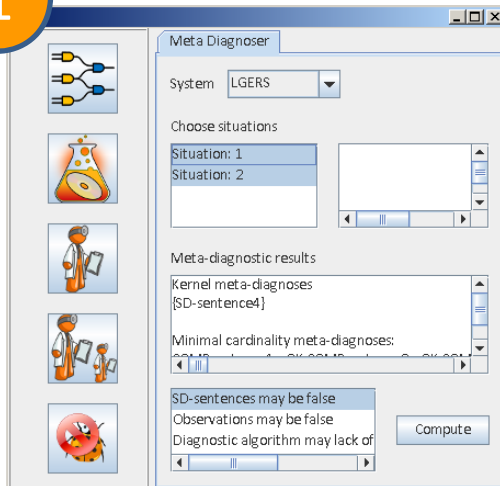
1



MEDITO: meta-diagnosis tool workflow

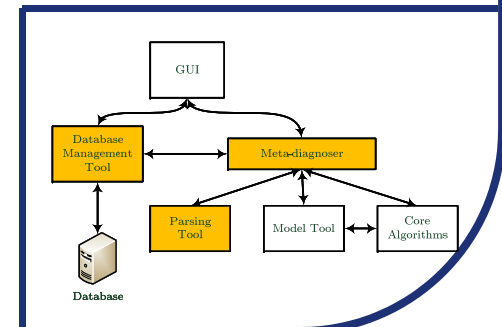
Data exploitation

1



2

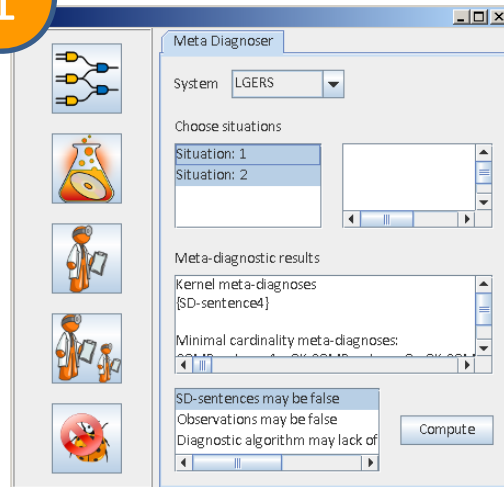
Parsing of user-input text SD and M-OBS into java objects.



MEDITO: meta-diagnosis tool workflow

Data exploitation

1

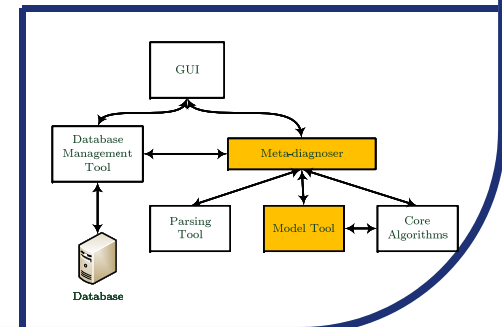


2

Parsing of user-input text SD and M-OBS into java objects.

3

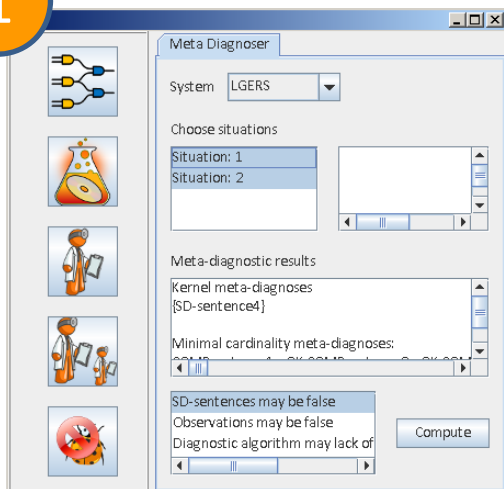
Creation of CHOCO model depending on user-input hypotheses.
(Choco Team, 2010)



MEDITO: meta-diagnosis tool workflow

Data exploitation

1



2

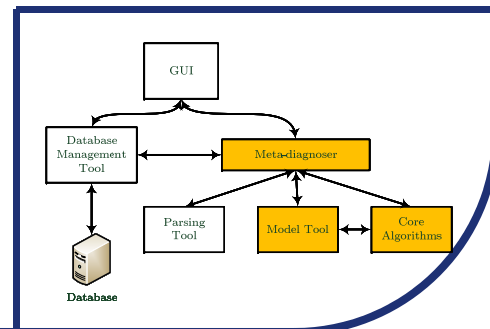
Parsing of user-input text SD and M-OBS into java objects.

