INPE
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Using Fault Injection on the Nanosatellite Subsystems Integration Testing

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LabV&Vsis

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Introduction

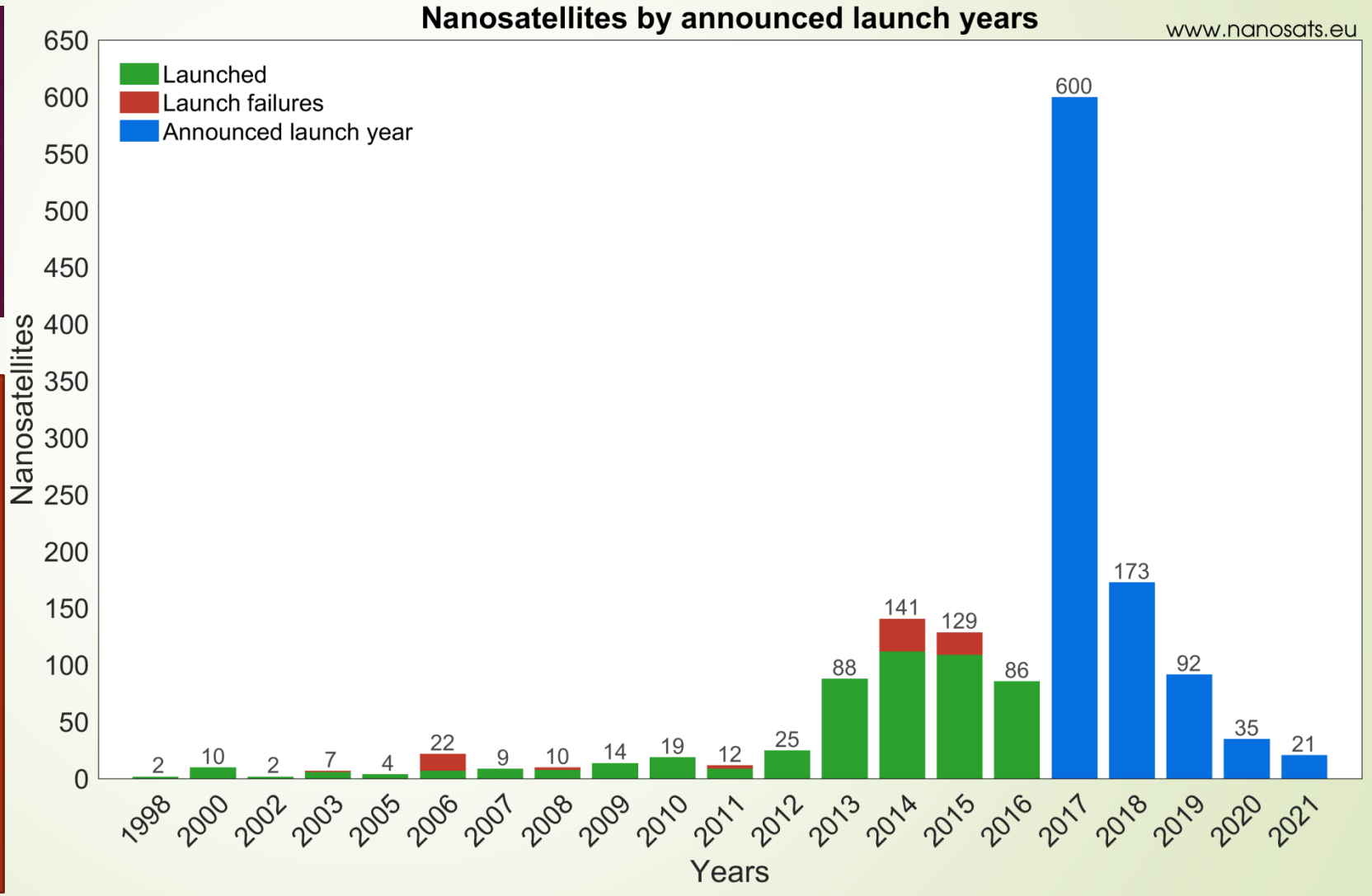
Facts as of 2017 January 8

- 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%)

