

Using Fault Injection on the Nanosatellite Subsystems Integration Testing

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Introduction

Facts as of 2017 January 8

Nanosats launched in total: 580
CubeSats launched in total: 510
Nanosatellites in orbit: 293
Operational nanosatellites: 213
Nanosats destroyed on launch: 70

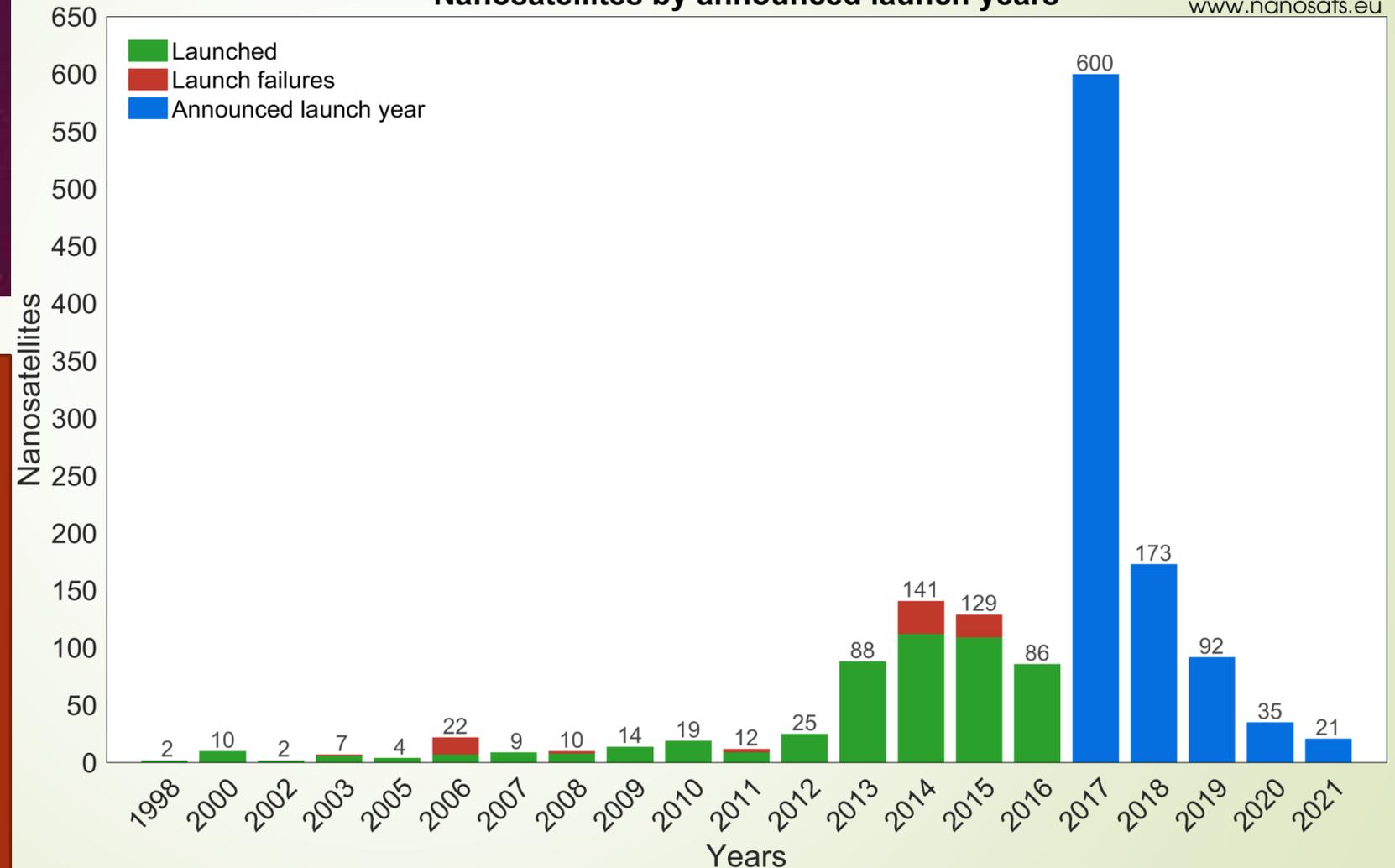
A great number of mission failures from hobbyists projects (60%)

VS

Failure Rates from traditional satellite developers around 10%.

Nanosatellites by announced launch years

www.nanosats.eu



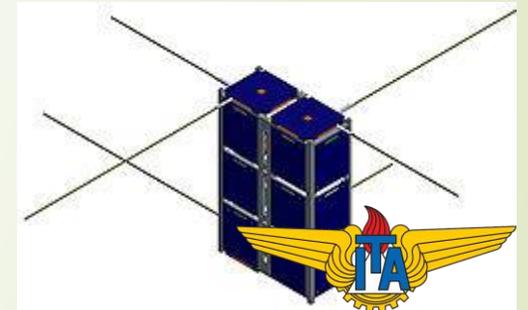
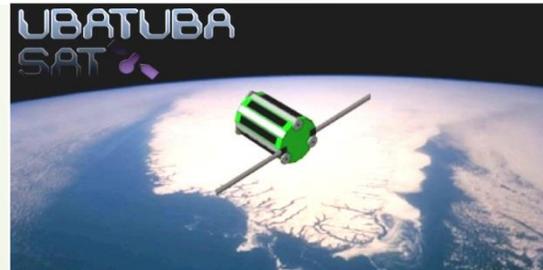
Introduction



CONASAT
CONSTELAÇÃO DE NANO SATÉLITES AMBIENTAIS



NANOSATC-BR,
Programa de Desenvolvimento
de Cubesats



The best hope for improving the performance [...] is to have system implement, best-practices in design, assembly and test that other developers utilize.
(Swartwout, 2016)

Concepts

FAULT

Due to a SUE, the A/D converter reads a wrong temperature measure.



ERROR

The Thermal Control Subsystem doesn't heat up the batteries.