3

Creation of CHOCO model depending on user-input hypotheses.
(Choco Team, 2010)

4

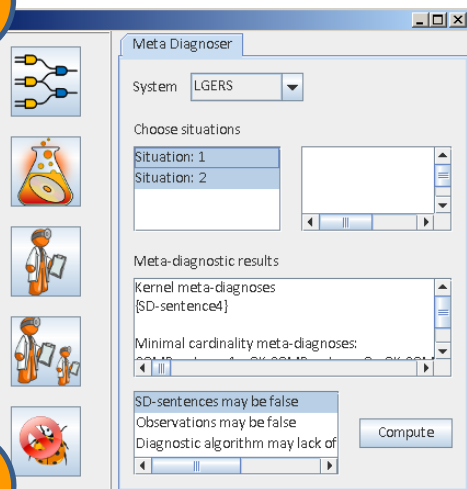
Running of Zhao and Ouyang diagnostic algorithms using CHOCO for consistency checking.
(Zhao & Ouyang, 2006)
(Zhao & Ouyang, 2007)



MEDITO: meta-diagnosis tool workflow

Data exploitation

1



2

Parsing of user-input text SD and M-OBS into java objects.

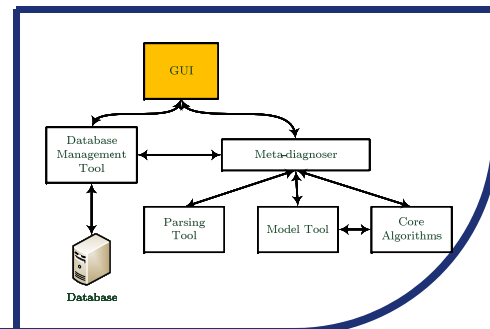
3

Creation of CHOCO model depending on user-input hypotheses.
(Choco Team, 2010)

4

Running of Zhao and Ouyang diagnostic algorithms using CHOCO for consistency checking.
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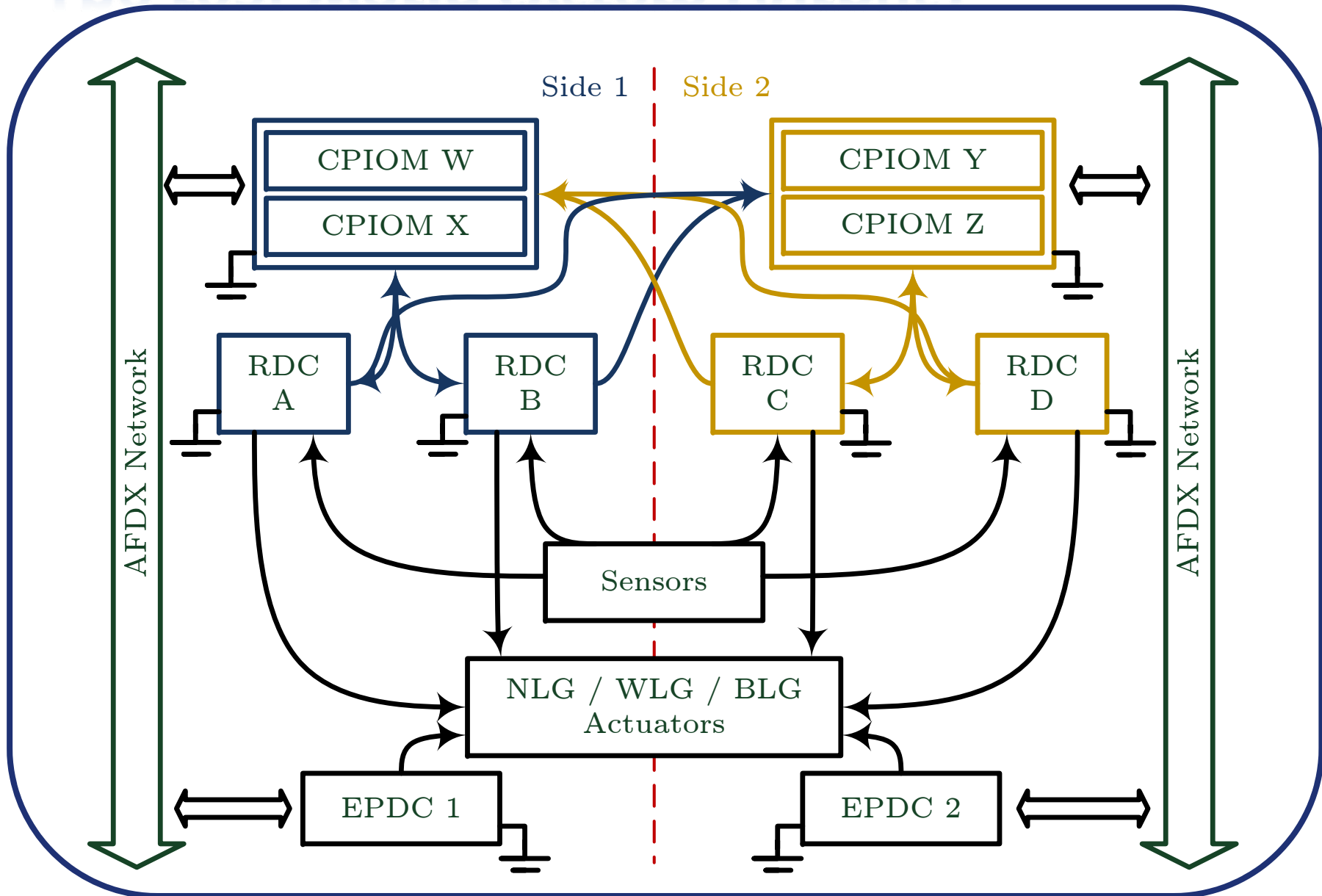
5