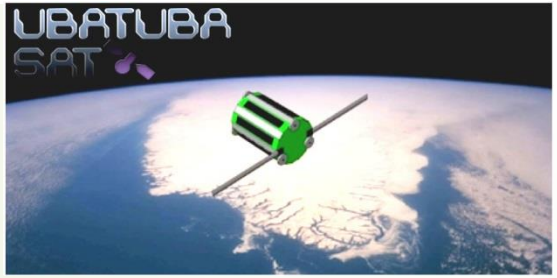
VS

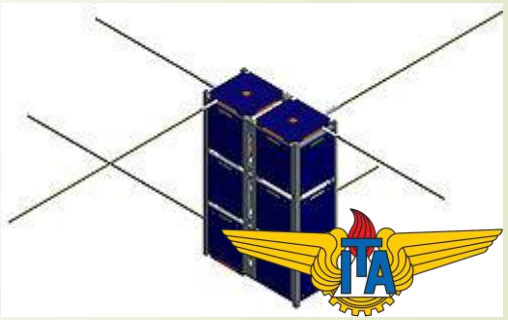
Failure Rates from traditional satellite developers around 10%.



Introduction

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

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

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

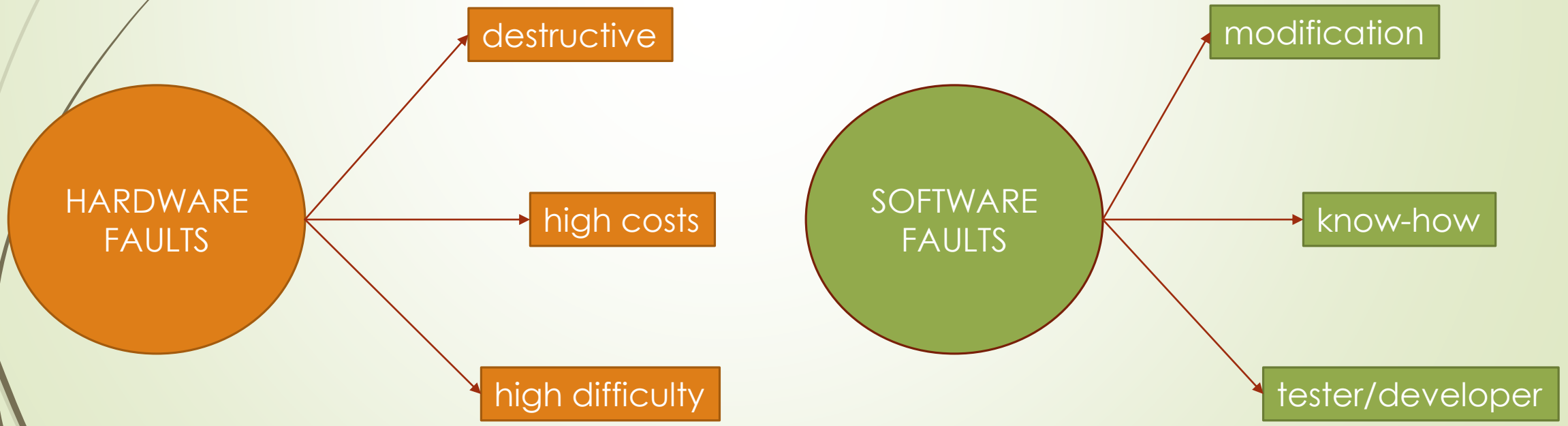
The batteries get too cold and stop working properly. System's Failure.

