DYNAMIC POSITIONING CONFERENCE
October 11-12, 2016

POWER/TESTING

Transocean's HIL Experience and Opportunities for Improvement

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HIL Experience, Improvements

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MTS DP Conference

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Introduction

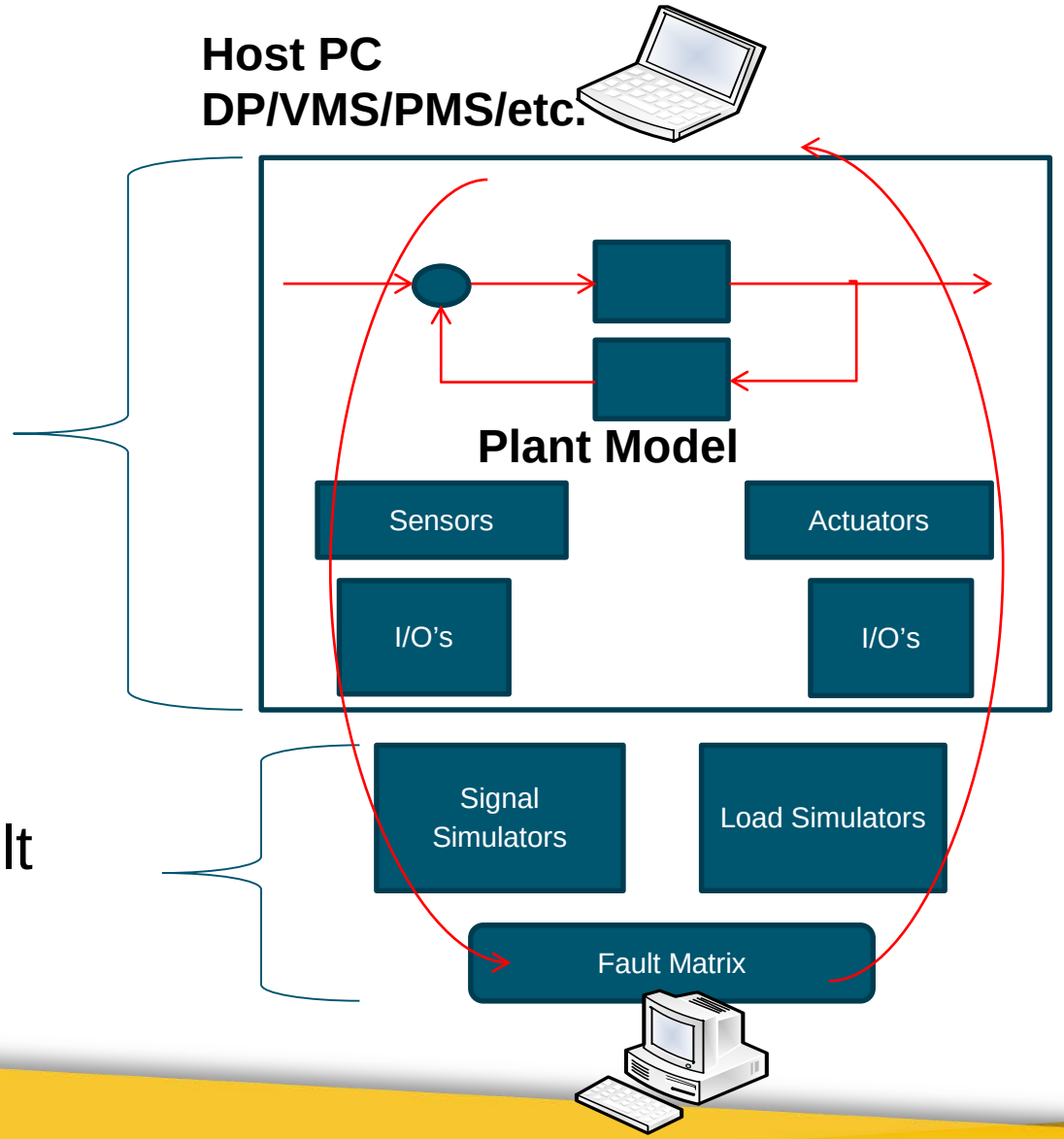
Hardware-in-the-Loop (HIL) simulation is a technique that is used for development and testing of control systems, primarily used for the operation of complex machines and systems.

HIL offers the ability to identify ways to improve processes and minimize risk, while providing further system improvements and system validation.

Introduction

Real-time Simulator networked with actual hardware

Signal & fault simulation



The host PC represents the behavior of the system being simulated utilizing software models.

Real components are then connected via their electrical interfaces, to a test simulator, which reproduces the behavior of the real-time environment.

