

FDIR Development Practices Based on a Probabilistic Reasoning Approach

ESA ADCSS Workshop (ESTEC, 26.10. 2011)



SCOPE

- **FDIR Background and Challenges**
 - FDIR Definition & Prior art
 - Requirements of the proposed FDIR methodology
- **FDIR & Probabilistic Reasoning using Bayesian Networks**
 - Bayesian Networks & Troubleshooting
 - An illustrative example
 - How Bayesian approach can meet FDIR requirements
- **Future Developments**
 - Bayesian Based FDIR C.A.S(ystem).E.
 - Bayesian Based FDIR SW Building Blocks (Satellite OSW & Ground Segment)
- **Project Partnership**



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**FDIR Development Practices based
on a Probabilistic Reasoning**
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FDIR Background and Challenges

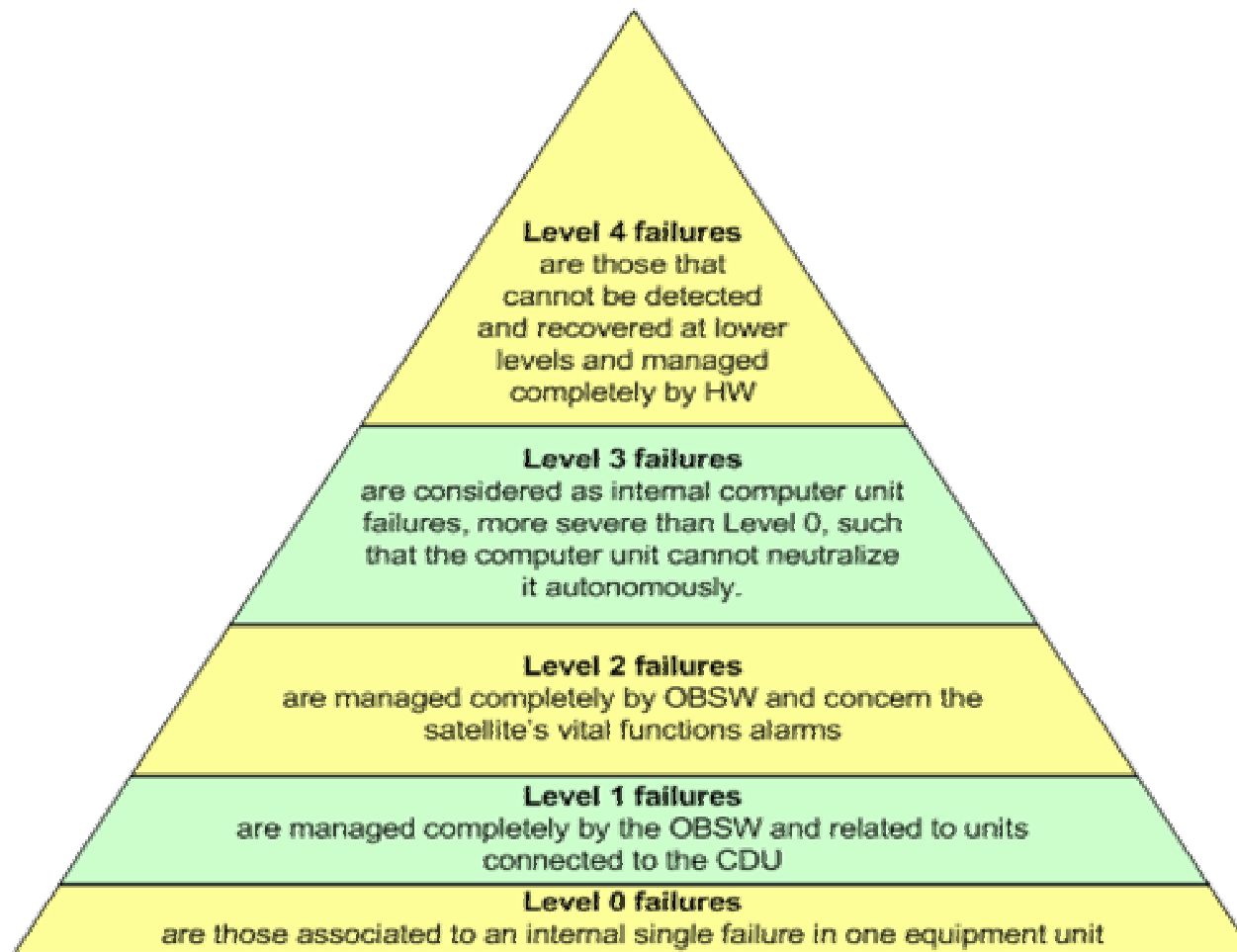
FDIR Concept & Prior Art - 1

- **Failure tolerant technology & FDIR**
- **The FDIR functions to satisfy the specific autonomy, reliability and availability needs for a space mission.**
- **FDIR as a relevant topic dealt with the entire project life-time.**
- **FDIR functionality improvement and update throughout the whole mission**
- **Current FDIR development practices:**
 - RAMS/FMECA/FTA
 - FDIR specification and development
- **Lack of a strong analytical methodology supporting system-level conception and implementation of diagnostic procedures**

FDIR Concept & Prior Art - 2

- **FDIR scope: Space System as a whole**
- **FDIR functions organized in a hierarchical breakdown (see figure in the next slide from GalileoSat FOC Project)**
- **Additional considerations (and subjects for further discussion):**
 - Level 2: failures related to complex and mutual-related issues, detected by the OBC processor which collects and analyses information coming from different units and subsystems; recovery performed by the On-Board Computer (OBC) processor
 - Level 3: failures related to the OBC, which are neither detectable nor neutralizable by the OBC processor (e.g. EDAC modules, processor watchdog)
 - Level 4: failures identified by ad-hoc surveillance systems, fully independent from the OBC, both allocated within the satellite platform (e.g. Power Alarm and Thermal Limit detectors) and/or the Ground Control Segment (e.g. TM data off-line analysis).

FDIR Concept & Prior Art - 3



Requirements of the proposed FDIR methodology - 1

- **Uncertain/stochastic information processing**
- **Direction of the reasoning not fixed in advance**
 - i.e. deduced via the collection of the information
- **Supporting Recovery Decisions**
- **FDIR focused on unit/SS models**
 - Models built from the expert knowledge and not only from sample/quality data
 - Interaction between the different models (divide & rule strategy)
 - top-down strategy to conceive S/S-level FDIR models
 - and bottom-up strategy to build up the system-level FDIR model

Requirements of the proposed FDIR methodology - 2

- **Flexibility and Generality**
 - Adaptation to different contexts and the acquired experience
 - OO paradigm: model inheritance and composition
- **Robustness**
- **Efficiency (Computational Resources)**
- **To support both system-level FDIR conception and the implementation of the related diagnostic procedures**
 - System & subsystem engineers to adopt the same models and the same terminology
 - Model Composition & Integration



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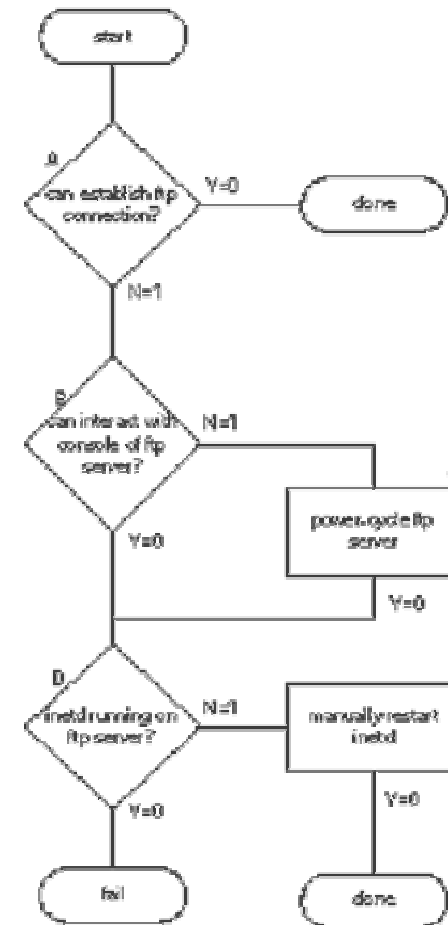


FDIR & Probabilistic Reasoning using Bayesian Networks

Bayesian Networks & Troubleshooting - 1

Thinking about FDIR ...

- FDIR is generally based on procedures
- This offers a deterministic and tested approach to fault detection, isolation and recovery
- But...
 - Alternative solutions are not explored
 - It is rigid to unexpected scenarios
 - Support to ground recovery is not flexible



Bayesian Networks & Troubleshooting - 2

Bayesian Approach to Fault Identification and Recovery

- The path to recover a fault can be driven by probabilistic reasoning, taking into account the trade-off between costs and repairing probability.
- As far as new evidence is collected, some observations and actions become more appropriate than others.
- This can lead to a more flexible and adaptive approach to FDIR.