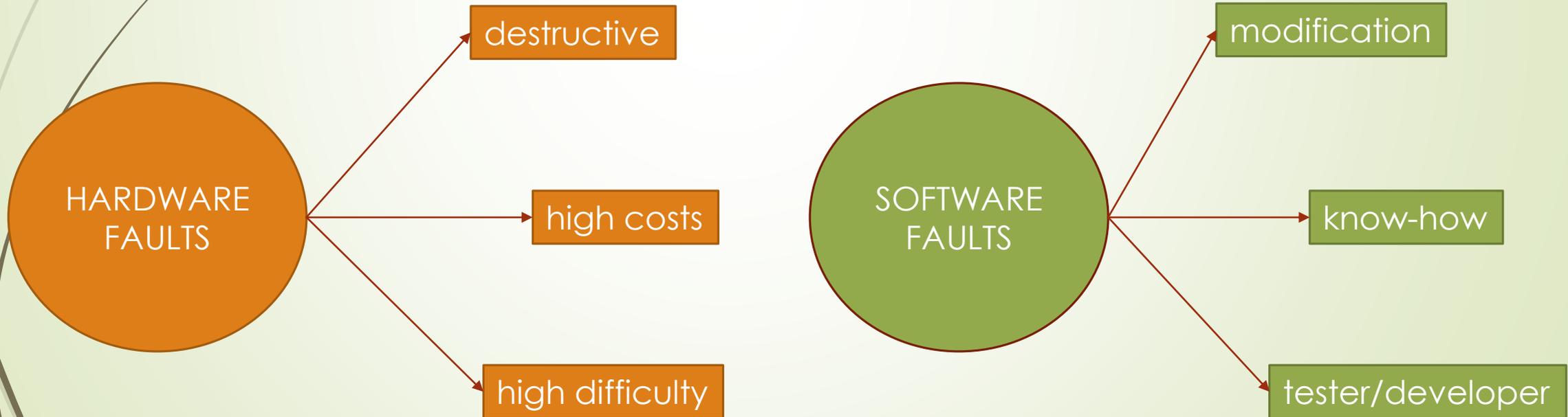
FAILURE

The batteries get too cold and stop working properly. System's Failure.

Concepts

FAULT INJECTION

Consists on deliberate inserting faults into a system in a way that emulates faults present in the system (Arlat, 1989)

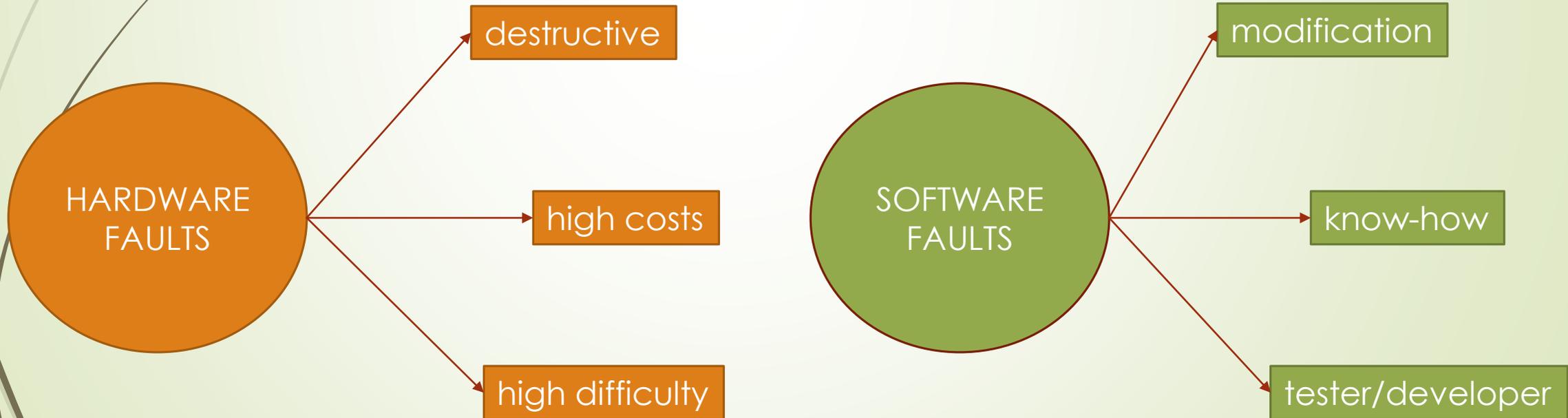


Concepts

FAULT INJECTION

Consists on deliberate inserting faults into a system in a way that emulates faults present in the system (Arlat, 1989)

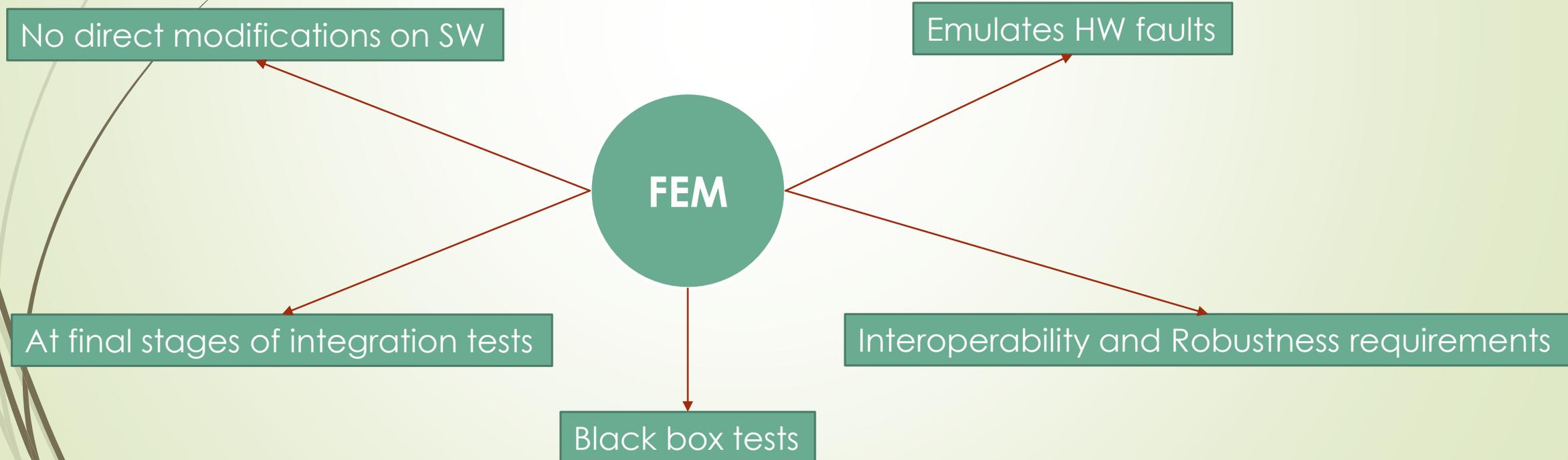
How to embarrass the developing team?