Adapted from Avizienis et al.,2004

Concepts

FAULT INJECTION

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

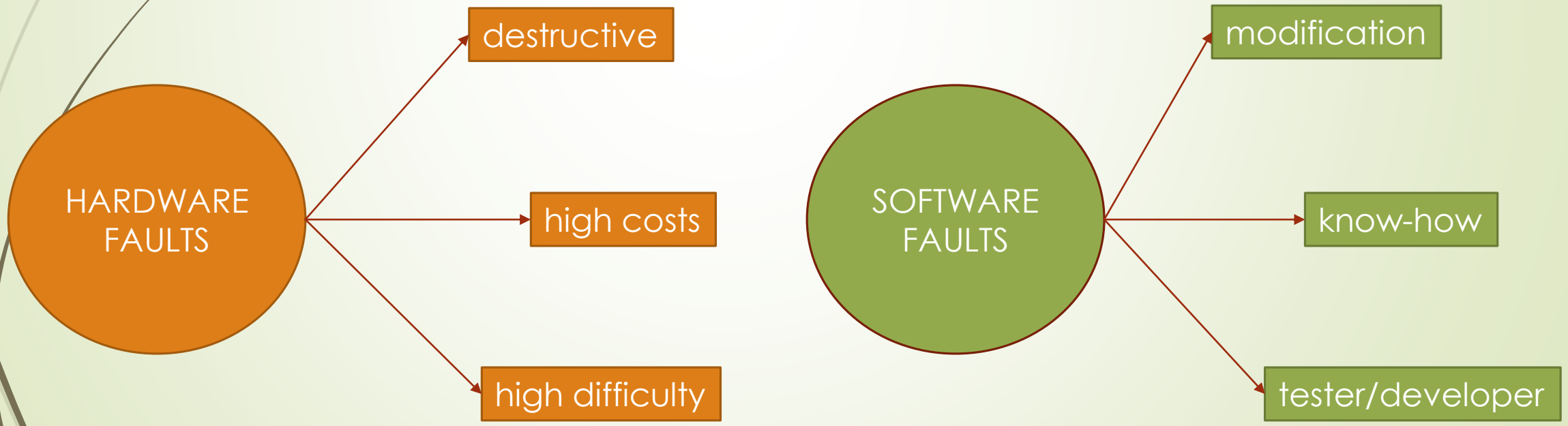


Concepts

FAULT INJECTION

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

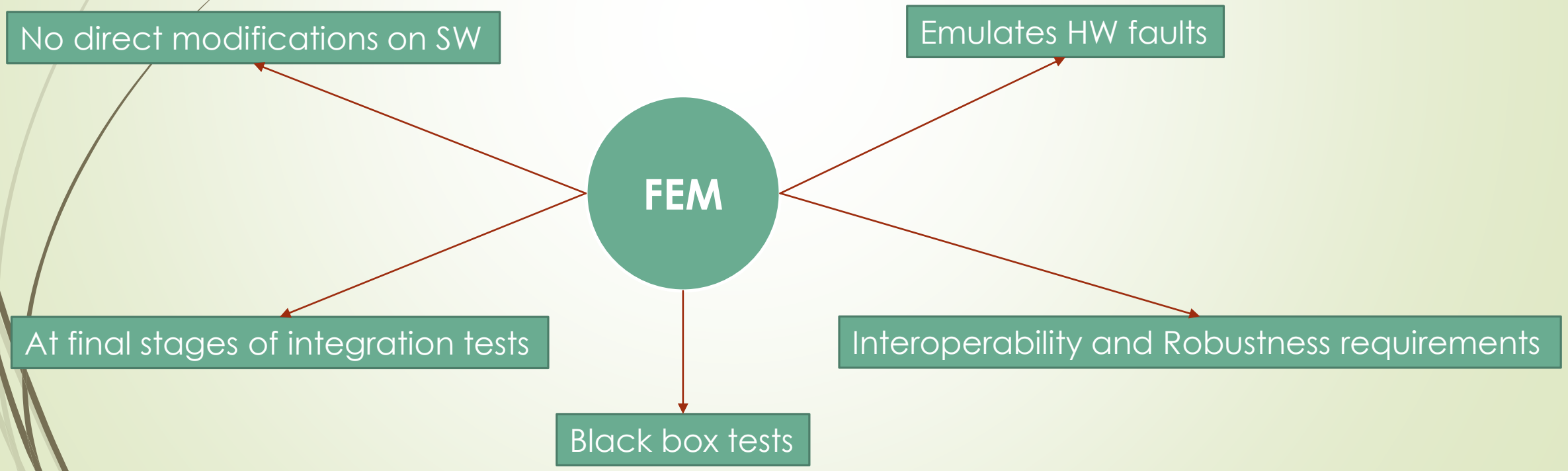
How to embarrass the developing team?