$$P(H/E) = \frac{P(E/H) P(H)}{P(E)}$$

where

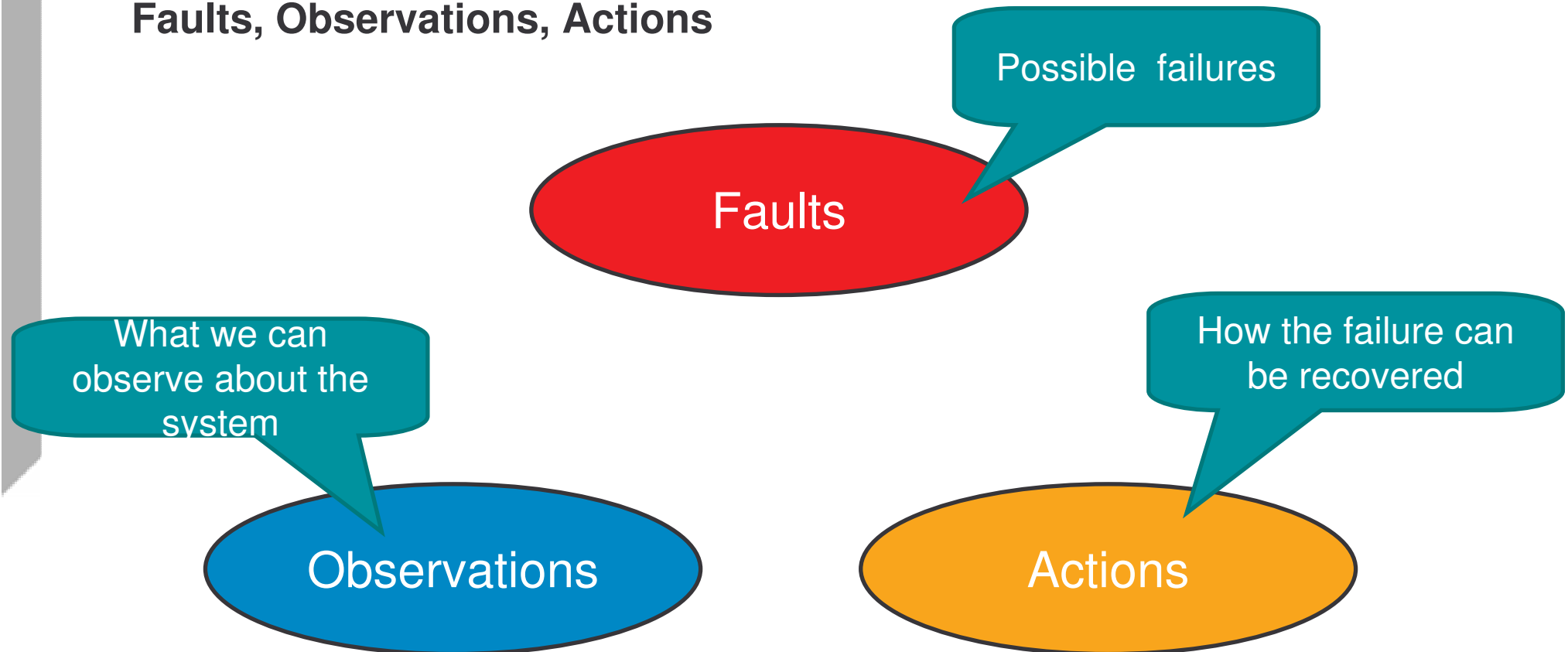
$P(H)$ = the previous or *a priori* probability that the hypothesis is true

$P(E)$ = the probability that an event will occur

$P(E/H)$ = the probability that the event will occur given that the hypothesis is true

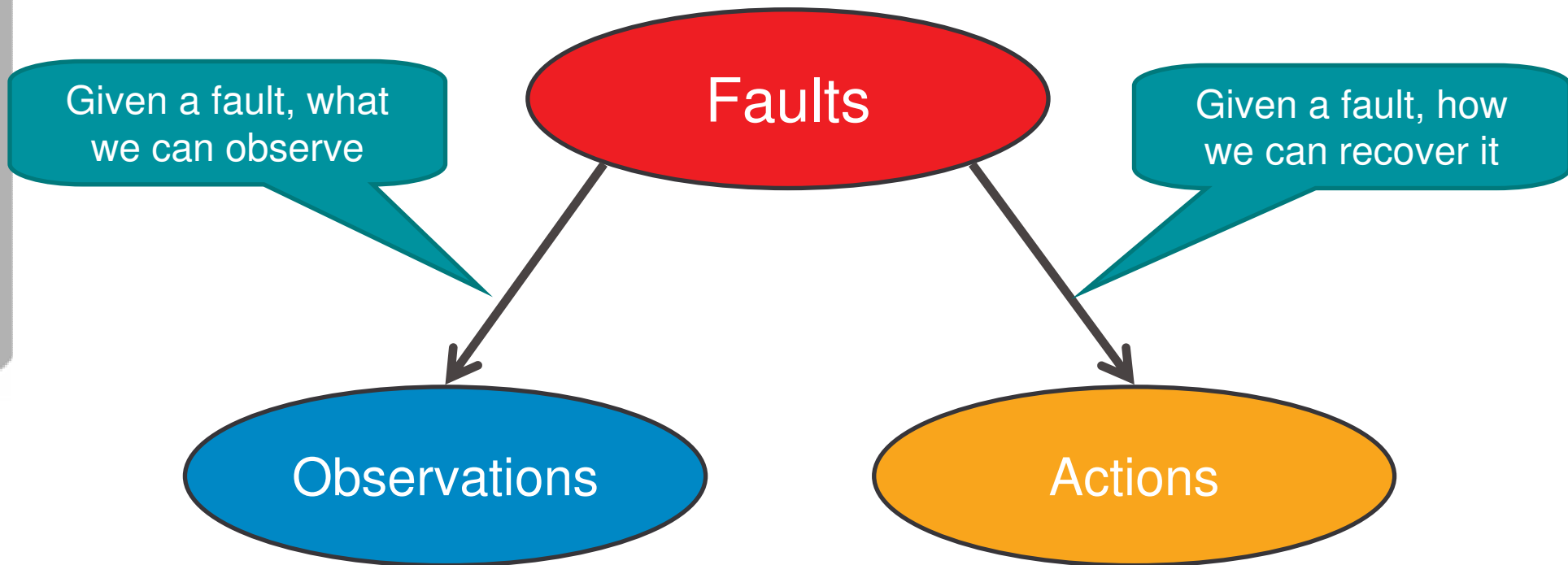
Bayesian Networks & Troubleshooting - 3

Faults, Observations, Actions



Bayesian Networks & Troubleshooting - 4

Faults, Observations, Actions



NOTICE: Relationships are not deterministic, but probabilistically determined.

Bayesian Networks & Troubleshooting - 5

Bayesian Troubleshooting

- Relationship between Faults, Actions and Observations
 - Bayesian Network Structure
- Cause-effects are not deterministic
 - Conditional probabilities
- Actions and Observations have an associated cost (e.g. time)
 - Decision utility

Bayesian Networks & Troubleshooting - 6

Decision Utility

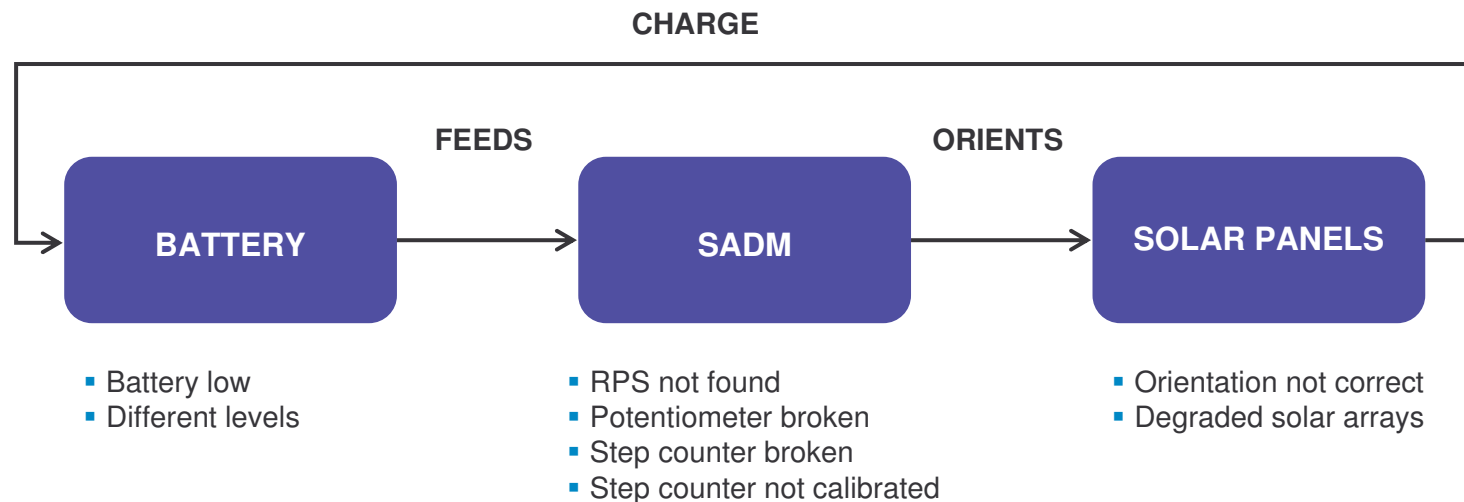
- Optimality objective:
 - **To minimize the cost of recovery (e.g. time)**
- Cost Sources:
 - **Expected Cost of Repairing (ECR)** is the cost we expect to have for recovering the failure
 - **Expected Cost of Observation (ECO)** is the repairing cost we expect after an observation is collected

An illustrative example - 1

➤ FDIR model integrating the following S/Ss

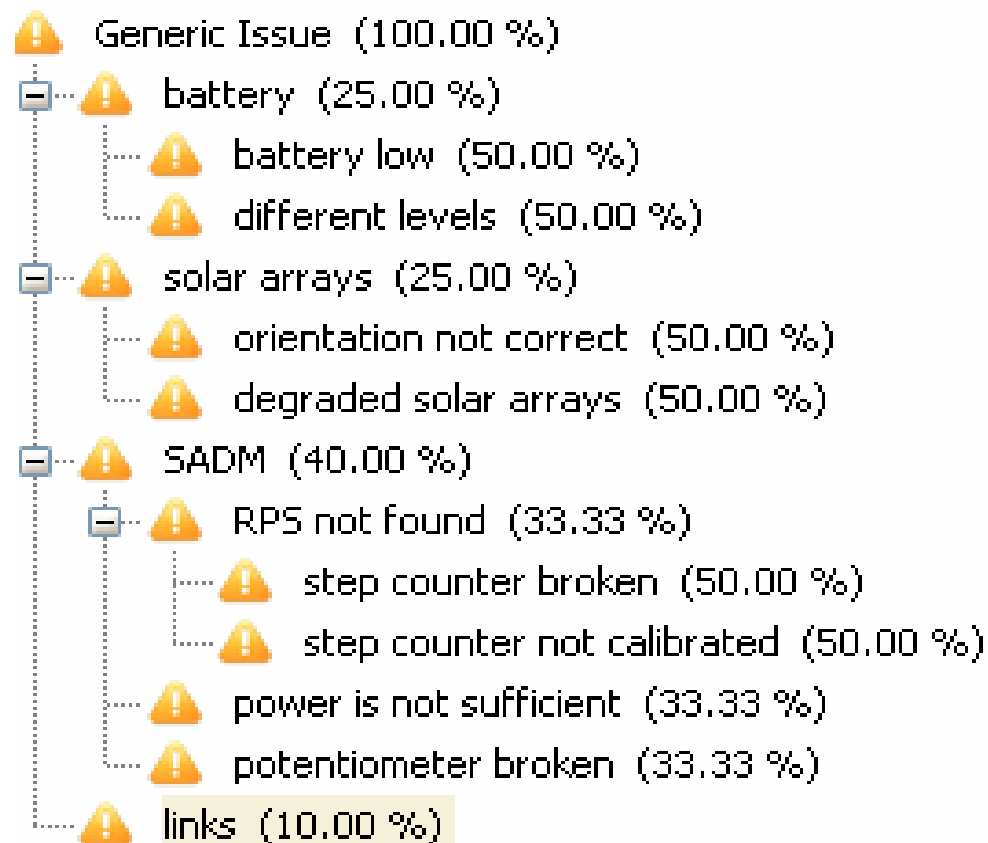
- Battery
- SADM
- Solar Panels

➤ S/S models interactions:



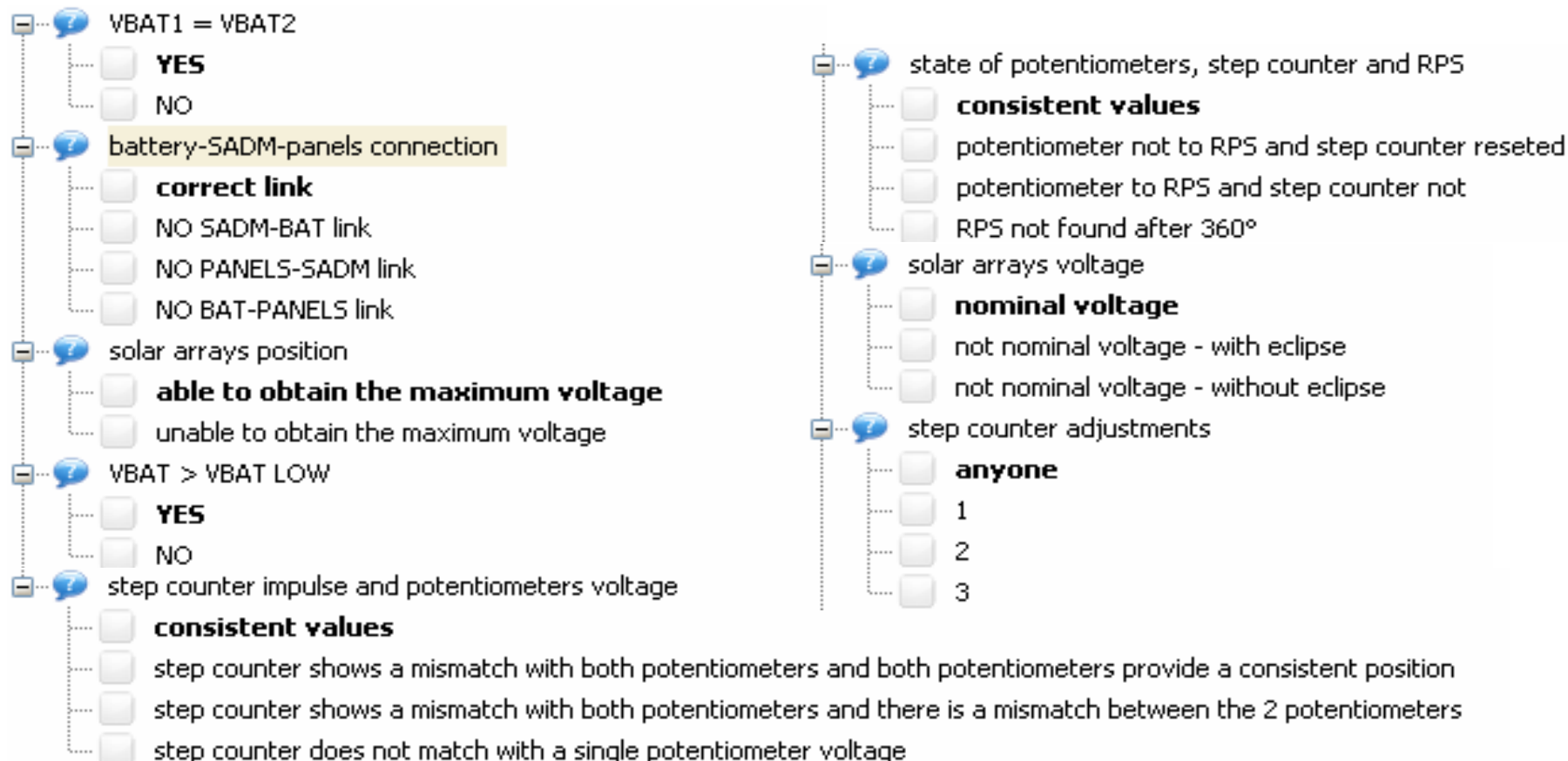
An illustrative example - 2

Integrated Model: Fault Tree










An illustrative example - 3

Integrated Model: Observations



An illustrative example - 4

SADM Model: Repairing Actions

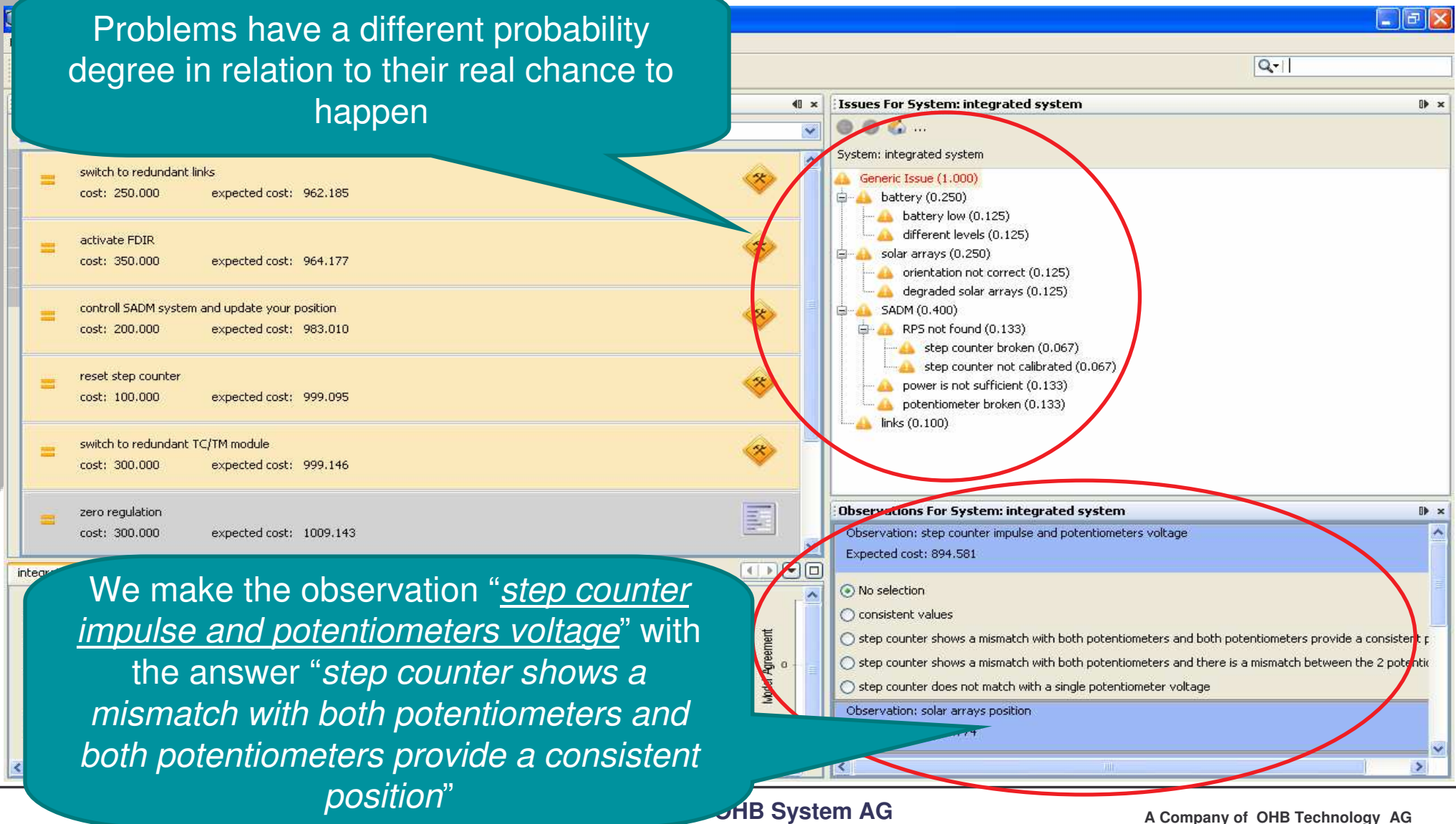
-  switch to redundant links
-  update the land
-  switch to redundant TC/TM module
-  switch to redundant step counter
-  reset step counter
-  activate FDIR
-  controll SADM system and update your position

An illustrative example - 5

- Once the model is fully specified, it can be delivered (on board?) in order to drive the B-FDIR component in solving a problem, once a failure becomes or it is likely evident ...
- For example, sometime, somewhere in the space, let us suppose the step counter stops working properly...
- We don't know where the problem is... but Huston we know there is a problem!!
- Let's discover and solve it!!

An illustrative example 6

Problems have a different probability degree in relation to their real chance to happen



The screenshot displays the FDIR development software interface. On the left, a list of issues is shown with their costs and expected costs. On the right, two panels are visible: 'Issues For System: integrated system' and 'Observations For System: integrated system'.