Concepts

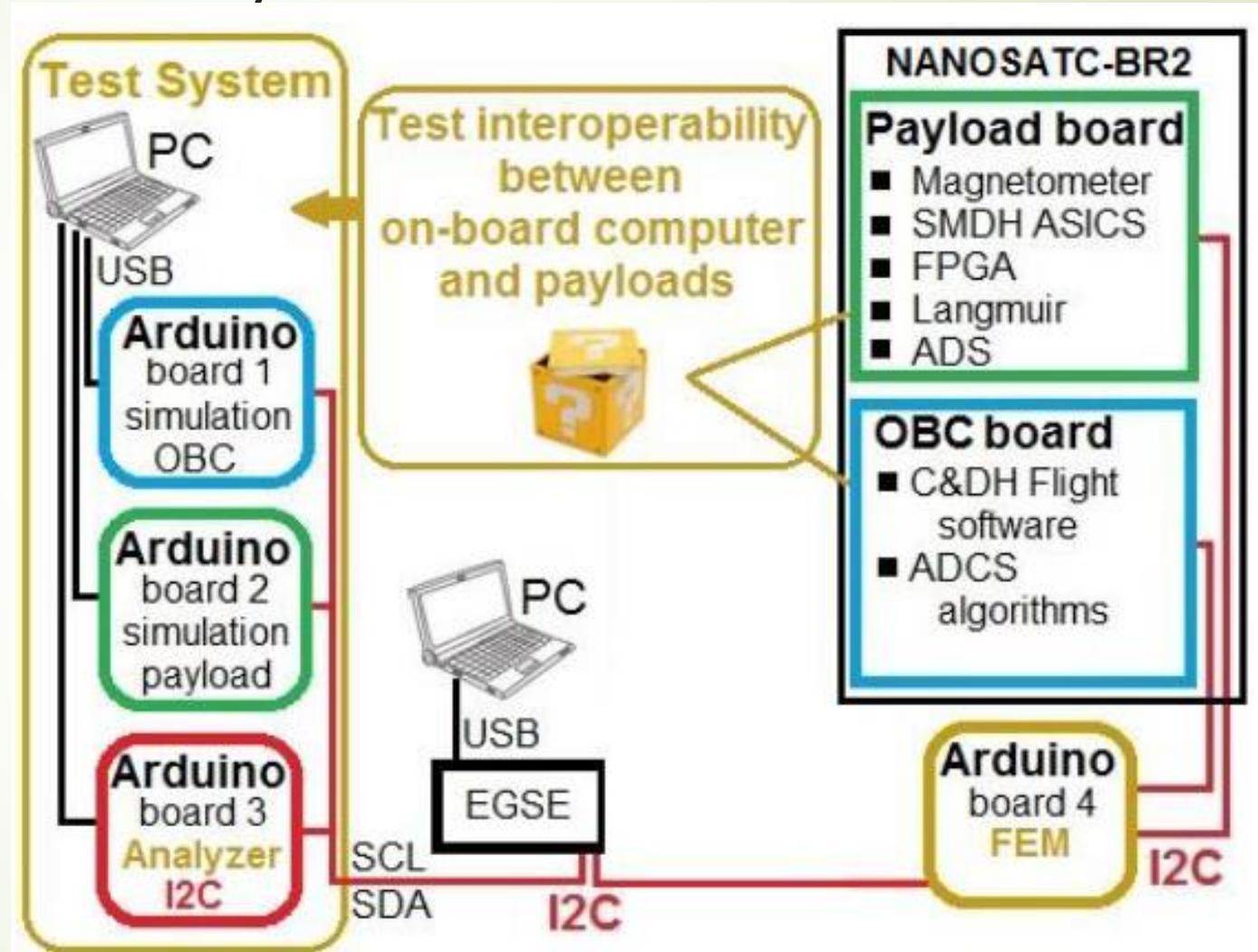
FAILURE EMULATOR MECHANISM

A test execution mechanism that can inject faults into the message exchanged between two software intensive subsystems at the communication channel.