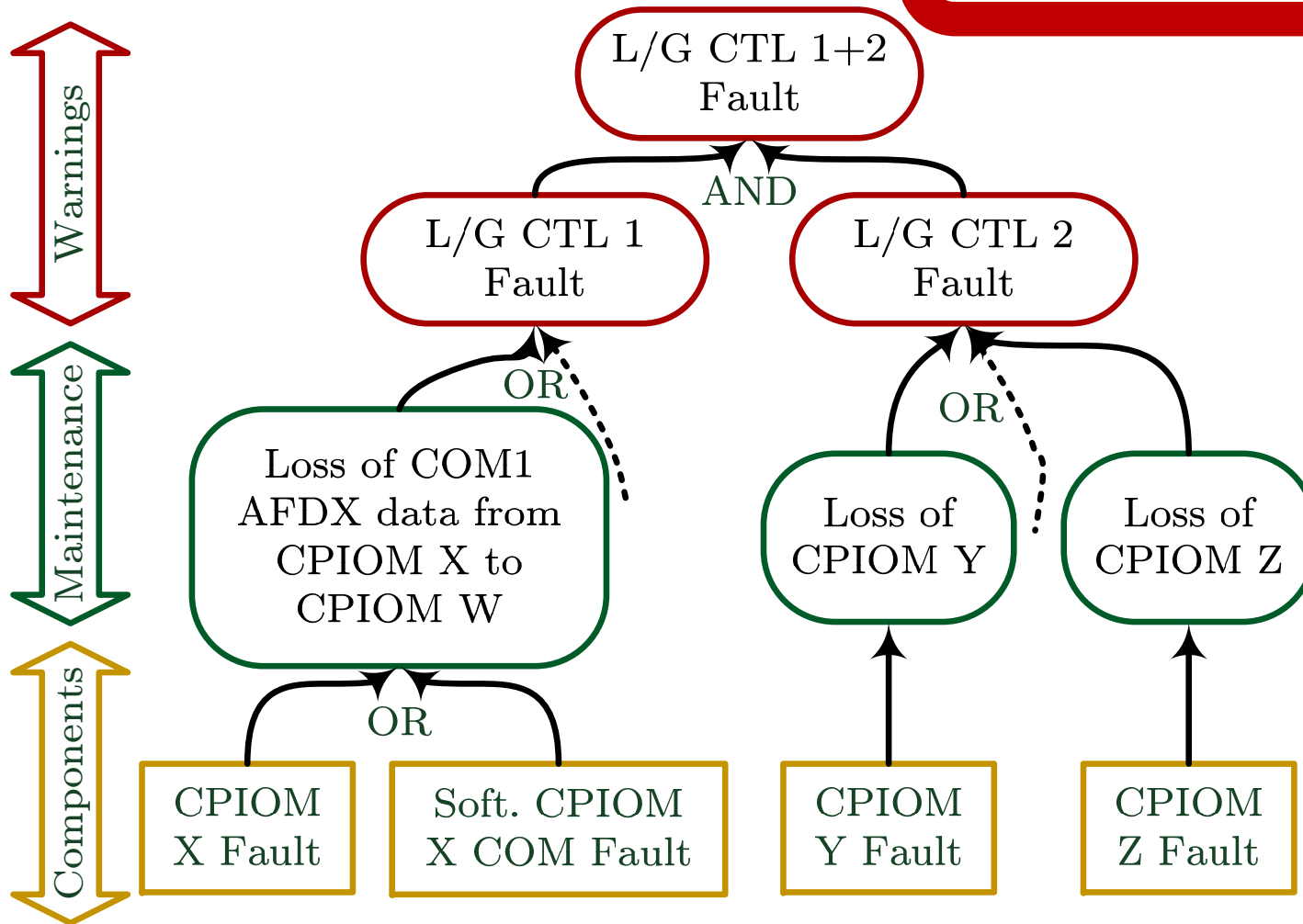
Meta-diagnosing an Airbus LGERS

The real-world system (Airbus)



The believed system

For confidentiality issues, the believed system (BS) in this slide is not a perfect copy of Airbus' LGERS BS (roughly with 6000 nodes)



The meta-observations

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus' real-life situations.

The meta-observations

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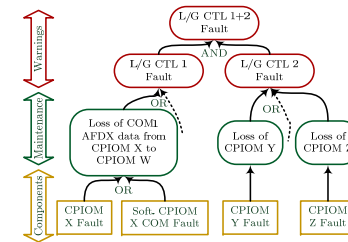
Situation 1