Issues For System: integrated system

Issue	Cost	Expected Cost
switch to redundant links	250,000	962,185
activate FDIR	350,000	964,177
controll SADM system and update your position	200,000	983,010
reset step counter	100,000	999,095
switch to redundant TC/TM module	300,000	999,146
zero regulation	300,000	1009,143

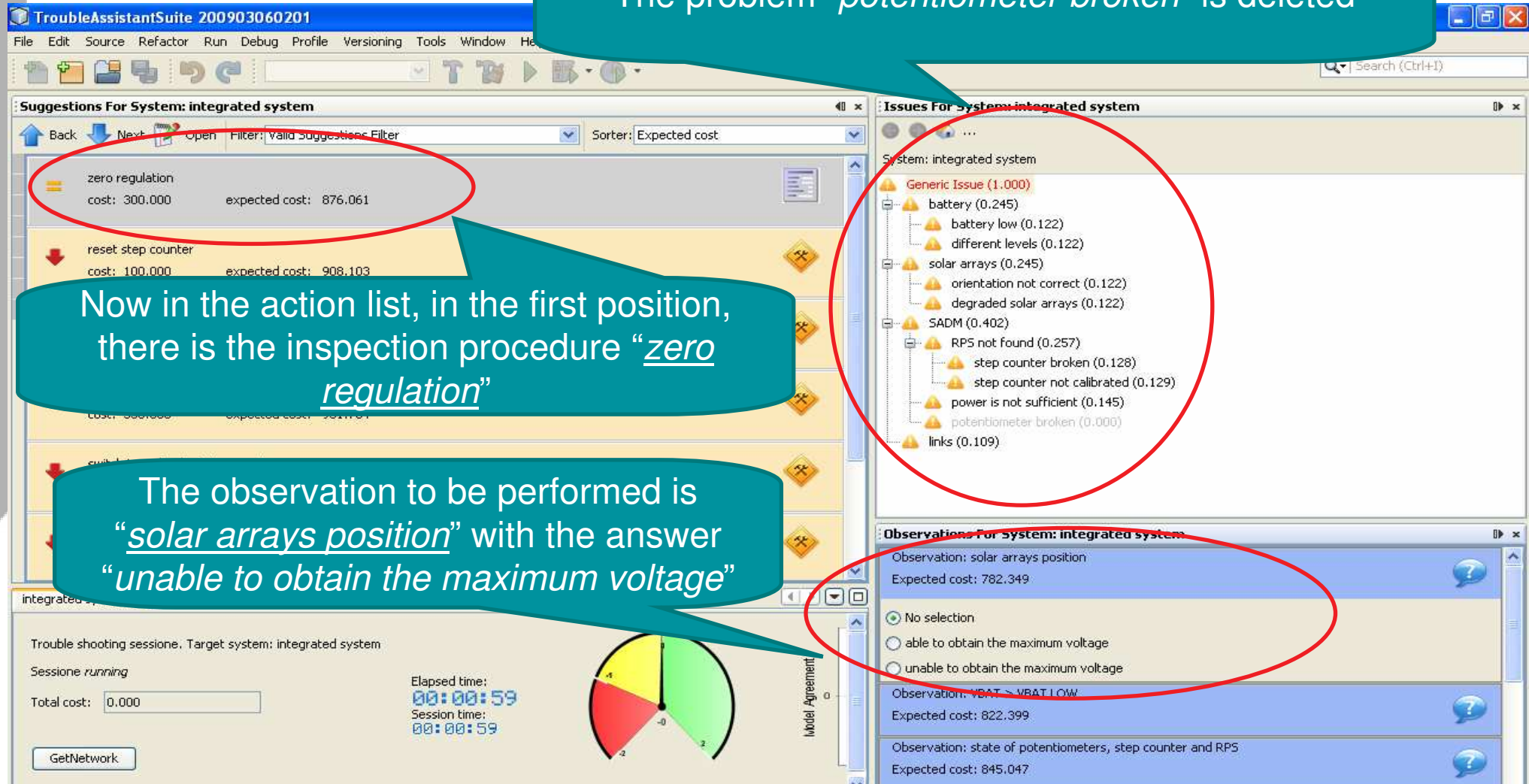
Observations For System: integrated system

- Observation: step counter impulse and potentiometers voltage
Expected cost: 894,581
- Observation: solar arrays position

We make the observation "step counter impulse and potentiometers voltage" with the answer "step counter shows a mismatch with both potentiometers and both potentiometers provide a consistent position"

An illustrative exam

The problem “*potentiometer broken*” is deleted



The screenshot displays the TroubleAssistantSuite 200903060201 interface. The main window is divided into several panes:

- Suggestions For System: integrated system:** This pane lists suggested actions. The first action, "zero regulation", is circled in red. It has a cost of 300.000 and an expected cost of 876.061.
- Issues For System: integrated system:** This pane shows a hierarchical list of issues. The "potentiometer broken (0.000)" issue is circled in red, indicating it has been deleted.
- Observations For System: integrated system:** This pane shows observations. The "Observation: solar arrays position" is circled in red. It has an expected cost of 782.349. Below it, there are radio buttons for "No selection", "able to obtain the maximum voltage", and "unable to obtain the maximum voltage".

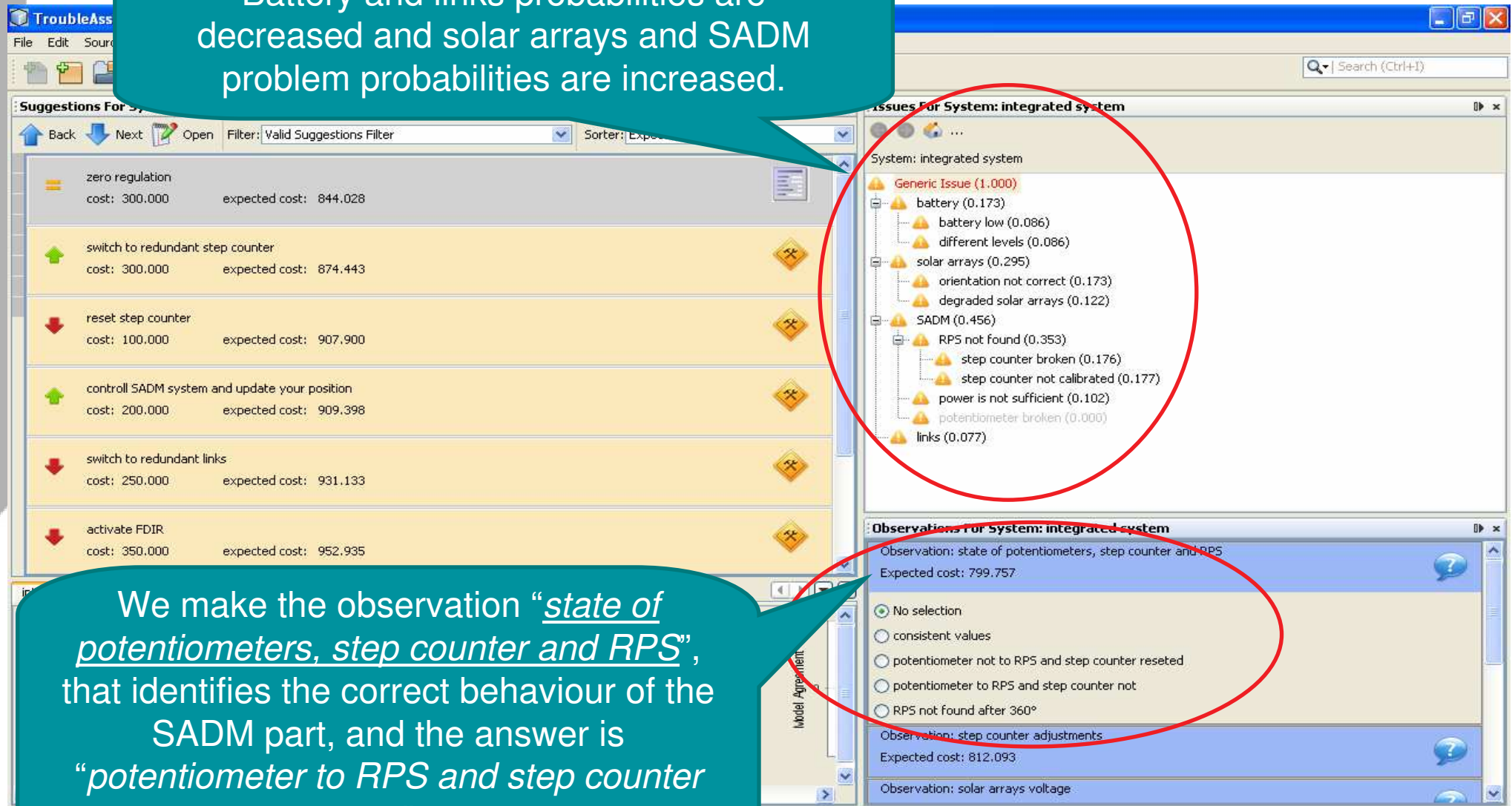
At the bottom of the interface, there is a section for "Trouble shooting session. Target system: integrated system". It shows "Session running", "Total cost: 0.000", and a "GetNetwork" button. A circular gauge is also visible, showing a value of -1.

Now in the action list, in the first position, there is the inspection procedure “zero regulation”

The observation to be performed is “solar arrays position” with the answer “unable to obtain the maximum voltage”

INSPECTION PROCEDURE is a particular kind of preliminary investigation that includes actions and observations: in this case the inspection procedure can exclude or focus on the SADM issues.

Battery and links probabilities are decreased and solar arrays and SADM problem probabilities are increased.



The screenshot displays the 'Troubleshoot' application interface. On the left, a 'Suggestions For System' panel lists several actions with their costs and expected costs. On the right, the 'Issues For System: integrated system' panel shows a hierarchical tree of issues, with 'battery' and 'links' issues circled in red. Below this, the 'Observations For System: integrated system' panel shows a list of observations, with the 'state of potentiometers, step counter and RPS' observation circled in red.