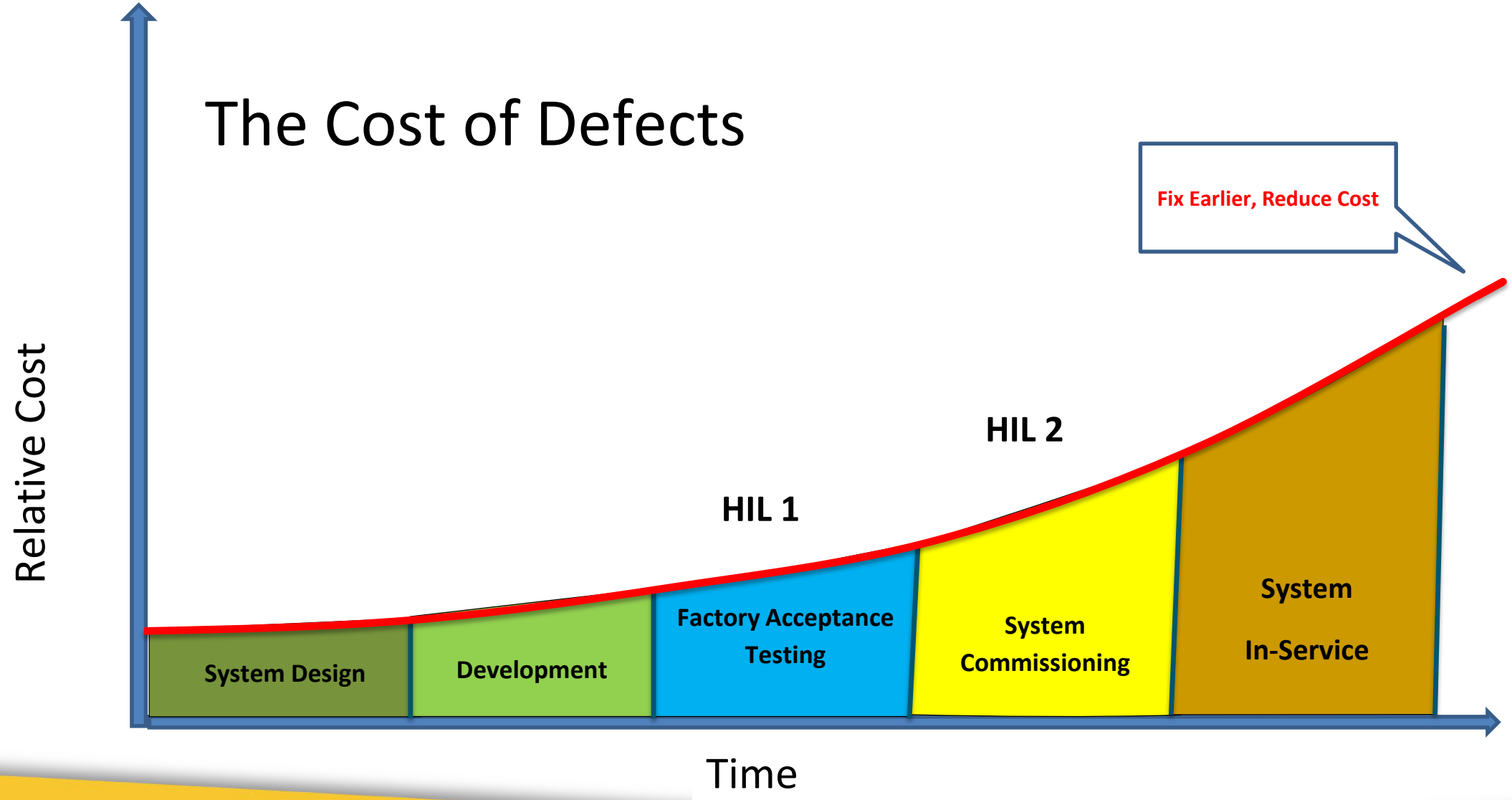
HIL Objectives

During our latest new build project, HIL testing had two primary objectives:

- Minimize software-related risks.
- Minimize commissioning time

All by leveraging additional model-based testing techniques

HIL Objectives



Requirements

- HIL tests applied to one drillship

- HIL test shall be performed on a dynamic positioning system (DPS), power management system (PMS), vessel management system (VMS), thruster Control system, drill control system and drilling Tools, **excluding** subsea system.

- Results of HIL testing to be made available for review to Transocean and our customer.

Requirements

- HIL shall be an effective means for addressing verification and validation of tasks during system development.

- The software being tested during HIL must be identical to what is running on board the vessel during commissioning.

Schedule & Planning

- HIL should not fall on the critical path of the drillship manufacturing project timeline.

- HIL simulator development would require sufficient time to gather data from the perspective suppliers (OEMs & other system interfaces) and any specific requirements from stakeholders (shipyard, Transocean & customer), as well as allowing time for reviewing and finalizing test procedures.