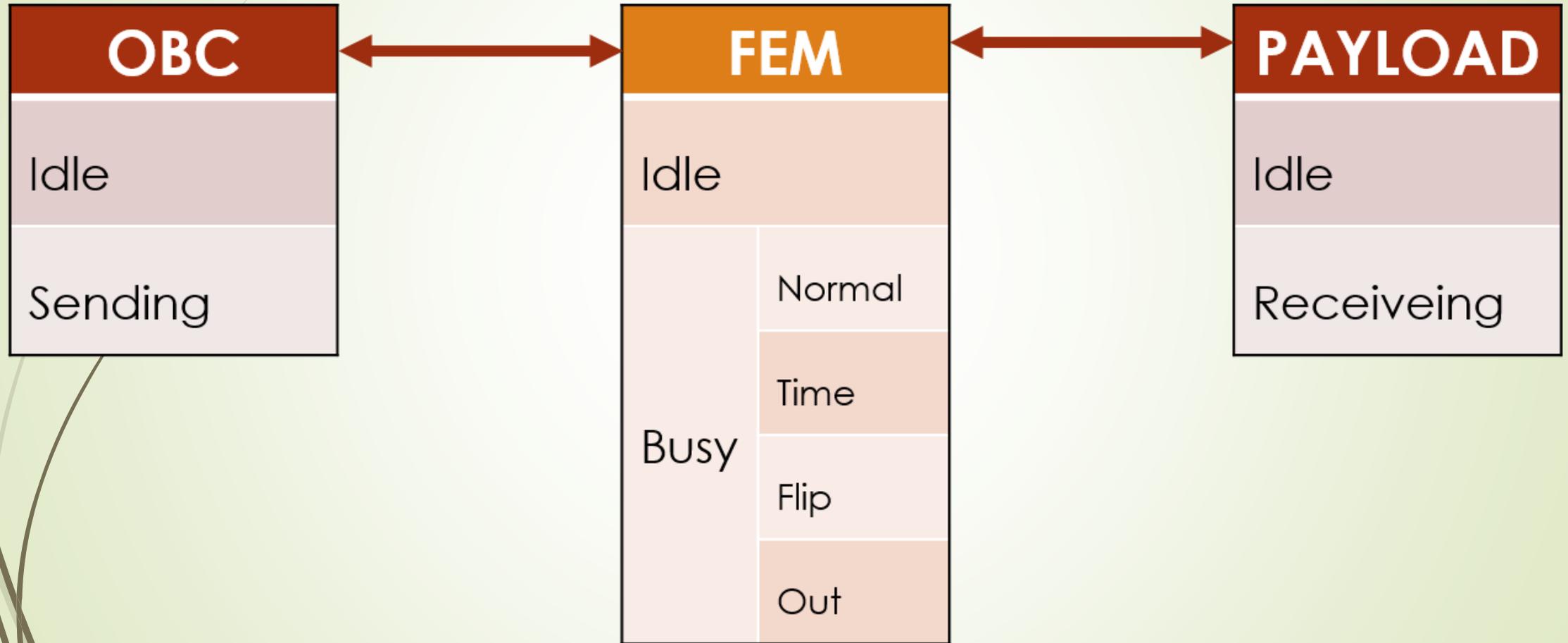


Proposed Test System

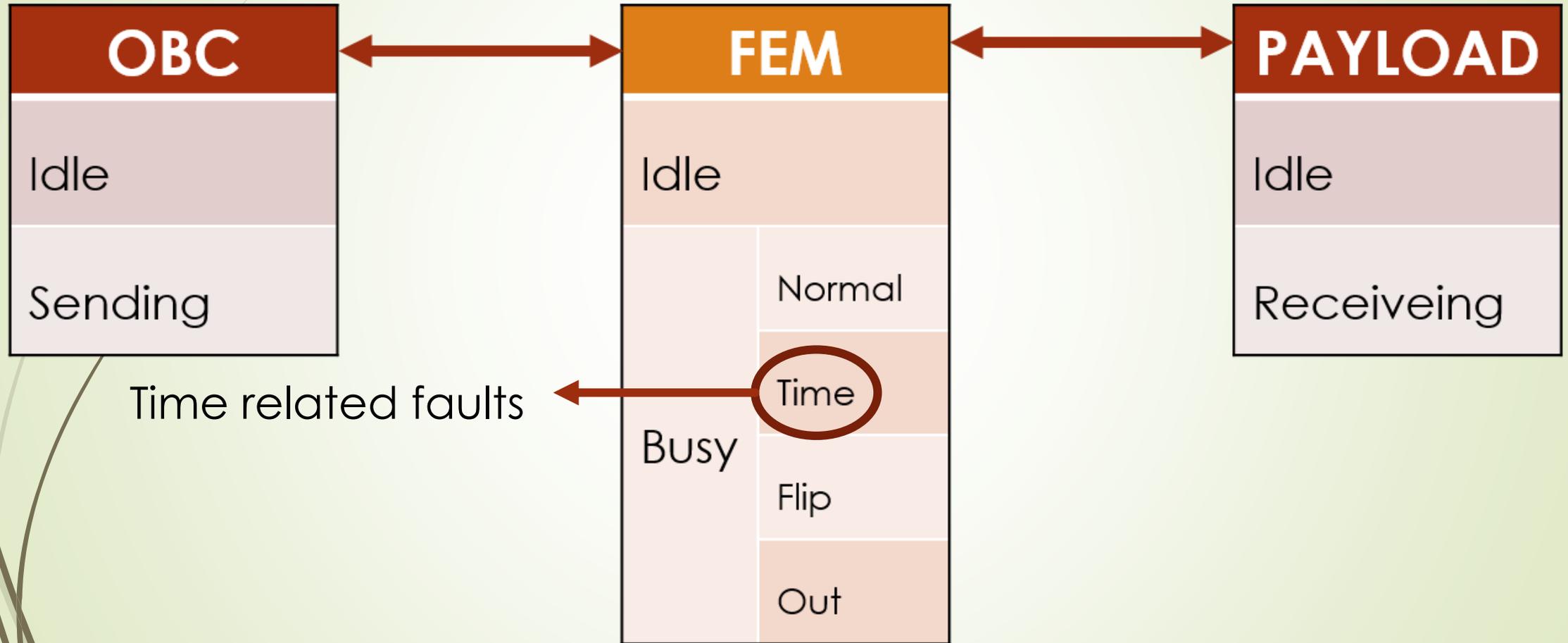
- Reusable Test System
- Support the On-Board SW development and
- Arduino Based
- CubeSat Backbone – I²C
- Different stages of development
- Derive test suites using MBT approach