LGERCTL1+2FAULT = \perp

LGERCTL1FAULT = T

LGERCTL2FAULT = \perp

CMS

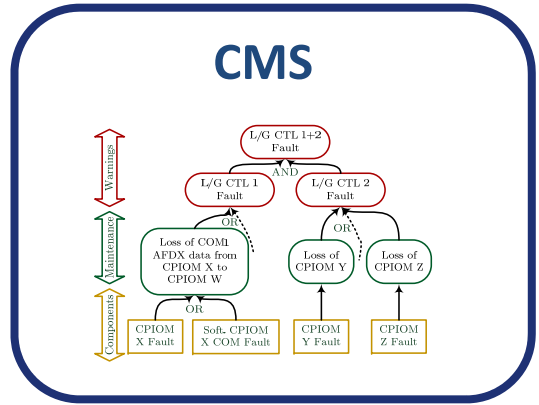


The meta-observations

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus' real-life situations.

Situation 1

- LGERCTL1+2FAULT = \perp
- LGERCTL1FAULT = T
- LGERCTL2FAULT = \perp

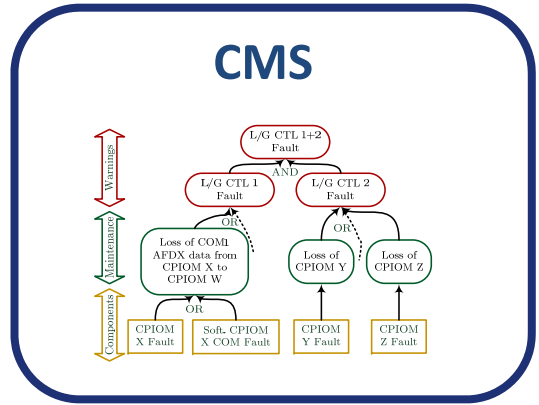
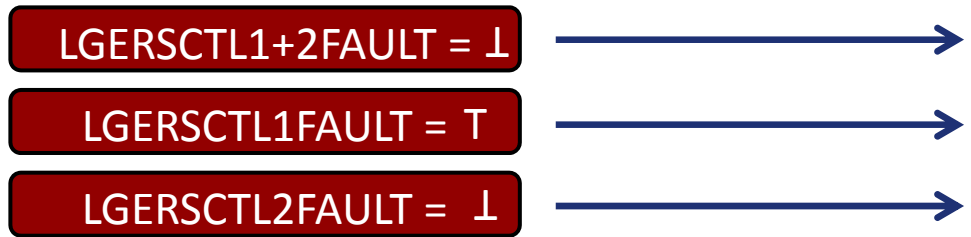


Line mechanic

The meta-observations

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus' real-life situations.