Execution

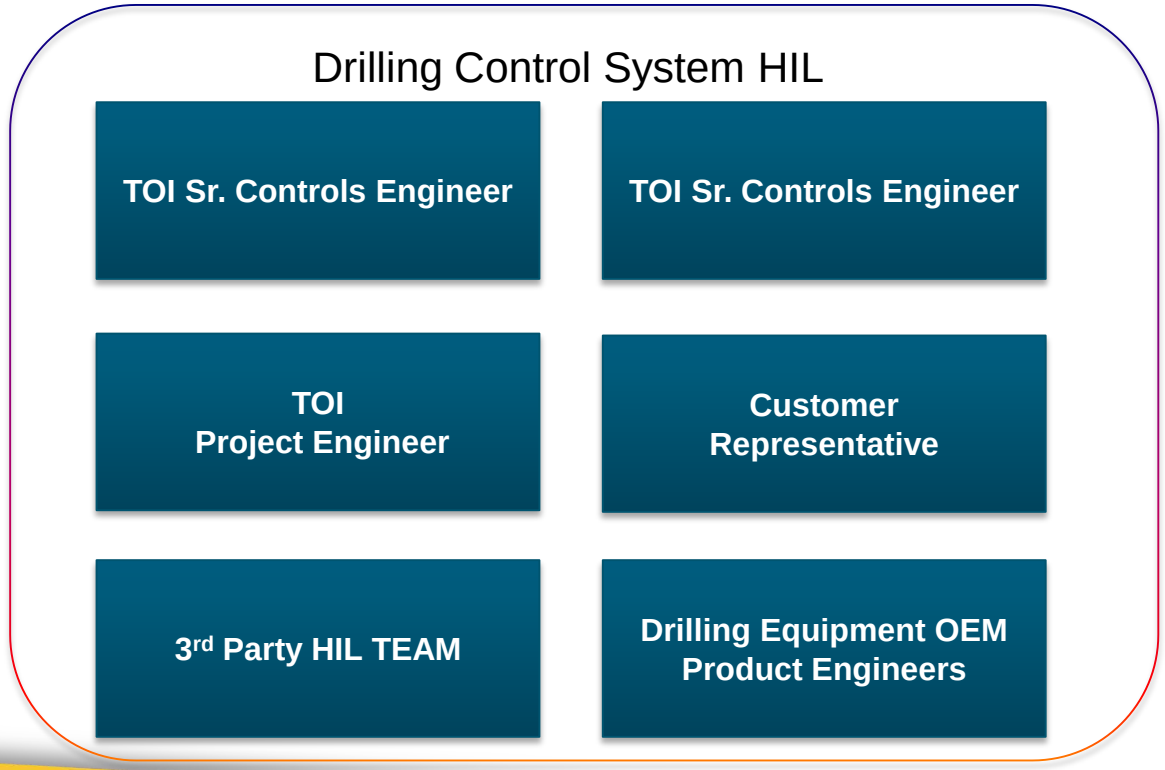
HIL should be arranged in two parts:

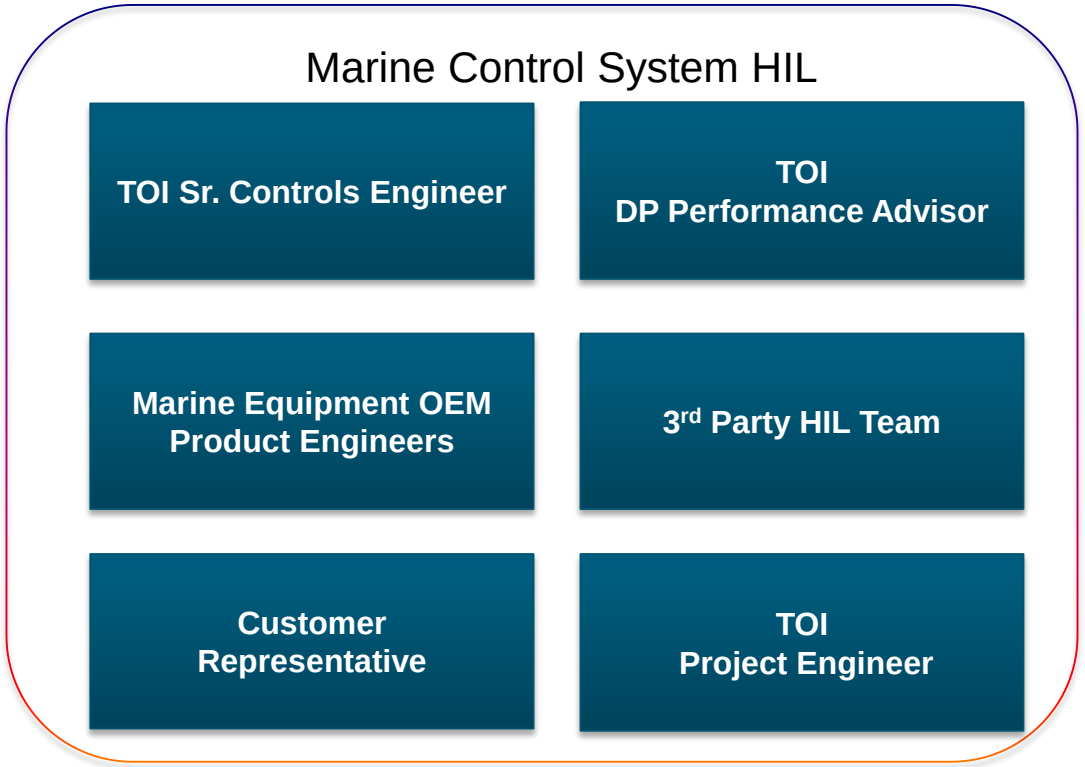
- HIL 1 should be performed at an earlier stage of the software maturity, preferably during FAT or prior to system installation on-board, with the primary intent to **minimize project risk**.