Concepts

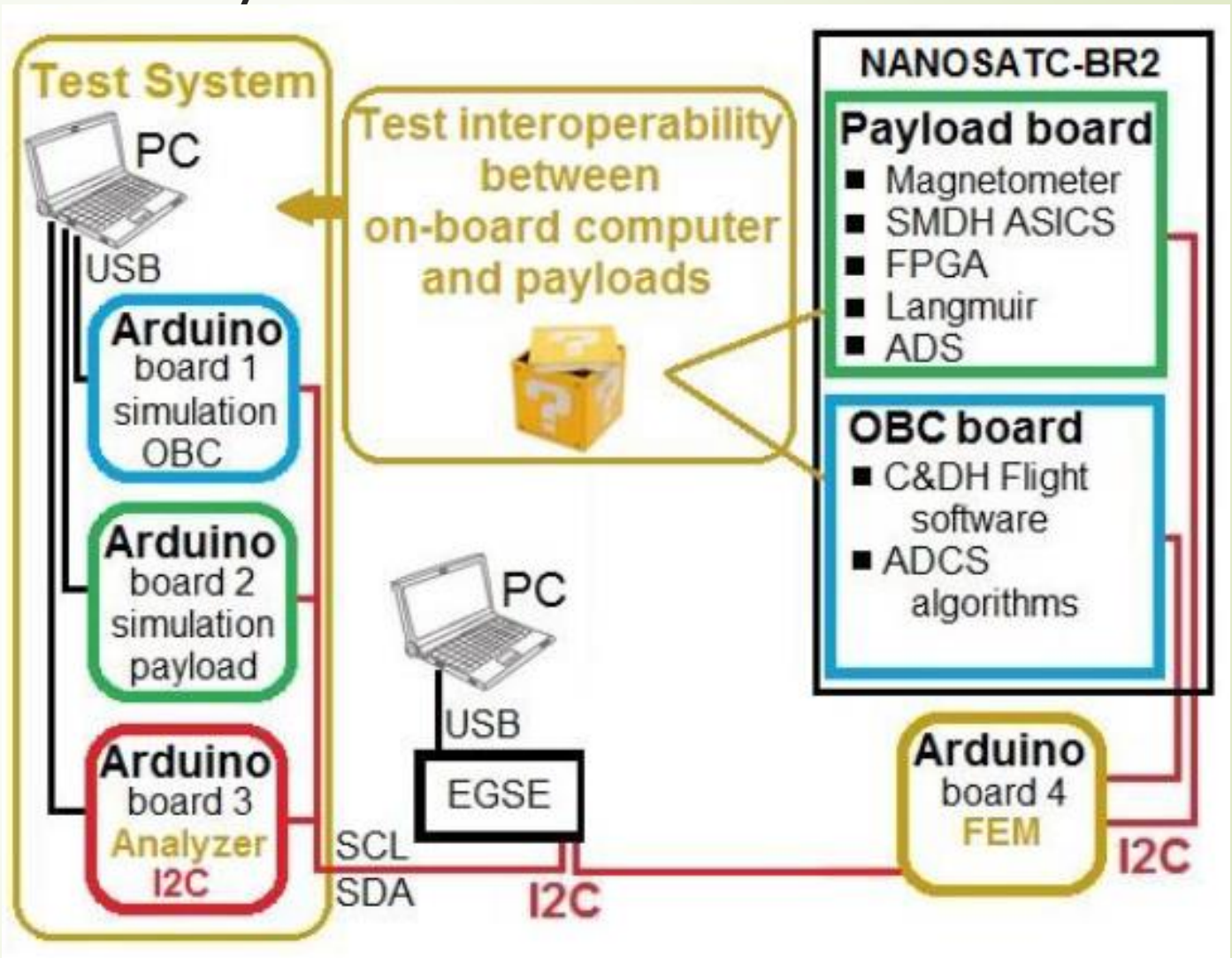
FAILURE EMULATOR MECHANISM

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



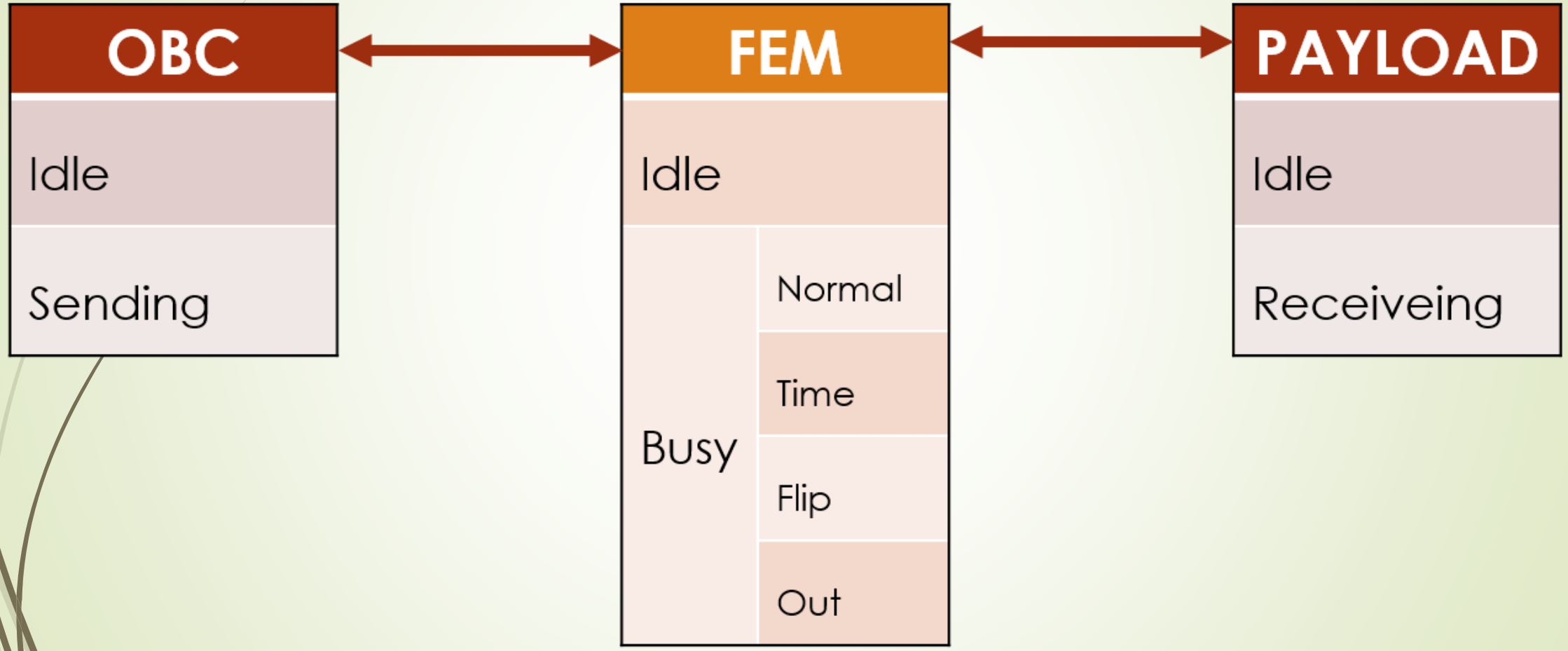
Proposed Test System