Situation 1



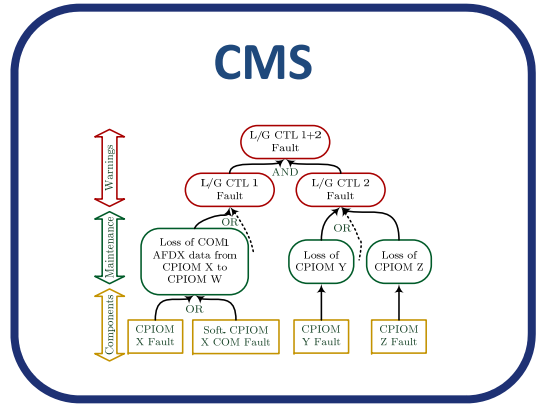
Line mechanic

The meta-observations

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus' real-life situations.

Situation 2

- LGERCTL1+2FAULT = \perp
- LGERCTL1FAULT = T
- LGERCTL2FAULT = \perp
- LOSSCOM1XtoW = \perp



- $\neg Ab(CPIOMZ)$
- $\neg Ab(SoftCPIOMXCOM)$
- $Ab(CPIOMW)$
- $\neg Ab(CPIOMX)$



Line mechanic

Meta-diagnoses

The screenshot shows the 'Meta Diagnoser' application window. On the left is a vertical toolbar with five icons: a network diagram, a beaker with a flame, a doctor with a clipboard, two doctors, and a bug with a red prohibition sign. The main window has a title bar with standard OS controls. Below the title bar is a tab labeled 'Meta Diagnoser'. The interface includes a 'System' dropdown menu set to 'LGERS', a 'Choose situations' section with a list containing 'Situation: 1' and 'Situation: 2', and a 'Meta-diagnostic results' section. This section has two text areas: 'Kernel meta-diagnoses' containing '{SD-sentence4}' (highlighted with a red box) and 'Minimal cardinality meta-diagnoses:'. At the bottom, there is a list of diagnostic warnings: 'SD-sentences may be false', 'Observations may be false', and 'Diagnostic algorithm may lack of'. A 'Compute' button is located at the bottom right of the main window.

Meta-diagnoses

Meta Diagnoser

System: LGERS

Choose situations

- Situation: 1
- Situation: 2

Meta-diagnostic results

Kernel meta-diagnoses

{SD-sentence4}

Minimal cardinality meta-diagnoses:

SD-sentences may be false
Observations may be false
Diagnostic algorithm may lack of

Compute

Where SD-sentence4 is:
 $Ab(CPIOMX) \vee Ab(SoftCPIOMXCOM)$
 $\Leftrightarrow [LossCOM1AFDXDataFromXtoW=T]$