- HIL 2 should be either prior to proving trials or following systems commissioning, with the primary intent to **minimize operational risk**.

Participation

Transocean engineering provided the oversight in the HIL testing process, working with the suppliers and stakeholders. We assembled a team dedicated to the drill floor and for the marine control system.





Marine System HIL

Dynamic positioning (DP)

Vessel management system (VMS)
Power management systems (PMS)
steering, propulsion and thrusters (SPT)

Functions & Failure Groups

Station keeping functions

- Station keeping
- Environment force compensation
- Dead reckoning
- DP Controllers and OS command transfer
- DP mode control
- DP backup positioning, including command transfer

HMI and alarms

- Operator interface
- Alarm and messaging functionality

Functions & Failure Groups

Thruster functions
- Thruster allocation
  * Variable
  * Bias
- Force and moment calculation

Sensor functions
- Sensor feedback handling and compensation

Position reference system functions
- Position reference feedback handling & compensation

Functions & Failure Groups

DP computer system HW

Monitoring functions

- Consequence analysis
- Online capability analysis and motion prediction
- DP backup monitoring
- Riser angle monitoring

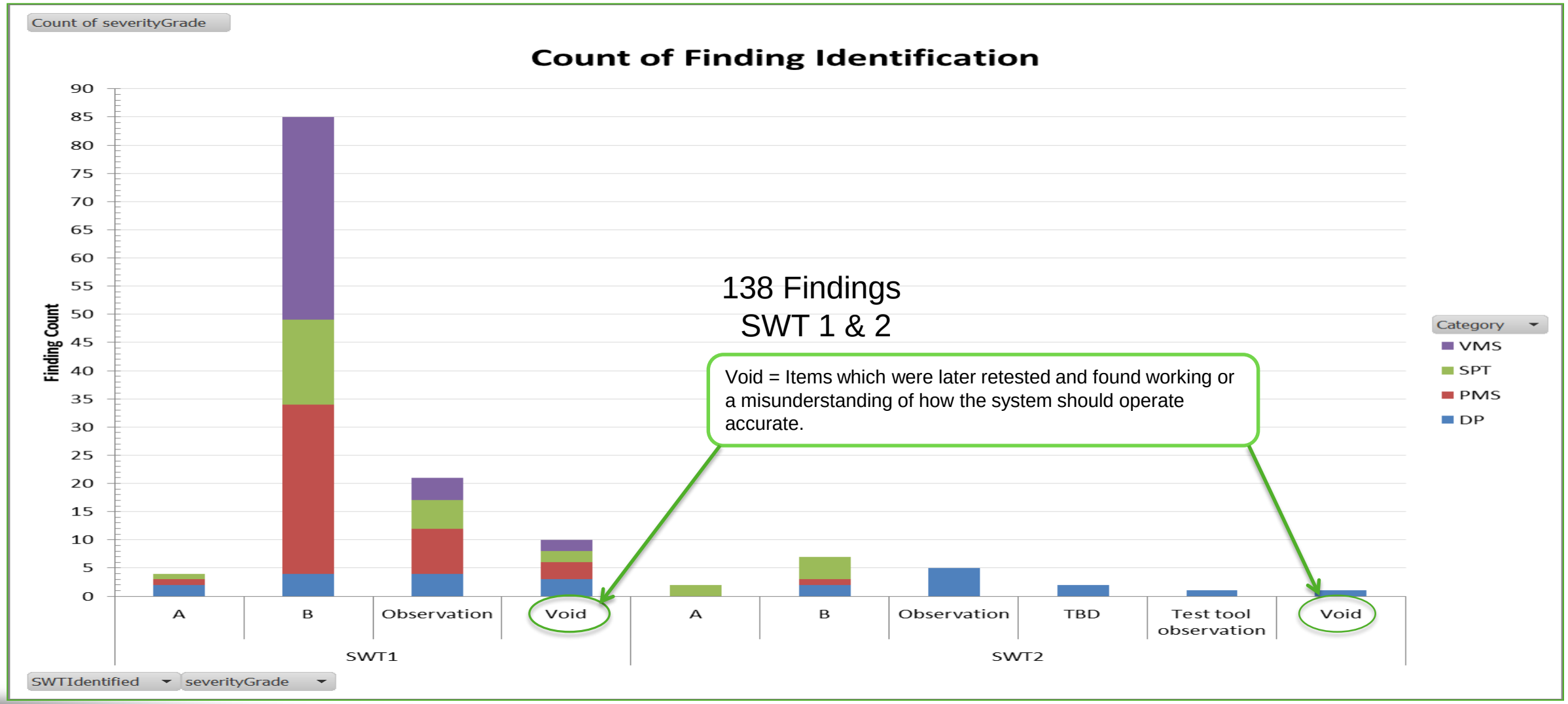
Network, Communication and Synchronization

- DPC and OS synchronization, reboot and changeover

HIL Findings Categories

- "**A**" or **high level finding** – nonconforming with system design, rules or regulations
- "**B**" or **low level findings** – nonconformity with requirements, specifications, industry guidelines, standards, stakeholders documentation (such as user manuals), or intended use
- **Observation** or **cosmetic** – would indicate valid and/or relevant finding such as HMI or grammatical issues.
- **VOID** – findings that are not relevant or invalid due to misunderstanding of test items, simulator capabilities and or interface problems outside of the scope of HIL
- **TBD – to be determined –** basically is an observation that requires further clarification. This category allows time to review FDS or possibly determine an area of improvement, especially if it is a function that was not part of the system deliverables.