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

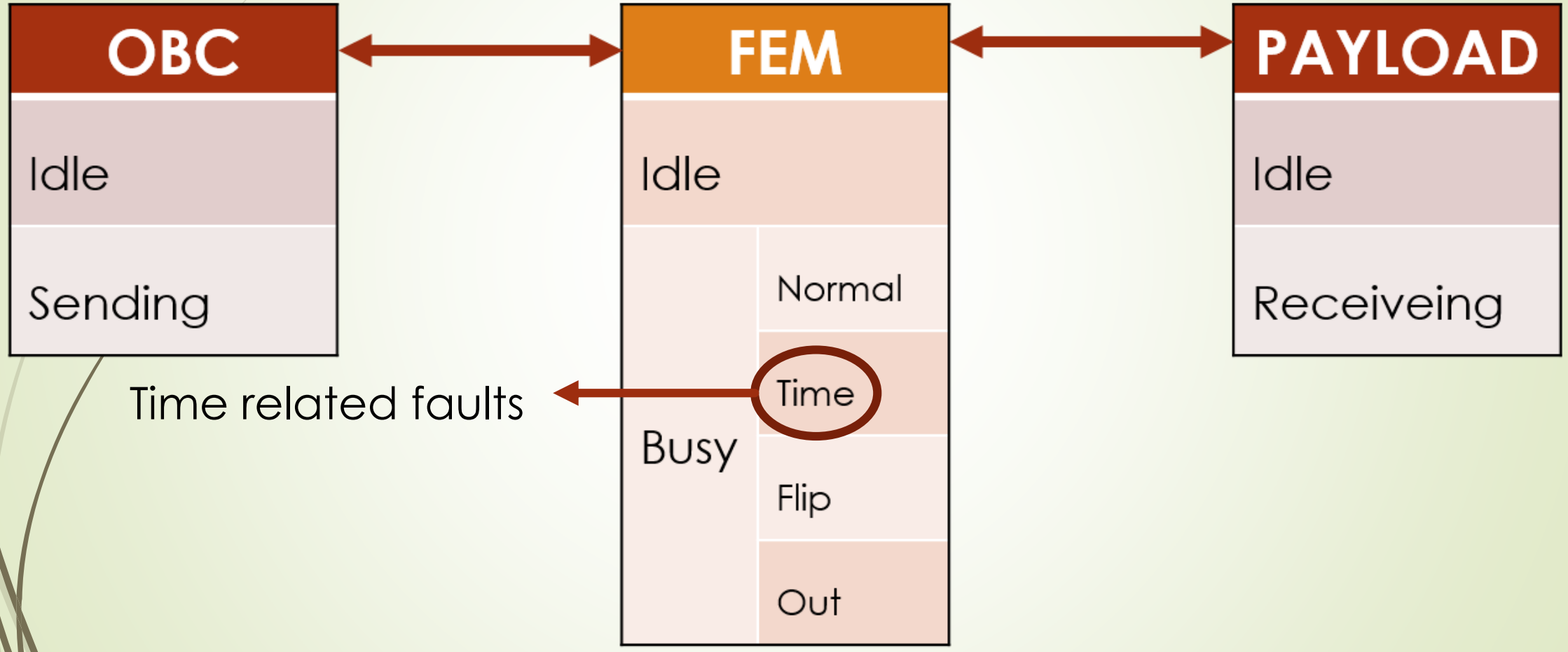


C. A. Conceicao, F. Mattiello-Francisco, and C. L. Batista, "Dependability verification of nanosatellite embedded