Suggestion	Cost	Expected Cost
zero regulation	300.000	844.028
switch to redundant step counter	300.000	874.443
reset step counter	100.000	907.900
controll SADM system and update your position	200.000	909.398
switch to redundant links	250.000	931.133
activate FDIR	350.000	952.935

Issues For System: integrated system

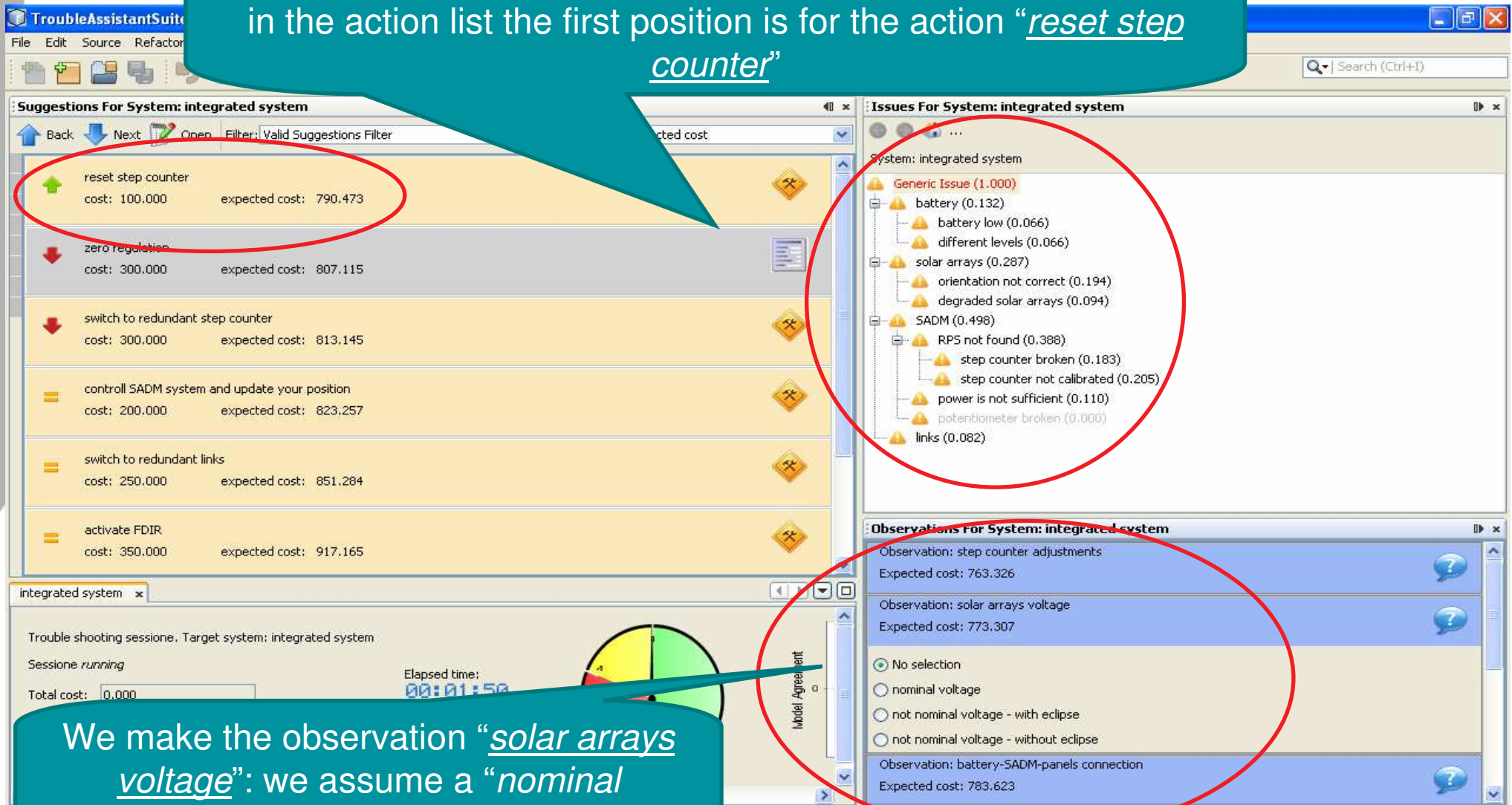
- Generic Issue (1.000)
 - battery (0.173)
 - battery low (0.086)
 - different levels (0.086)
 - solar arrays (0.295)
 - orientation not correct (0.173)
 - degraded solar arrays (0.122)
 - SADM (0.456)
 - RPS not found (0.353)
 - step counter broken (0.176)
 - step counter not calibrated (0.177)
 - power is not sufficient (0.102)
 - potentiometer broken (0.000)
 - links (0.077)

Observations For System: integrated system

- Observation: state of potentiometers, step counter and RPS
 - Expected cost: 799.757
 - ☒ No selection
 - ☐ consistent values
 - ☐ potentiometer not to RPS and step counter reseted
 - ☐ potentiometer to RPS and step counter not
 - ☐ RPS not found after 360°
- Observation: step counter adjustments
 - Expected cost: 812.093
- Observation: solar arrays voltage

We make the observation "state of potentiometers, step counter and RPS", that identifies the correct behaviour of the SADM part, and the answer is "potentiometer to RPS and step counter not".

Problem probability is changed and, as we have increased the probability of the problem “*step counter not calibrated*”, in the action list the first position is for the action “*reset step counter*”



The screenshot displays the Troubleshooting Assistant Suite interface for an integrated system. The main window is divided into three panes: Suggestions, Issues, and Observations.

Suggestions For System: integrated system

Action	Cost	Expected Cost
reset step counter	100.000	790.473
zero regulation	300.000	807.115
switch to redundant step counter	300.000	813.145
controll SADM system and update your position	200.000	823.257
switch to redundant links	250.000	851.284
activate FDIR	350.000	917.165

Issues For System: integrated system

- Generic Issue (1.000)
 - battery (0.132)
 - battery low (0.066)
 - different levels (0.066)
 - solar arrays (0.287)
 - orientation not correct (0.194)
 - degraded solar arrays (0.094)
 - SADM (0.498)
 - RPS not found (0.388)
 - step counter broken (0.183)
 - step counter not calibrated (0.205)
 - power is not sufficient (0.110)
 - potentiometer broken (0.000)
 - links (0.082)

Observations For System: integrated system

Observation	Expected Cost
Observation: step counter adjustments	Expected cost: 763.326
Observation: solar arrays voltage	Expected cost: 773.307
No selection	
nominal voltage	
not nominal voltage - with eclipse	
not nominal voltage - without eclipse	
Observation: battery-SADM-panels connection	Expected cost: 783.623

At the bottom, a status bar shows "Trouble shooting session. Target system: integrated system", "Session running", "Total cost: 0.000", and "Elapsed time: 00:01:50". A circular progress indicator is also visible.

We make the observation “*solar arrays voltage*”: we assume a “*nominal voltage*”

An i

Having gathered “nominal voltage”, we exclude
“battery low” e “degraded solar arrays” from the
possible problems

The screenshot displays the TroubleAssistantSuite application window. The main interface is divided into several panes. The left pane, titled 'Suggestions For System: integrated system', lists various actions with their associated costs and expected costs. The right pane, titled 'Issues For System: integrated system', shows a hierarchical tree of system issues. A red circle highlights the 'battery' issue, which includes sub-issues like 'battery low' and 'different levels'. Another red circle highlights the 'Observations For System: integrated system' pane, which shows two observations: 'step counter adjustments' and 'battery-SADM-panels connection'. The 'battery-SADM-panels connection' observation is selected, and its details are shown in the bottom pane, including radio button options for 'No selection', 'correct link', 'NO SADM-BAT link', 'NO PANELS-SADM link', and 'NO BAT-PANELS link'. The 'correct link' option is selected.

Suggestions For System: integrated system

Action	cost	expected cost
zero regulation	300.000	687.358
reset step counter	100.000	701.225
switch to redundant step counter	300.000	727.777
controll SADM system and update your position	200.000	740.990
switch to redundant links	250.000	777.243
switch to redundant TC/TM module	300.000	863.855

Issues For System: integrated system

- System: integrated system
 - Generic Issue (1.000)
 - battery (0.093)
 - battery low (0.016)
 - different levels (0.077)
 - solar arrays (0.227)
 - orientation not correct (0.227)
 - degraded solar arrays (0.000)
 - SADM (0.583)
 - RPS not found (0.455)
 - step counter broken (0.215)
 - step counter not calibrated (0.240)
 - power is not sufficient (0.129)
 - potentiometer broken (0.000)
 - links (0.096)

Observations For System: integrated system

- Observation: step counter adjustments
 - Expected cost: 608.332
- Observation: battery-SADM-panels connection
 - Expected cost: 628.279

Model Agreement

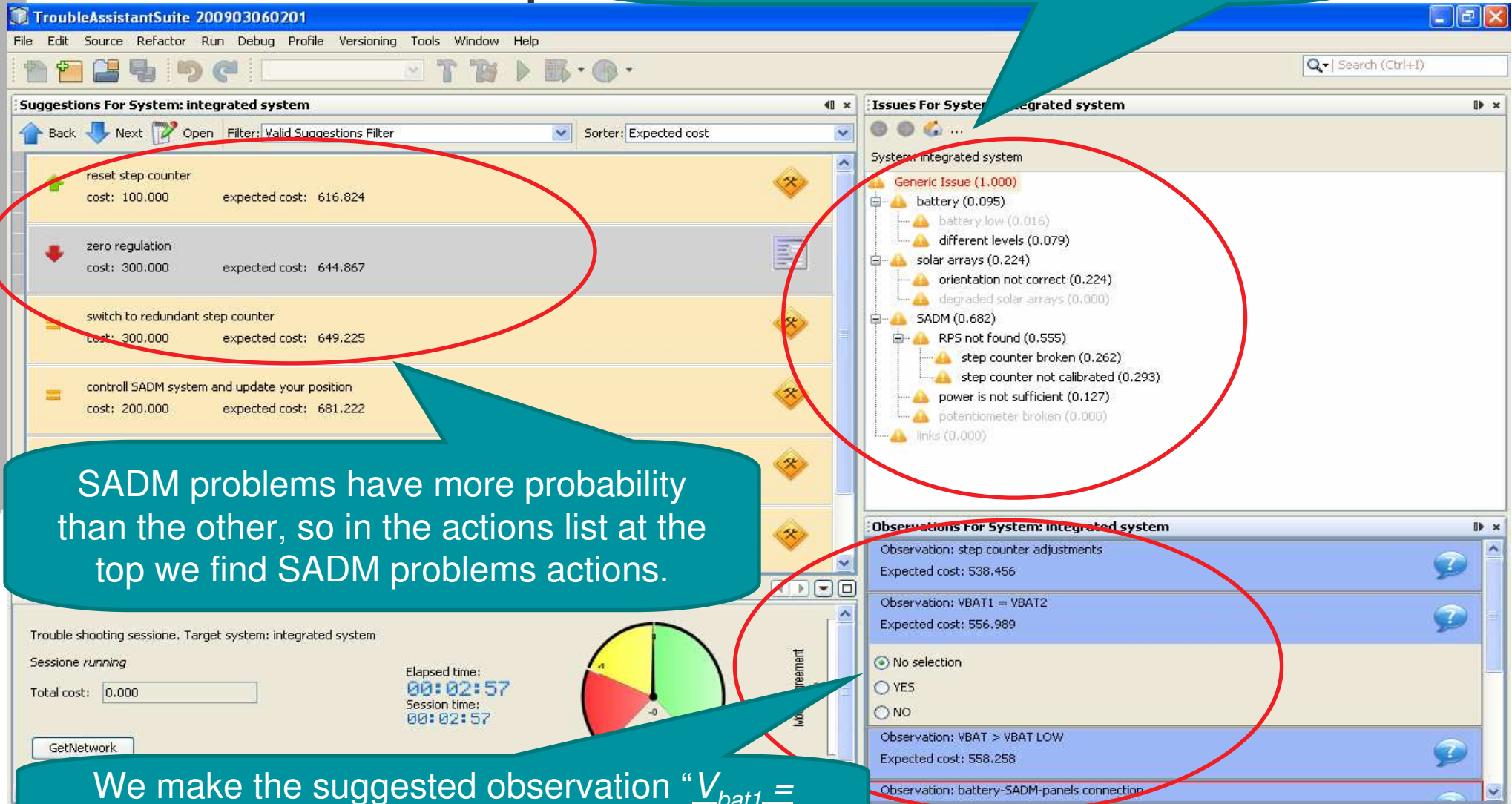
- ☒ No selection
- ☐ correct link
- ☐ NO SADM-BAT link
- ☐ NO PANELS-SADM link
- ☐ NO BAT-PANELS link

Observation: VBAT1 = VBAT2

The recommended observation is
“battery-SADM-panels connection”: we
suppose “correct link”.