Marine System HIL Findings



Track Changes

Test result sheet (TRS) – Written for all observations, category “A” & “B”, and void recorded findings, then they were reviewed in the test summary meeting and evaluated by the test representatives.

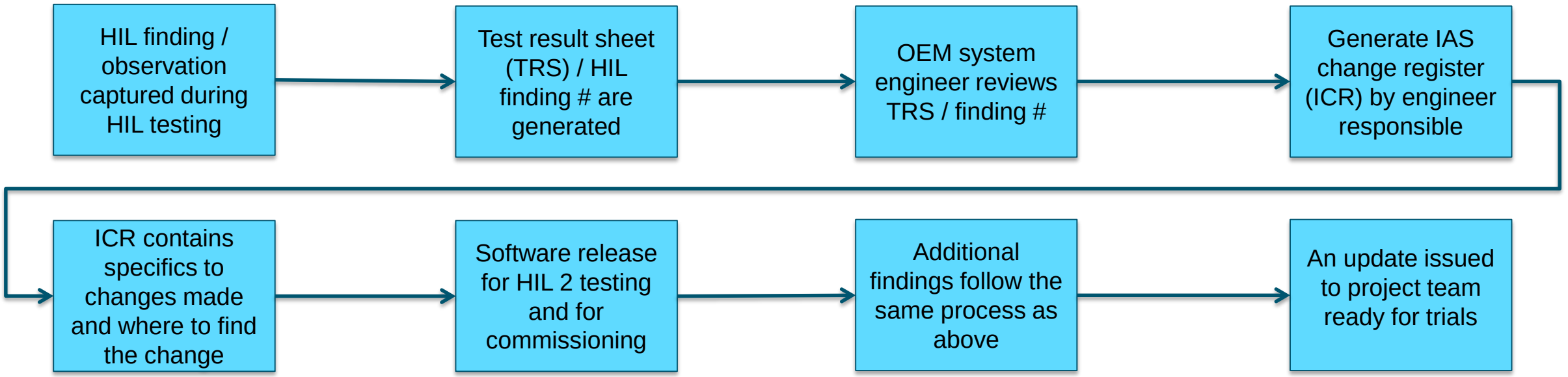
OEM IAS change register (ICR) – Written for all observations and category “A” & “B” findings.

ICR database is the OEM’s tracking tool used for registration of all changes occurring in a project.

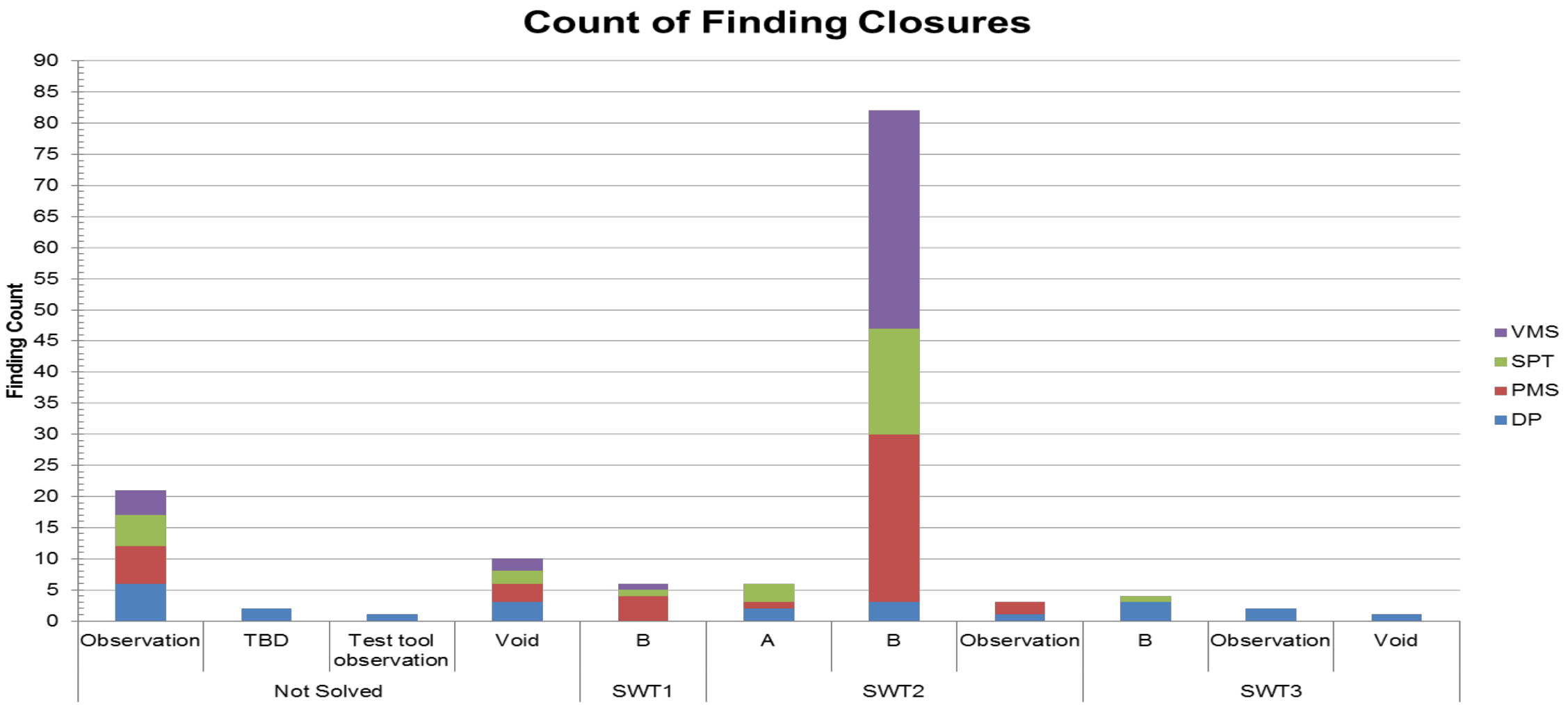
Note: Changes entered in this database specify for which system the change is critical and clearly state where to find the change, i.e. in a specific field station, a particular mimic or software code, etc.