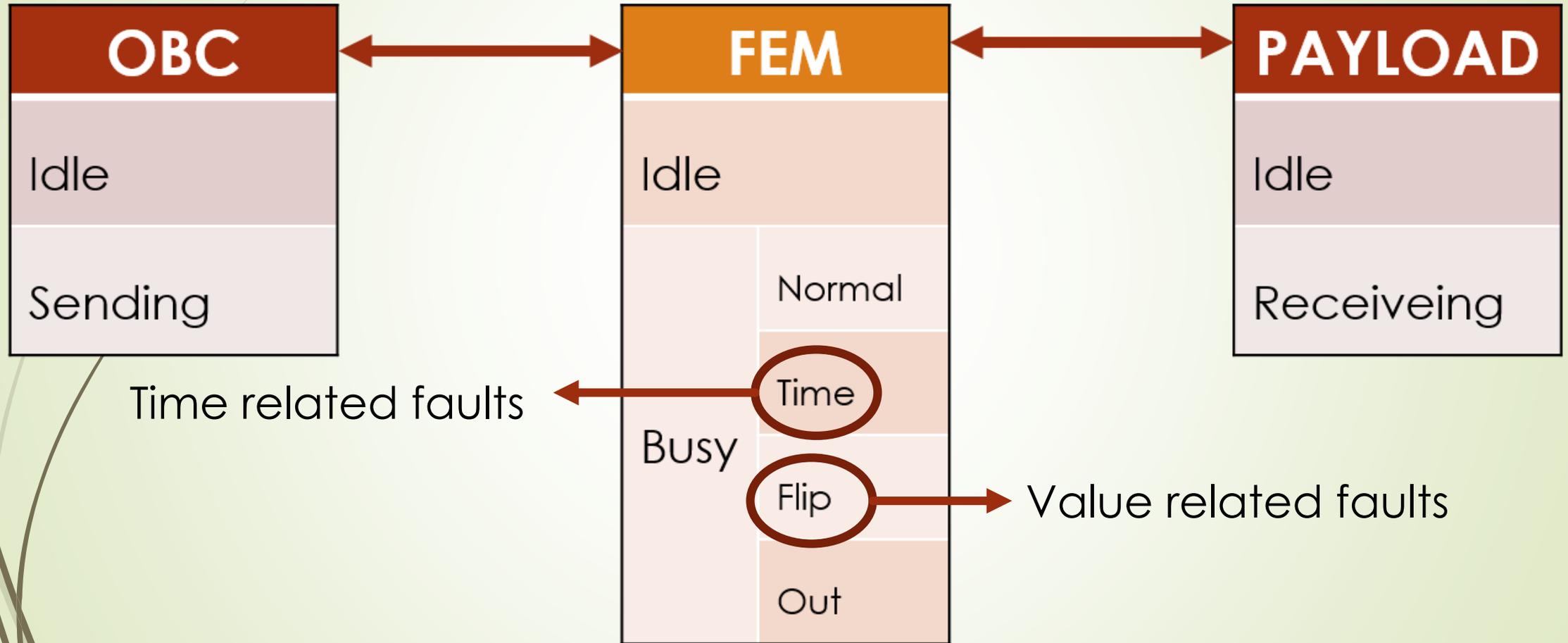
Development: Model



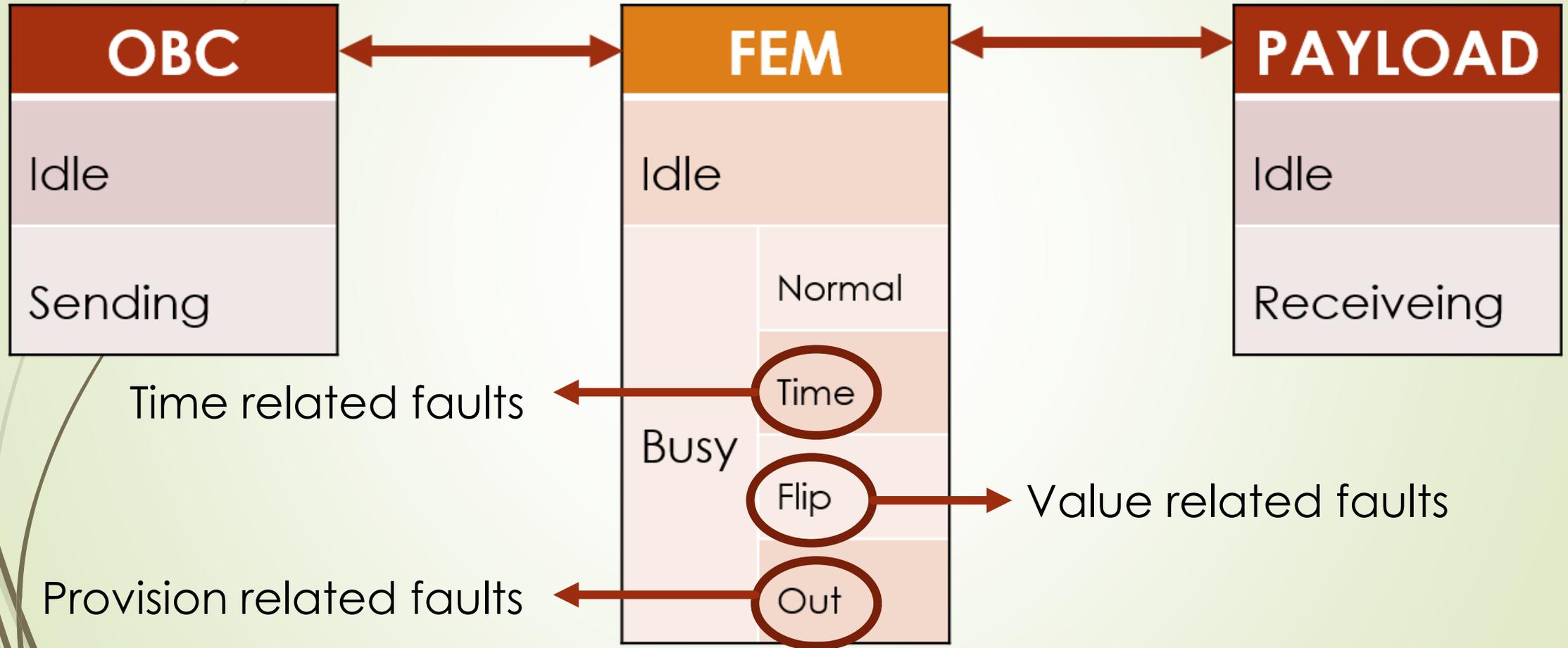
Development : Model



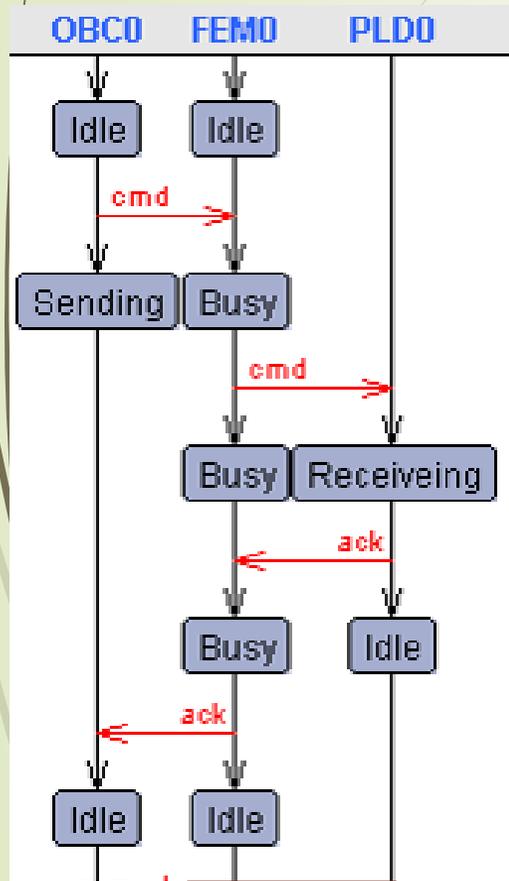
Development : Model



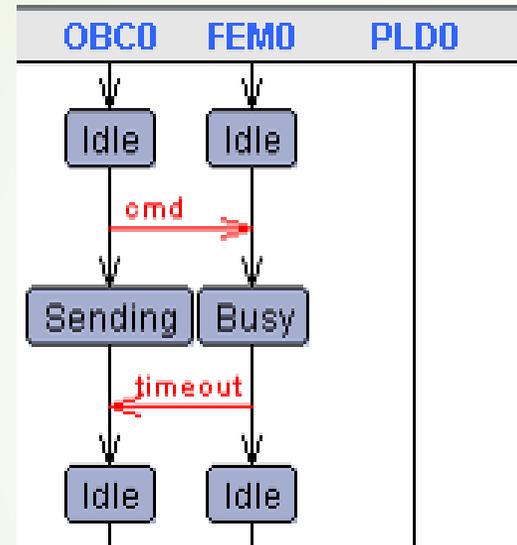
Development : Model



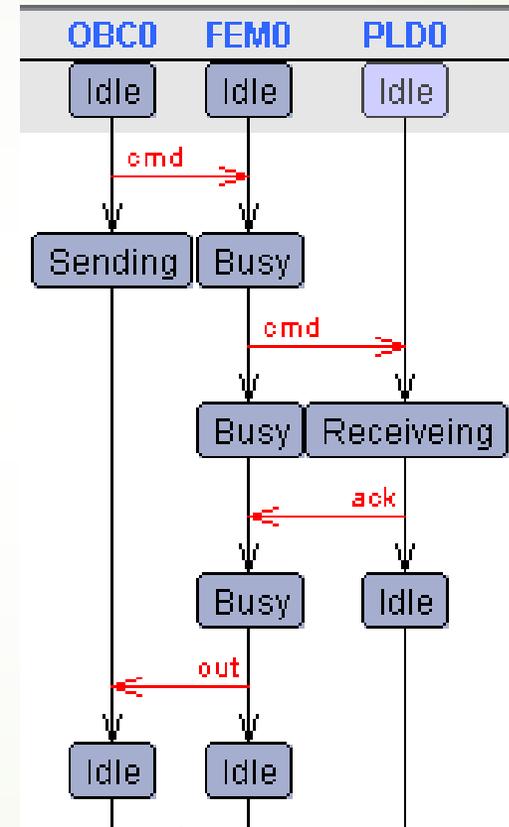
Development : Model



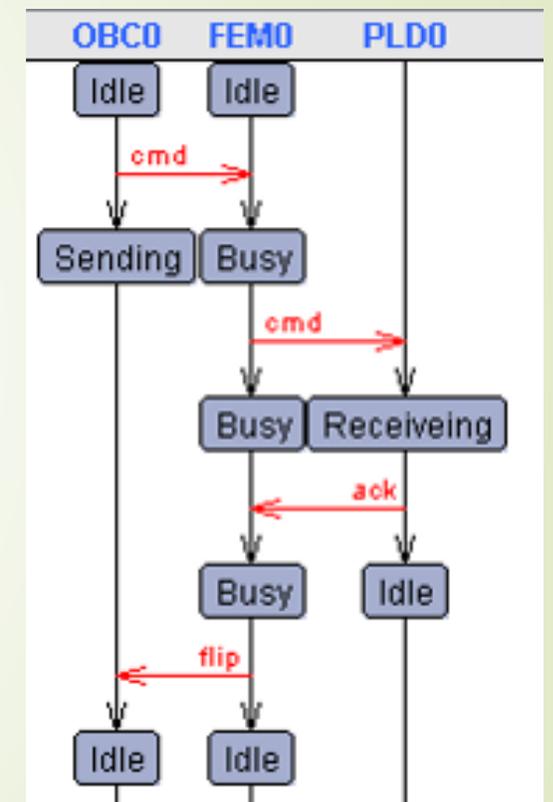
Normal



Timeout

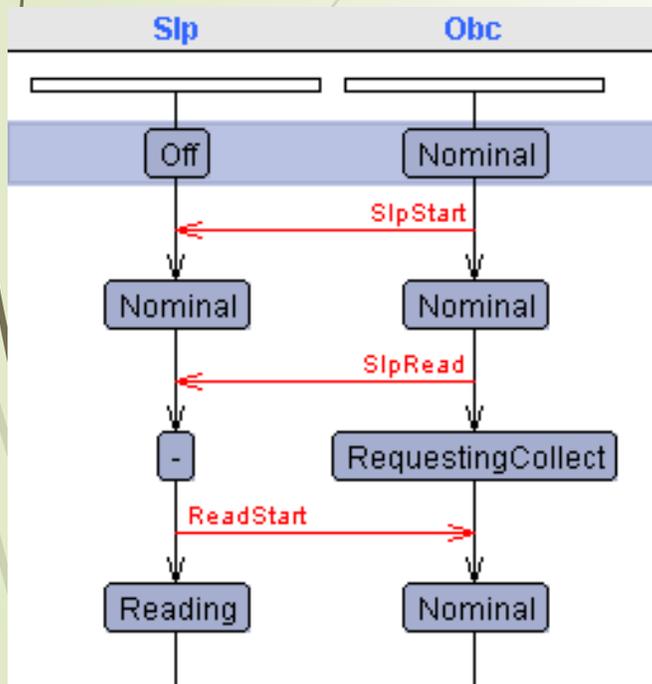


Out of Range

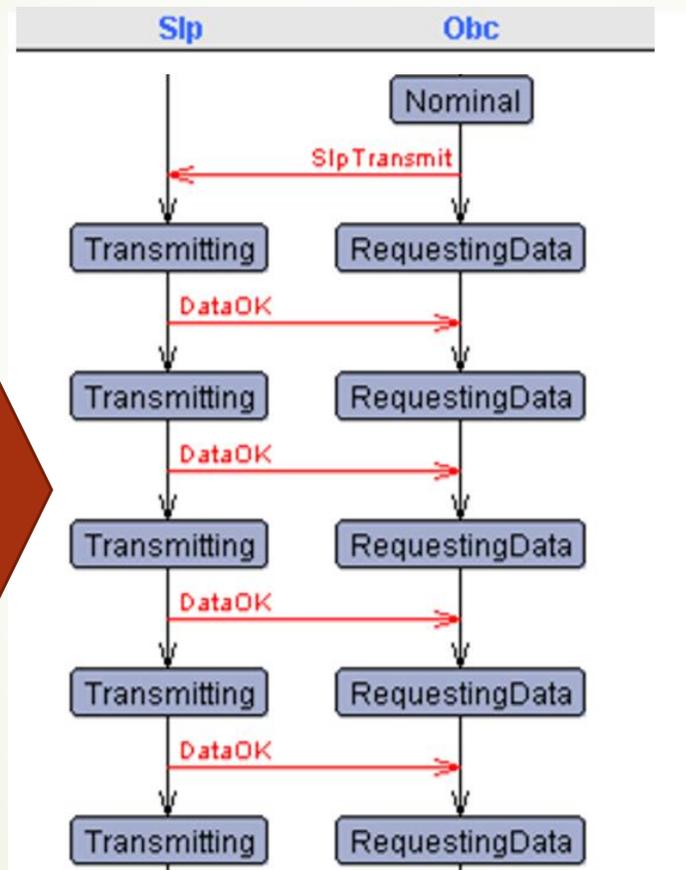


Bit-Flip

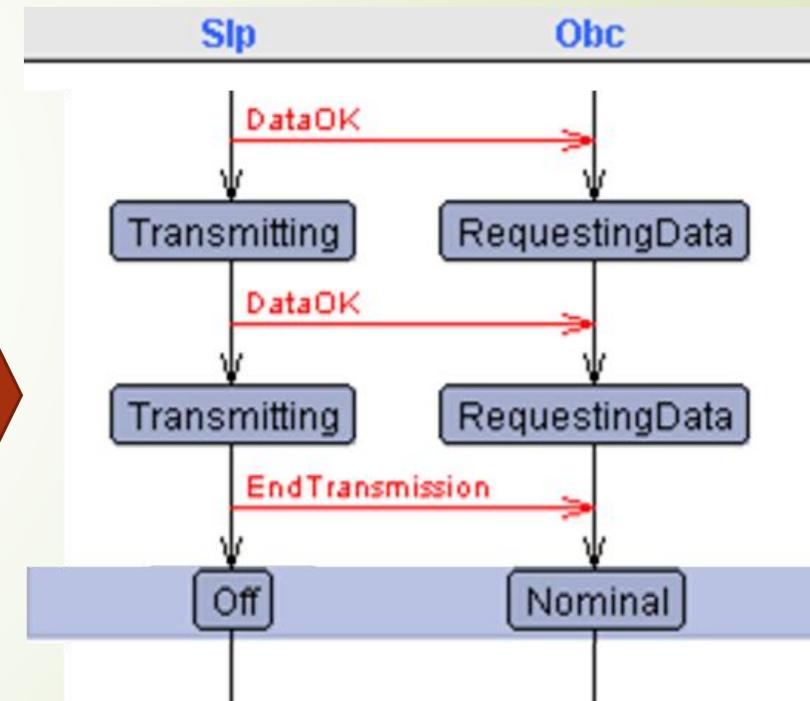
Development : Model



OBC cmd SLP Start



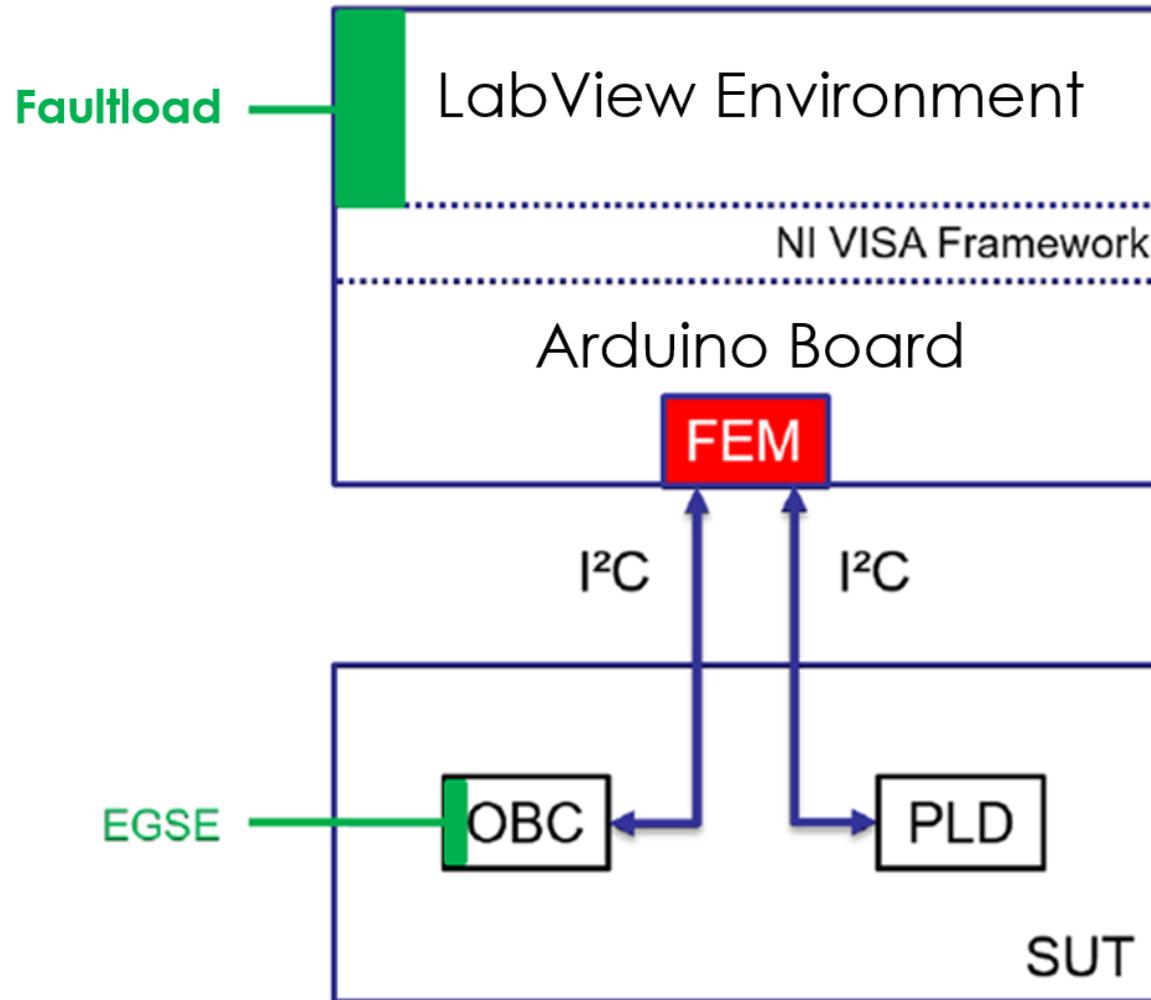
OBC request data



SLP end transmission

Development: Architecture