Meta-diagnoses

Meta Diagnoser

System LGERS

Choose situations

Situation: 1
Situation: 2

Meta-diagnostic results

Kernel meta-diagnoses
{SD-sentence4}

Minimal cardinality meta-diagnoses

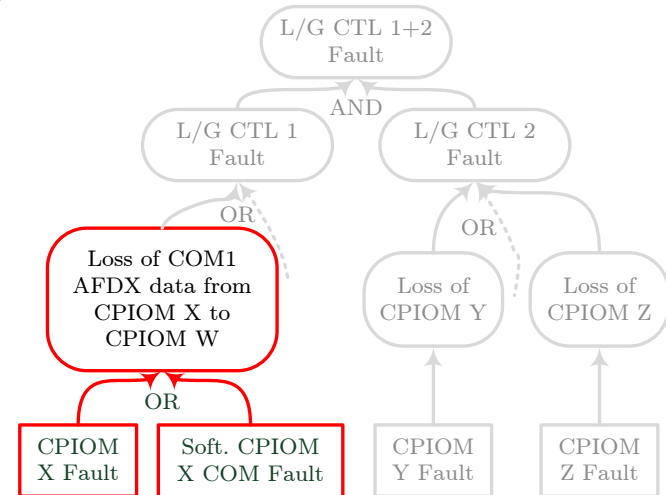
SD-sentences may be false

Observations may be false

Diagnostic algorithm may be false

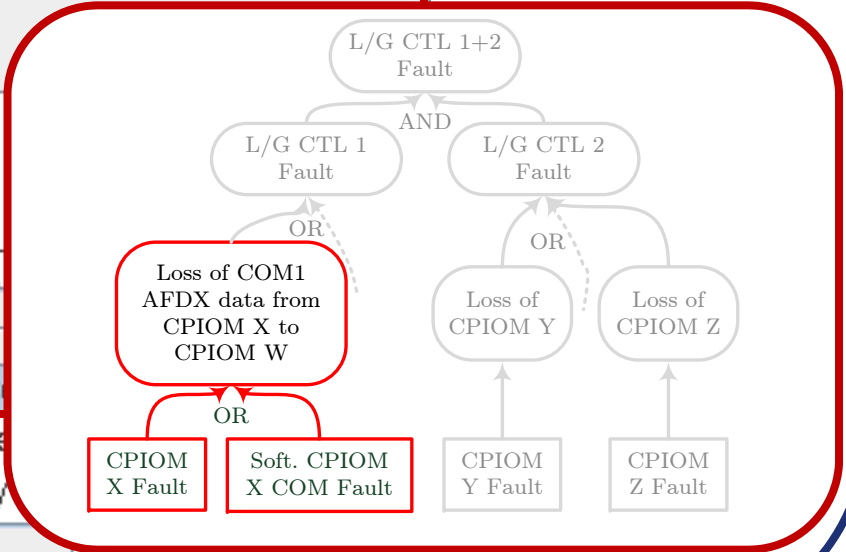
Where SD-sentence4 is:

$Ab(CPIOMX) \vee Ab(SoftCPIOMXCOM)$
 $\Leftrightarrow [LossCOM1AFDXDataFromXtoW=T]$



Meta-diagnoses

Where SD-sentence4 is:

$$Ab(CPIOMX) \vee Ab(SoftCPIOMXCOM) \Leftrightarrow [LossCOM1AFDXDataFromXtoW=T]$$


Engineers later determined that lack of preconditions $Ab(CPIOMW) \vee Ab(SoftCPIOMWCOM)$ explained the SD-sentence 4 abnormality

Conclusions

Conclusions

1. The theory of meta-diagnosis provides a formal framework for detecting and isolating abnormalities in diagnostic systems.
2. MEDITO provides empirical proof supporting meta-diagnosis claim that any sound and complete diagnostic algorithm can be used to solve a meta-diagnostic problem.
3. The usage of MEDITO for treating an Airbus problem supports the usage of meta-diagnosis in real-world problems.
4. Meta-diagnosis inherits from diagnosis complexity problems. This is why we plan, in future works, on using classical Model-Based Diagnosis complexity management techniques such as hierarchical approaches.



Thank you for your attention



AIRBUS



[1] REITER R. (1987). A theory of diagnosis from first principles. In Artificial Intelligence, 32(1).

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[3] DAVIS R. (1984). Diagnostic reasoning based on structure and behavior. In Artificial Intelligence, 24(1-3).

[4] BELARD N., PENCOLÉ Y. and COMBACAU M. (2011). A Theory of Meta-Diagnosis: Reasoning About Diagnostic Systems. In IJCAI-11 22nd International Joint Conference on Artificial Intelligence.

[5] BELARD N., PENCOLÉ Y. and COMBACAU M. (2010). Defining and exploring properties in diagnostic systems. In DX-10 21st International Workshop on Principles of Diagnosis.

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[8] ZHAO X. and OUYANG D. (2006). A method of combining se-tree to compute all minimal hitting sets. Progress in Natural Science, 16.

[9] ZHAO X. and OUYANG D. (2007). Improved algorithms for deriving all minimal conflict sets in model-based diagnosis. In Proc. of the 3rd ICIC,