An illustrative example

“Link” problems were eliminated



The screenshot displays the Troubleshooting Suite 200903060201 interface. The main window is divided into several panes:

- Suggestions For System: integrated system:** This pane lists four suggestions with their costs and expected costs. A red circle highlights the first two suggestions: "reset step counter" (cost: 100.000, expected cost: 616.824) and "zero regulation" (cost: 300.000, expected cost: 644.867). A teal callout bubble points to the "zero regulation" suggestion.
- Issues For System: integrated system:** This pane shows a hierarchical list of issues. A red circle highlights the "battery" issue (0.095), which includes sub-issues like "battery low (0.016)", "different levels (0.079)", "solar arrays (0.224)", "orientation not correct (0.224)", and "degraded solar arrays (0.000)".
- Observations For System: integrated system:** This pane lists observations with their expected costs. A red circle highlights the "Observation: VBAT1 = VBAT2" (expected cost: 556.989) and the "Observation: VBAT > VBAT LOW" (expected cost: 558.258). A teal callout bubble points to the "Observation: VBAT1 = VBAT2" observation.

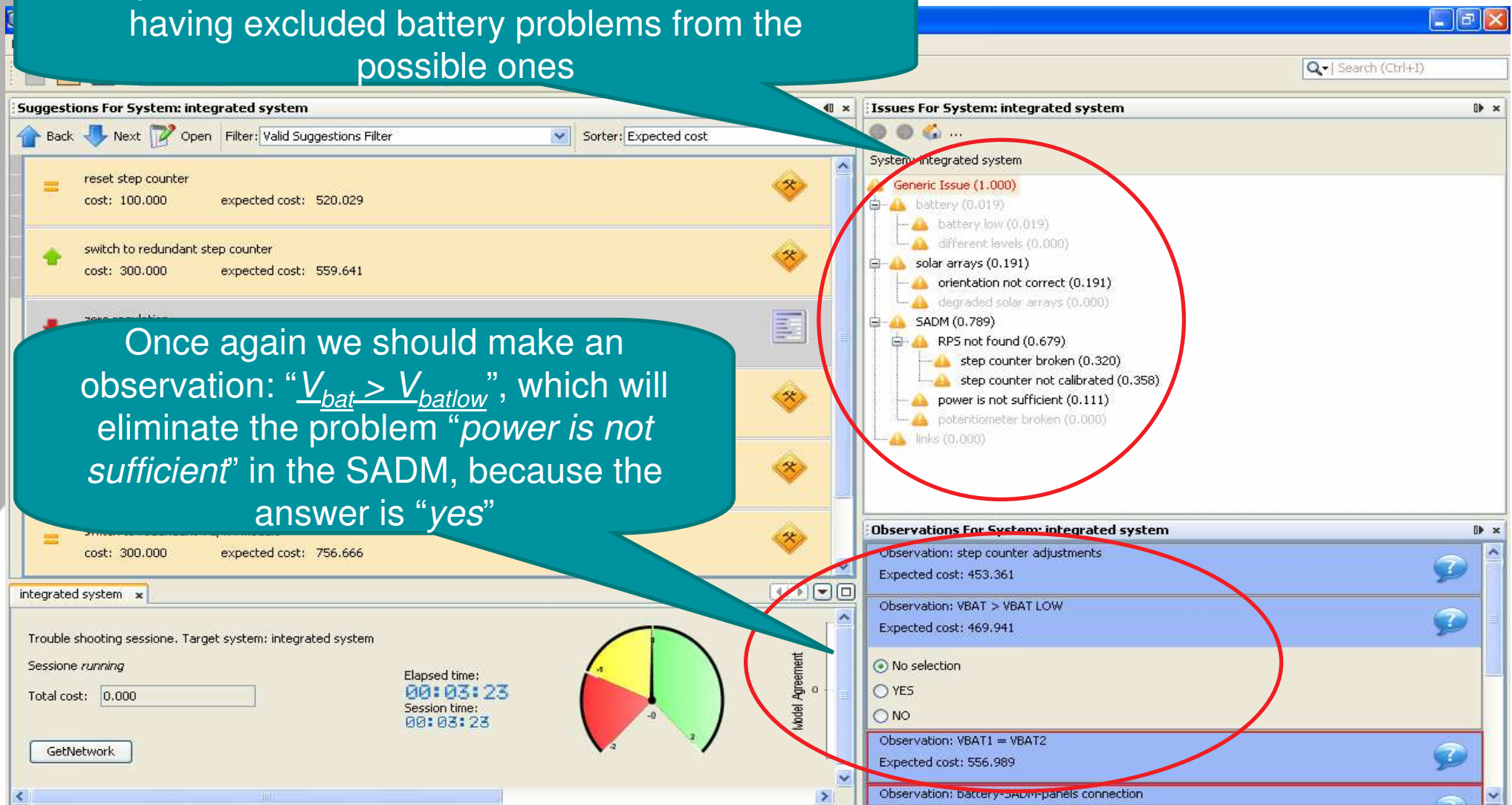
At the bottom of the interface, there is a status bar showing "Trouble shooting session, Target system: integrated system", "Session running", "Total cost: 0.000", "Elapsed time: 00:02:57", and "Session time: 00:02:57". A "GetNetwork" button is also visible.

SADM problems have more probability than the other, so in the actions list at the top we find SADM problems actions.

We make the suggested observation " $V_{bat1} = V_{bat2}$ " with the answer "yes".

The problem “*different levels*” is eliminated as well,
having excluded battery problems from the
possible ones

Once again we should make an
observation: “ $V_{bat} > V_{batlow}$ ”, which will
eliminate the problem “*power is not
sufficient*” in the SADM, because the
answer is “yes”

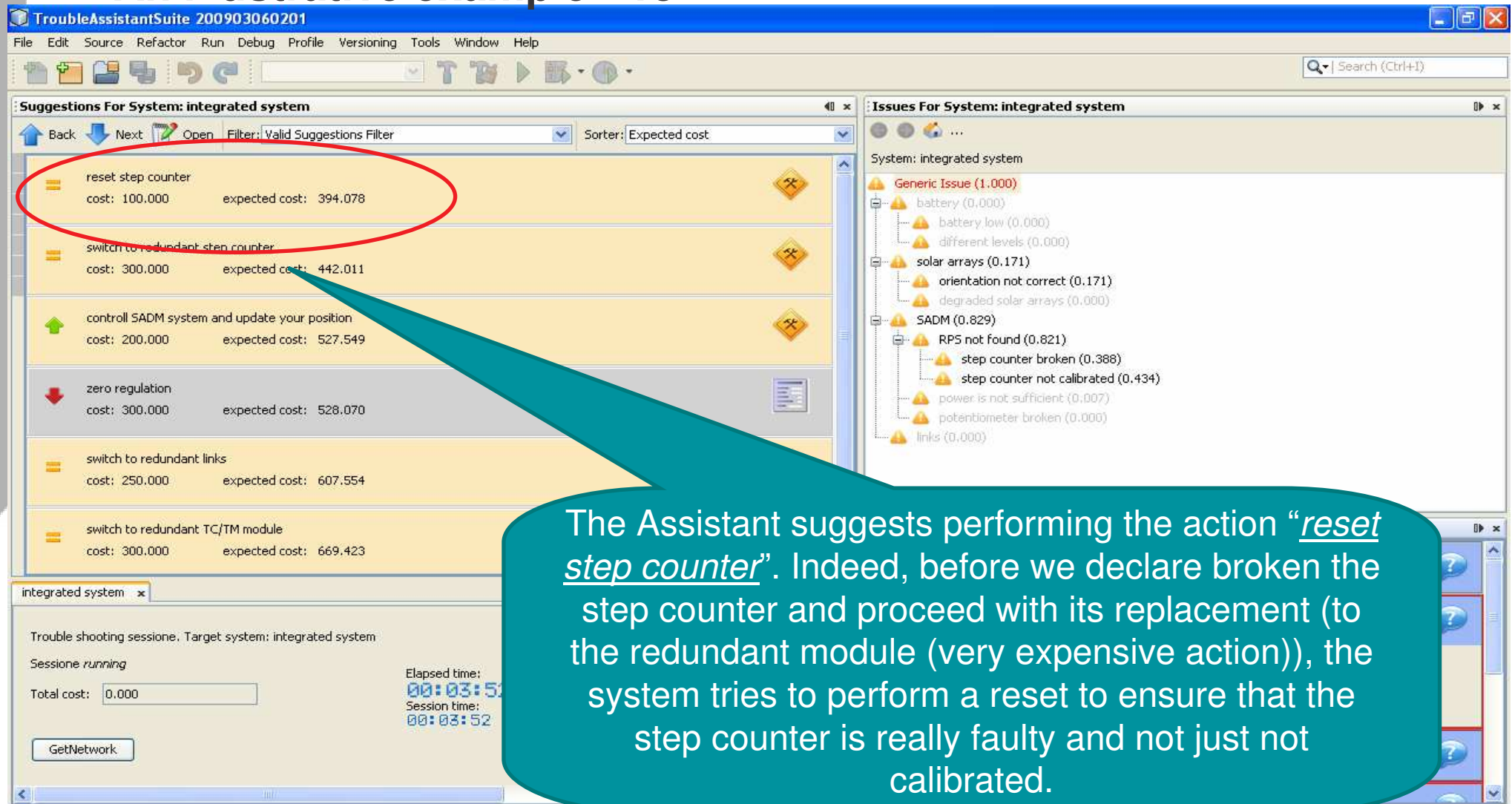


The screenshot displays the FDIR Development Practices software interface for an integrated system. The interface is divided into several panels:

- Suggestions For System: integrated system**: This panel lists suggestions with their costs and expected costs. The suggestions are:
 - reset step counter: cost: 100.000, expected cost: 520.029
 - switch to redundant step counter: cost: 300.000, expected cost: 559.641
 - switch to redundant step counter: cost: 300.000, expected cost: 756.666
- Issues For System: integrated system**: This panel shows a hierarchical tree of issues. The issues are:
 - Generic Issue (1.000)
 - battery (0.019)
 - battery low (0.019)
 - different levels (0.000)
 - solar arrays (0.191)
 - orientation not correct (0.191)
 - degraded solar arrays (0.000)
 - SADM (0.789)
 - RPS not found (0.679)
 - step counter broken (0.320)
 - step counter not calibrated (0.358)
 - power is not sufficient (0.111)
 - potentiometer broken (0.000)
 - links (0.000)
- Observations For System: integrated system**: This panel lists observations with their expected costs. The observations are:
 - Observation: step counter adjustments: Expected cost: 453.361
 - Observation: VBAT > VBAT LOW: Expected cost: 469.941
 - Observation: VBAT1 = VBAT2: Expected cost: 556.989
 - Observation: battery-SADM-panels connection

At the bottom of the interface, there is a section for the trouble shooting session. It includes a target system (integrated system), a session running status, a total cost (0.000), a GetNetwork button, and a circular gauge showing the elapsed time (00:03:23) and session time (00:03:23). A red circle highlights the 'Model Agreement' section, which shows a value of 0.