Test System



Tester Interface
Upload Faultload to Arduino
Where? When? What?

Automatic Testing
Cheap
Fast Implementation
OpenSource

First Results

MASTER

```
STATE 01 - SLP Ready
Sending cmd... 0xF0
Receiving... 0xFA !OK!OK!
STATE 02 - Sending Time
Time... 0x74A260EA3E8C42A4
STATE 03 - Requesting Data
Data 0x74
Data 0xA2
Data 0x60
Data 0xEA
Data 0x3E
Data 0x8C
Data 0x42
Data 0xA4
Data 0x7
Data 0x31
Data 0x49
```

```
Write 1 Read 1
Write 2 Read 1
Write 3 Read 2
```

SLAVE

```
!OK!OK!OK!OK! 0xF0
TimeStamp 0x74A260EA3E8C42A4
Data to Send 0 to 32 bytes.
Data 0x74
Data 0xA2
Data 0x60
Data 0xEA
Data 0x3E
Data 0x8C
Data 0x42
Data 0xA4
Data 0x7
Data 0x31
Data 0x49
```

OBC Serial Monitor
States
Requests
Commands

FEM Serial Monitor
Busy Mode
Normal Activ
Monitoring

SLP Serial Monitor
Received
Confirmation
Data



First Results

MASTER

SLAVE

```

STATE 01 - SLP Ready
Sending cmd... 0xF0
Receiving... 0xFA !OK!OK!
STATE 02 - Sending Time
Time... 0x74A260EA3E8C42A4
STATE 03 - Requesting Data
Data 0x74
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Data 0xA4
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Data 0x49

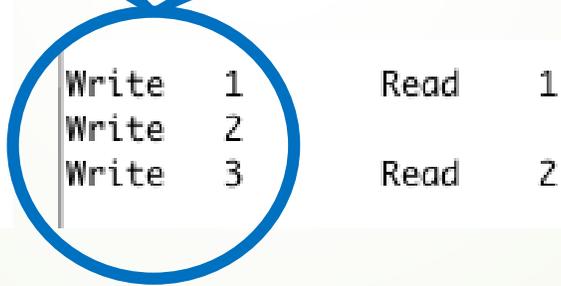
```

```

!OK!OK!OK!OK! 0xF0
TimeStamp 0x74A260EA3E8C42A4
Data to Send 0 to 32 bytes.
Data 0x74
Data 0xA2
Data 0x60
Data 0xEA
Data 0x3E
Data 0x8C
Data 0x42
Data 0xA4
Data 0x7
Data 0x31
Data 0x49