MOC Process

OEM utilized the following MOC process



Track Changes



Drilling Control HIL

Drilling Control System & Tools

- Hydraracker IV main & aux well
- Fingerboard w/bellyboard
- Riser handling catwalk w/tail arm
- Pipe handling catwalk machine shuttle w/tailarm
- Hydraulic power unit (HPU) for ringline system
- Wireline riser tension
- Anti collision system (ACS)

Drilling Control System & Tools

- Drawworks main & aux well
- Mud pump control system
- Top-drive main & aux well
- Iron roughneck main & aux well
- Hydraulic mud bucket
- Rotary table main & aux well
- Machine interlocks
- Guide-arm in derrick

Drilling System Test Program

Normal operation for each individual tool

- Verify HMI controls are according to the documentation
- Verify normal operation of the equipment, including feedback to the operator
- Verify safe operation is supported by interlocks and operator messages (alarms, warnings, indicators, measurements).
- Verify emergency stop activation and deactivation is safe

Drilling System Test Program

Normal operation with all applicable tools require (Main & Aux)

- Verify trip in & out operations
- Verify stand build & break operations
- Verify drilling operation on main & aux station

Failure and Degraded Mode Testing

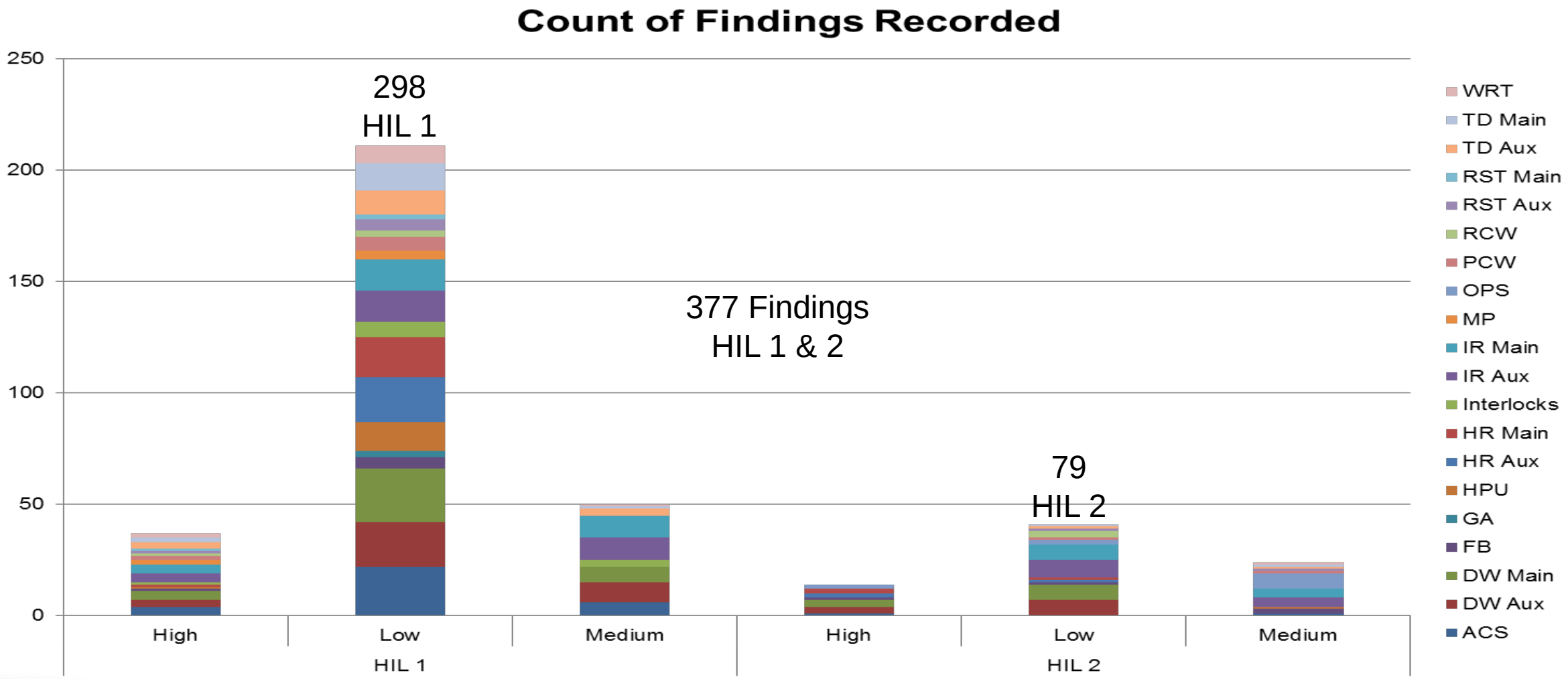
Verify the control system handles failure situations in a safe method by activating applicable protection functions, alarms and indicators.