An illustrative example - 13



Suggestions For System: integrated system

Action	cost	expected cost
reset step counter	100.000	394.078
switch to redundant step counter	300.000	442.011
control SADM system and update your position	200.000	527.549
zero regulation	300.000	528.070
switch to redundant links	250.000	607.554
switch to redundant TC/TM module	300.000	669.423

Issues For System: integrated system

- System: integrated system
 - Generic Issue (1.000)
 - battery (0.000)
 - battery low (0.000)
 - different levels (0.000)
 - solar arrays (0.171)
 - orientation not correct (0.171)
 - degraded solar arrays (0.000)
 - SADM (0.829)
 - RPS not found (0.821)
 - step counter broken (0.388)
 - step counter not calibrated (0.434)
 - power is not sufficient (0.007)
 - potentiometer broken (0.000)
 - links (0.000)

integrated system

Trouble shooting session. Target system: integrated system

Session running

Total cost: 0.000

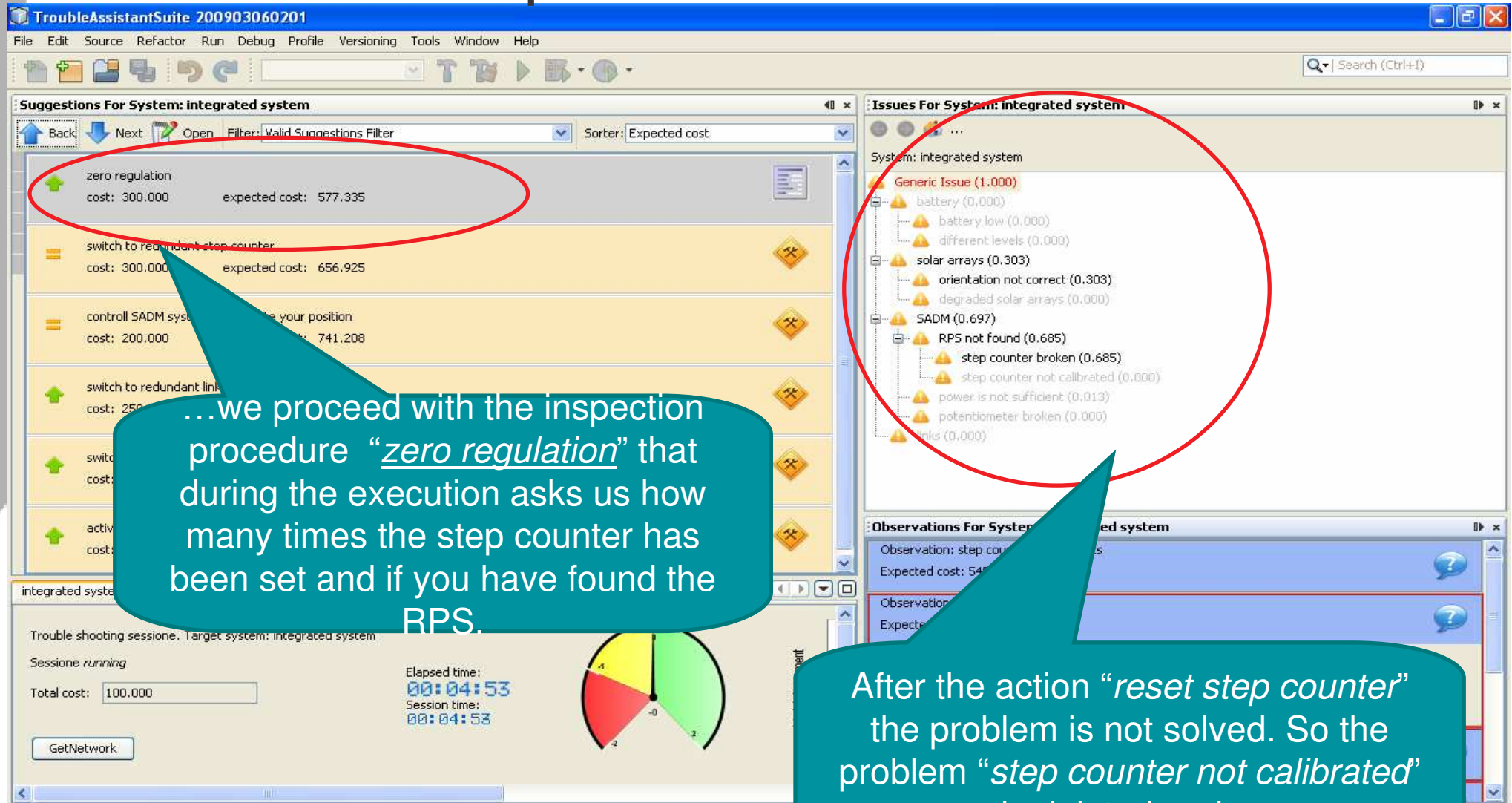
Elapsed time: 00:03:52

Session time: 00:03:52

GetNetwork

The Assistant suggests performing the action “reset step counter”. Indeed, before we declare broken the step counter and proceed with its replacement (to the redundant module (very expensive action)), the system tries to perform a reset to ensure that the step counter is really faulty and not just not calibrated.

An illustrative example - 14



The screenshot shows the TroubleAssistantSuite 200903060201 interface. The main window is divided into several panes. The left pane, titled "Suggestions For System: integrated system", lists various actions with their costs and expected costs. The right pane, titled "Issues For System: integrated system", shows a hierarchical list of issues. The bottom pane, titled "Observations For System: integrated system", shows a list of observations.

Suggestions For System: integrated system

Action	cost	expected cost
zero regulation	300,000	577,335
switch to redundant step counter	300,000	656,925
controll SADM system to your position	200,000	741,208
switch to redundant link	250,000	
switch to redundant link	250,000	
switch to redundant link	250,000	

Issues For System: integrated system

- System: integrated system
 - Generic Issue (1.000)
 - battery (0,000)
 - battery low (0,000)
 - different levels (0,000)
 - solar arrays (0,303)
 - orientation not correct (0,303)
 - degraded solar arrays (0,000)
 - SADM (0,697)
 - RPS not found (0,685)
 - step counter broken (0,685)
 - step counter not calibrated (0,000)
 - power is not sufficient (0,013)
 - potentiometer broken (0,000)
 - links (0,000)

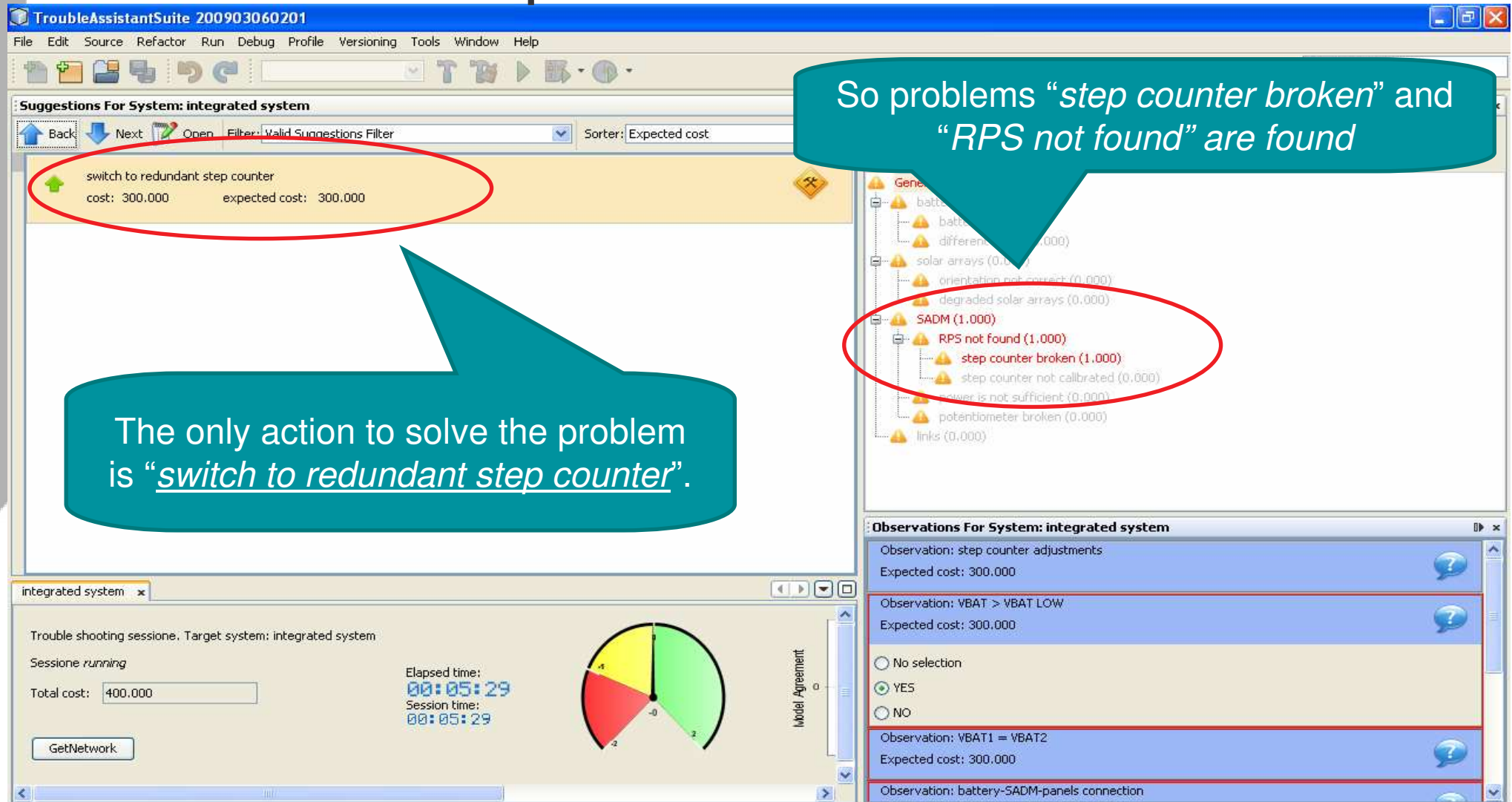
Observations For System: integrated system

Observation	Expected cost
Observation: step counter	541,208
Observation: step counter	541,208

...we proceed with the inspection procedure "zero regulation" that during the execution asks us how many times the step counter has been set and if you have found the RPS.