```

Commands



OBC Serial Monitor
 States
 Requests
 Cammands

FEM Serial Monitor
 Busy Mode
 Normal Activ
 Monitoring

SLP Serial Monitor
 Received
 Confirmation
 Data



First Results

OBC (master)

SLP (slave)

```
STATE 01 - SLP Ready
Sending cmd      0xFE
Receiving...    0xFA  !OK!OK!
STATE 02 - Sending Time
Time...         0x74A260EA3E8C42A4
STATE 03 - Requesting Data
Data            0x74
Data            0xA2
Data            0x60
Data            0xEA
Data            0x3E
Data            0x8C
Data            0x42
Data            0xA4
Data            0x7
Data            0x31
Data            0x49
```

```
!OK!OK!OK!OK!  0xFE
TimeStamp      0x74A260EA3E8C42A4
Data to Send   0 to 32 bytes.
Data           0x74
Data           0xA2
Data           0x60
Data           0xEA
Data           0x3E
Data           0x8C
Data           0x42
Data           0xA4
Data           0x7
Data           0x31
Data           0x49
```

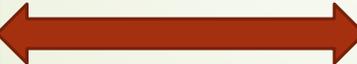
Requests

Write	1	Read	1
Write	2	Read	2
Write	3		

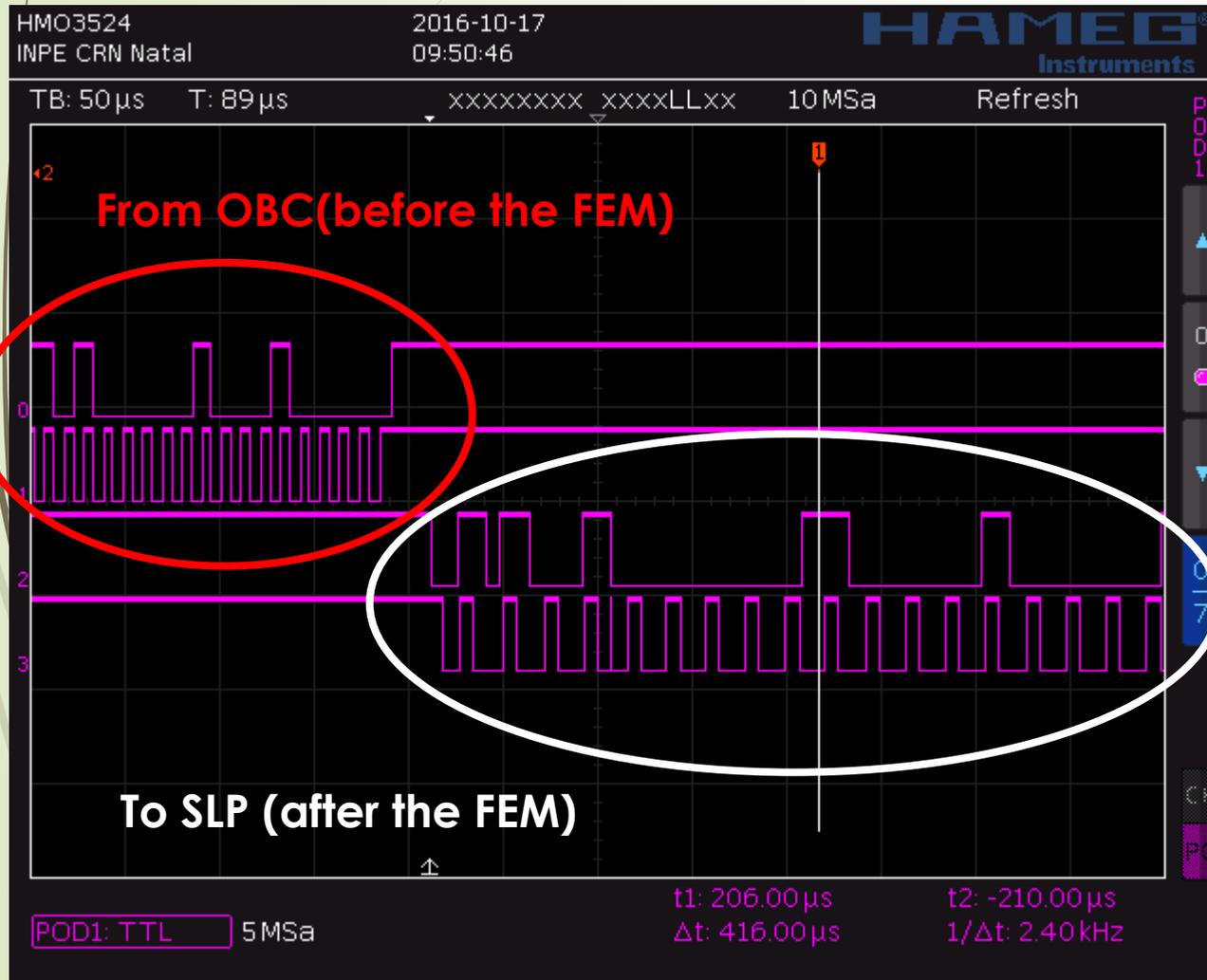
OBC Serial Monitor
States
Requests
Commands

FEM Serial Monitor
Busy Mode
Normal Activ
Monitoring

SLP Serial Monitor
Received
Confirmation
Data



First Results



- First attempt to see how delay faults actually works on I2C bus
- Due to the resolution of the oscilloscope, the result is inconclusive
 - **Low resolution causes the lost of data (the oscilloscope doesn't read all bits)**
 - **High resolution narrows the window (impossible to see the complete message)**

Conclusions

The fault injection has already proved itself as an efficient tool for software requirements verification but its use on integration tests of space systems is still a step to be reached.

- With a good model driven design it is possible to reach the agility and quality level required for a good V&V process on Nanosat/CubeSat mission even with a low budget.
- **The use of models and FEM prototyped in Arduino on I2C bus highlights the problems inherent to I2C protocol itself.**
- Efforts on improving the FEM model and the NI LabView interface are necessary
- FEM as a whole will be tested with real satellite subsystems in the loop

Using Fault Injection on the Nanosatellite Subsystems Integration Testing



Thank you!

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Questions ?

**1st IAA LATIN AMERICAN
SYMPOSIUM ON SMALL SATELLITES**
7-10th March 2017
Buenos Aires, ARG