HIL Findings Categories

Findings summary:

- **Cosmetic** – primarily related to the presentation or the layout of the data
- **Minor** – defects which can or have caused low-level disruption of function, but not decreased safety
- **Moderate** – defects with an acceptable workaround. – no impact on safety
- **Major** – defects that have seriously degraded the performance caused unintended action or incorrect data transmit. No workaround exists
- **Critical** – defects that have halted or are capable of halting the operation

Drilling Control HIL Findings



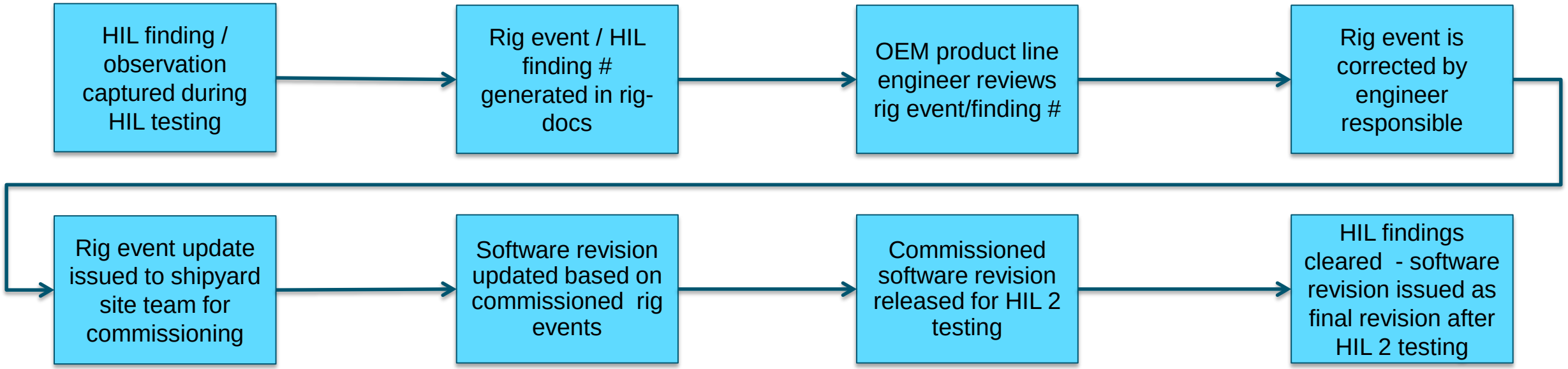
Track Changes

OEM’s finding register report consist of the following:

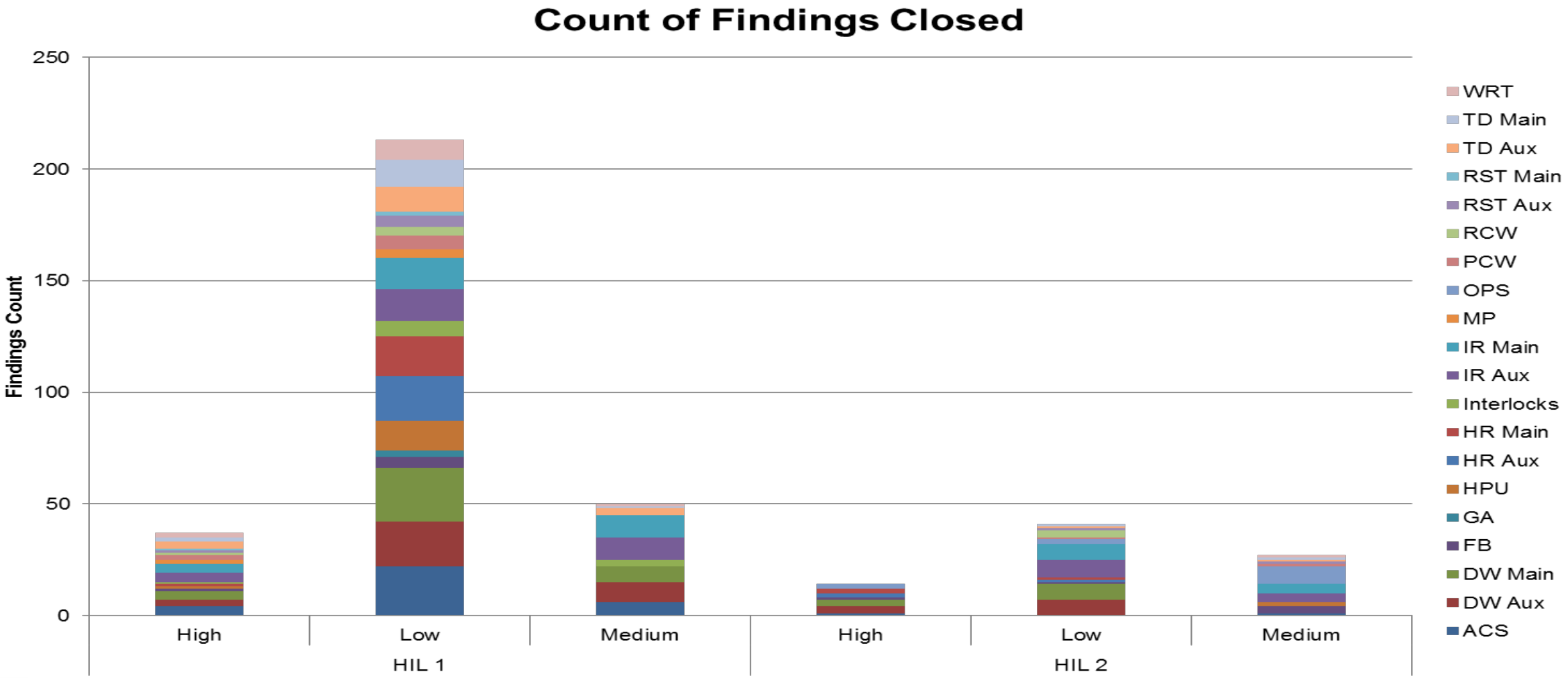
- ✓Test results summary – captures summary of test results.
- ✓Findings summary – captures testing findings / observations based on severity rating.
- ✓Software versions group - captures software revision tested against.

MOC Process

OEM utilized the following MOC process



Track Changes



Method of Measurements

HIL could easily be measured by a basic concept, that for every HIL finding, it would take an individual up to a day to:

- Confirm the finding
- Determine best solution
- Solve the issue / finding
- Retest solution for its robustness in a control environment
- Document action taken
- And release as a new version.

As an example:

Drilling controls: 377 findings = 377 man days

Marine systems: 138 findings = 138 man days

Lessons Learned

- FAT software punch list items should be included in validation during HIL testing.
- HIL 1 should start promptly after or during FAT.
- HIL 2 should start after system commissioning
- Better tracking of KPI's compared to I&C shipyard findings vs. HIL findings.
- System tools (i.e. DP, Drawworks, etc.) responsible engineers should be readily accessible during HIL testing.
- Improved HIL documentation during testing (FDS, Ops manual, maintenance manual)
- Improved HIL models – (i.e. hydraulic models, MCC/power plant models, VFD models, thruster models, etc.)

Opportunities for Improvements

New approach high level FDS summary document

- HIL model definitions
- List systems – software dependent system (SDS)
  - ✓ Station keeping (DP control system)
  - ✓ Vessel monitoring & control systems (VMS, PMS, SPT, etc.)
  - ✓ Safety systems (ESD – F&G)
  - ✓ Industrial mission systems (pipe or cable laying, drilling, diving, construction, etc.)

Opportunities for Improvements - FDS summary

- HIL1 – OEMs should incorporate HIL testing as part of their FAT (FAT/HIL)
- HIL2 integrated (all parties) simultaneous (real time) testing, including all available interfaces possible and involve a third party to aid in validation.
- Purpose statement - safety, software risk, optimizing performance
- Describe MOC process – track HIL findings thru commissioning and operation – life of vessel concept
- Reference HIL program-philosophy document / MTS TECHOP

Opportunities for Improvements

Industry collaboration on a HIL program document / MTS TECHOP

1. Define HIL
2. Life of vessel concept
3. HIL harness availability
4. Integrators / third parties
5. Define structure of interfaces
6. Interface simulator from all suppliers
7. Test results standard categorize and documents
8. Suitability of model testing

Opportunities for Improvements

9. Specify “integrity” testing
10. MOC process, including settings and parameters
11. Change order / software freeze
12. Ownership / Intellectual property
13. Leveraging HIL methodology for development
14. Schedule sequence of events
15. Testing organizational structure
16. ADHOC testing

Conclusion / Benefits of HIL

HIL testing is a software intensive effort, particularly with well-developed system models. Our findings demonstrated the MOC process followed and provide recommendations on methods of improving for future HIL testing. HIL is another tool with much potential and benefits that cannot be overlooked, such as:

- Identifies design issues prior to system deployment
- Shortens validation and commissioning processes
- Keep HIL simulator available for ad-hoc testing for the life of the vessel
- Test software updates on a repeatable base HIL tested software

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Questions?