After the action "reset step counter" the problem is not solved. So the problem "step counter not calibrated" is deleted and...

An illustrative example - 15



TroubleAssistantSuite 200903060201

File Edit Source Refactor Run Debug Profile Versioning Tools Window Help

Suggestions For System: integrated system

Back Next Open Filter: Valid Suggestions Filter Sorter: Expected cost

switch to redundant step counter
cost: 300.000 expected cost: 300.000

Observations For System: integrated system

Observation: step counter adjustments
Expected cost: 300.000

Observation: VBAT > VBAT LOW
Expected cost: 300.000

☐ No selection
☒ YES
☐ NO

Observation: VBAT1 = VBAT2
Expected cost: 300.000

Observation: battery-SADM-panels connection

integrated system

Trouble shooting session. Target system: integrated system

Session running

Total cost: 400.000

GetNetwork

Elapsed time: 00:05:29
Session time: 00:05:29

Model Agreement

So problems “step counter broken” and “RPS not found” are found

The only action to solve the problem is “switch to redundant step counter”.

How Bayesian approach can meet FDIR requirements - 1

- **Uncertain/stochastic information processing**
 - Bayesian networks are deeply-investigated, robust and well-defined methods to handle uncertainty in causal models
- **Direction of the reasoning not fixed in advance**
 - Bayesian based FDIR is able to address a problem dynamically by choosing most appropriate actions as far as new evidence regarding the failure is being collected
- **Supporting Recovery Decisions**
 - Recovery can be performed automatically or by interacting with humans, supporting them in selecting best options.
- **FDIR focused on unit/SS models**
 - Bayesian models can be organized, instanced and integrated by sub-models in order to cope with the system structure and complexity

How Bayesian approach can meet FDIR requirements - 2

➤ Flexibility and Generality

- Algorithms are coded only once, with their behaviour controlled via model parameters, thus reducing validation and maintainability activities
- Models can be composed and/or extended.

➤ Robustness

- Models do not strictly depend on parameters, as we are interested only in the order actions are sorted and suggested (i.e. outcomes do not fluctuate radically as consequence of minor changes in the Bayesian Network)

➤ Efficiency (Computational Resources)

- Efficient algorithms to deal with Bayesian inference
- But... attention should be paid to on-board implementations.

➤ To support both system-level FDIR conception and the implementation of the related diagnostic procedures

- Bayesian models at S/S level can be easily integrated in larger models at system level and reused for FDIR procedure implementation.



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on a Probabilistic Reasoning**
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Future Developments

Bayesian Based FDIR C.A.S(ystem).E. - 1

FDIR MODEL DESIGN

DESIGNER
(HMI/XML)

FDIR PROCEDURE GENERATION

**CASE
CONFIGURATOR
& SCENARIO SETTING
(HMI/XML)**

**PROCEDURE
SYNTHETIZER
& INTEGRATION**

FDIR PROCEDURE VALIDATION

**PROCEDURE
VALIDATOR**

**PROCEDURE
SENSITIVITY
ANALIZER**

**PROCEDURE
OPTIMIZER**

FAULT INJECTOR

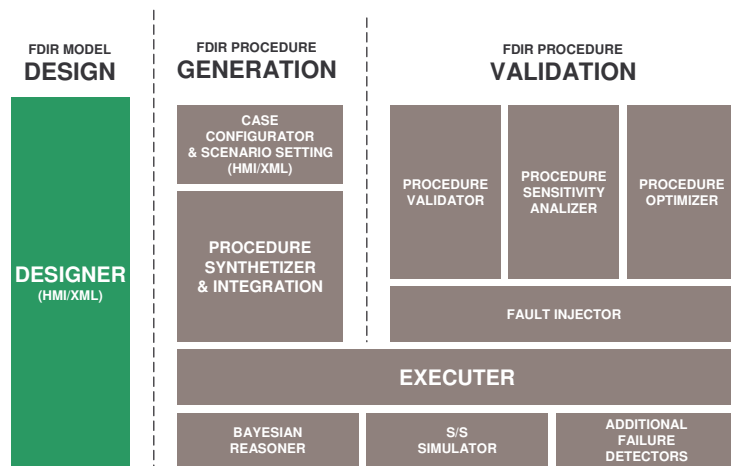
EXECUTER

**BAYESIAN
REASONER**

**S/S
SIMULATOR**

**ADDITIONAL
FAILURE
DETECTORS**

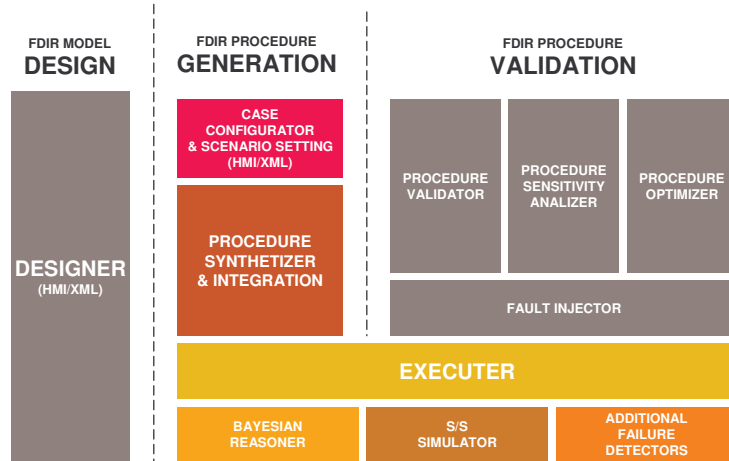
Bayesian Based FDIR C.A.S(ystem).E. - 2



S/S FDIR Model Structure & Parameter definition:

- failures, observations, and action
- failure occurrences
- observation/failure correlation indices
- action & observation costs
- action/failure repairing indices

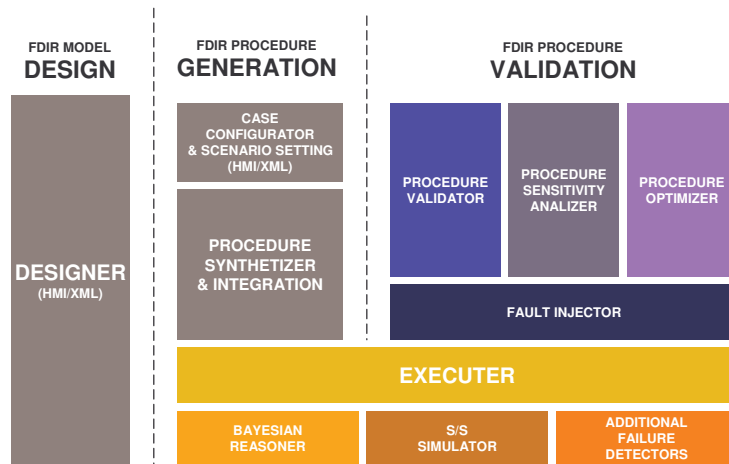
Bayesian Based FDIR C.A.S(ystem).E. - 3



FDIR Procedure Generation:

- FDIR Models are used as inputs
- FDIR Models translation into Bayesian Networks (Executer)
- Scenario and CASE Configurations (from the user)
- Scenario Execution (Executer, with the support of the Bayesian Reasoner, S/S Simulator & Additional Failure Detectors)
- Procedures are built and integrated
- Procedures made available on target support
- Additional Failure Detectors: limit monitoring, correlation tests, S/S & unit built-in test, Kalman filtering.

Bayesian Based FDIR C.A.S(ystem).E. - 4



FDIR Procedure Validation:

Failure injection to :

- validate the generated procedures (Procedure Validation)
- stress the procedure robustness (Procedure Sensitivity Analyzer)
- tune and optimize the FDIR model Parameters (Procedure Optimizer)

Bayesian Based FDIR SW Building Blocks

- **FDIR SW Building Blocks: Core (Algorithms) & declarative I/F**
- **Algorithms configurable via tables**
 - decisional trees, scenarios, inputs and sub-systems
- **Applicability to levels 2 (OSW) and 4 (Ground Segment)**
- **OSW/GS FDIR centralised or distributed approach**
- **Reusability, deployment, reconfigurability, portability without carrying out a time-consuming V&V process (the core does not change)**
 - Model/Configuration Table V&V
- **Operational benefits and FDIR adaptability to the lessons learnt during the phase E.**
 - Patching in PM/SGM RAM of the only FDIR configuration tables

Project Partnership

- **OHB System AG** (B. Brünjes)
 - Satellite System Integrator, Software Design and Development for On-board Systems, Test Facilities, Simulators, and Mission Control Centres
- **CGS SPA** (M. Tipaldi)
 - Small Satellite Manufacturer, Space Systems Design, ISS facility, EO Applications, Ground Segments, Software Engineering
- **University of Sannio** (L. Troiano)
 - ranked top 20 for teaching and research quality in Italy, excellence in research regarding Computational Intelligence, Software Engineering, Software Architectures, Security, Process modelling
- **Intelligentia s.r.l.** (D. De Pasquale & M.C. Vitelli)
 - spin-off company of University of Sannio focused on Computational and Artificial Intelligence