software supported by a reusable test system," in Dependable Computing (LADC), 2016 Seventh Latin-American Symposium on. IEEE, 2016, pp. 157–163.

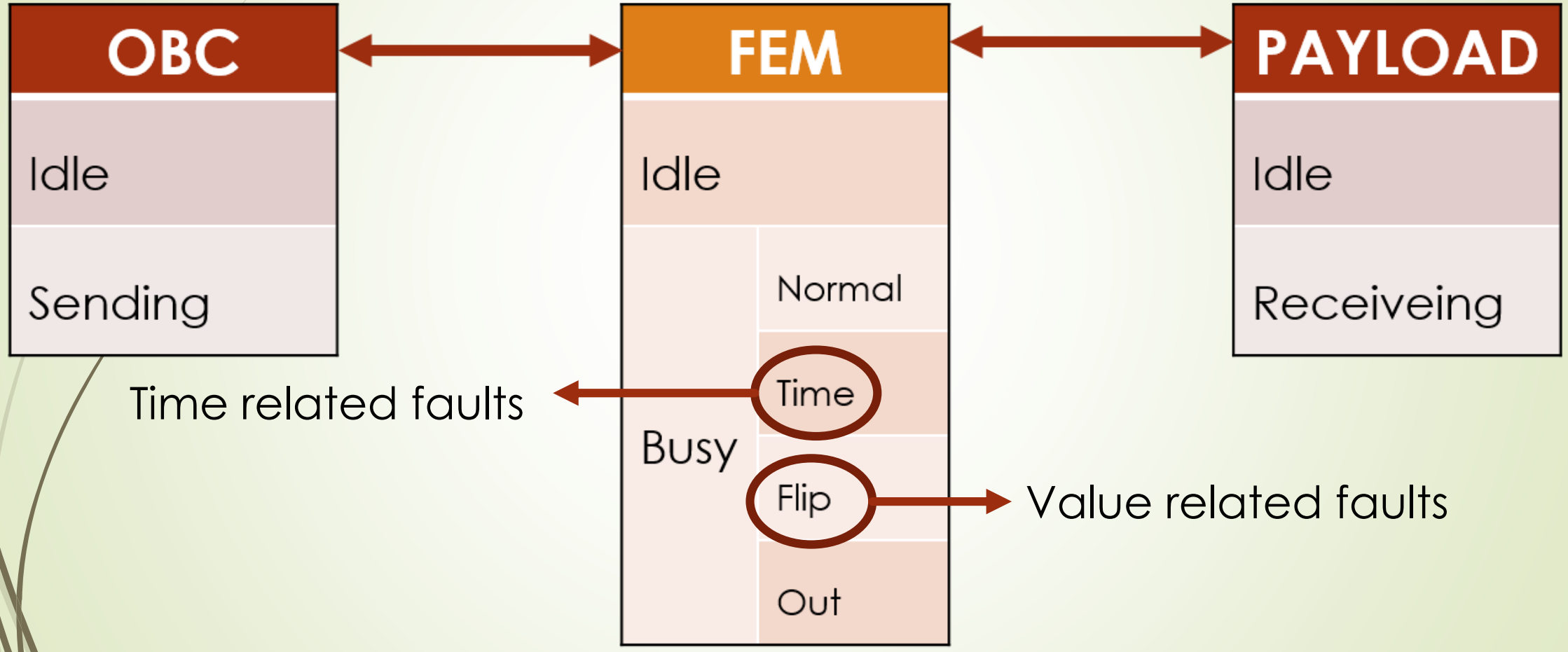
Development: Model



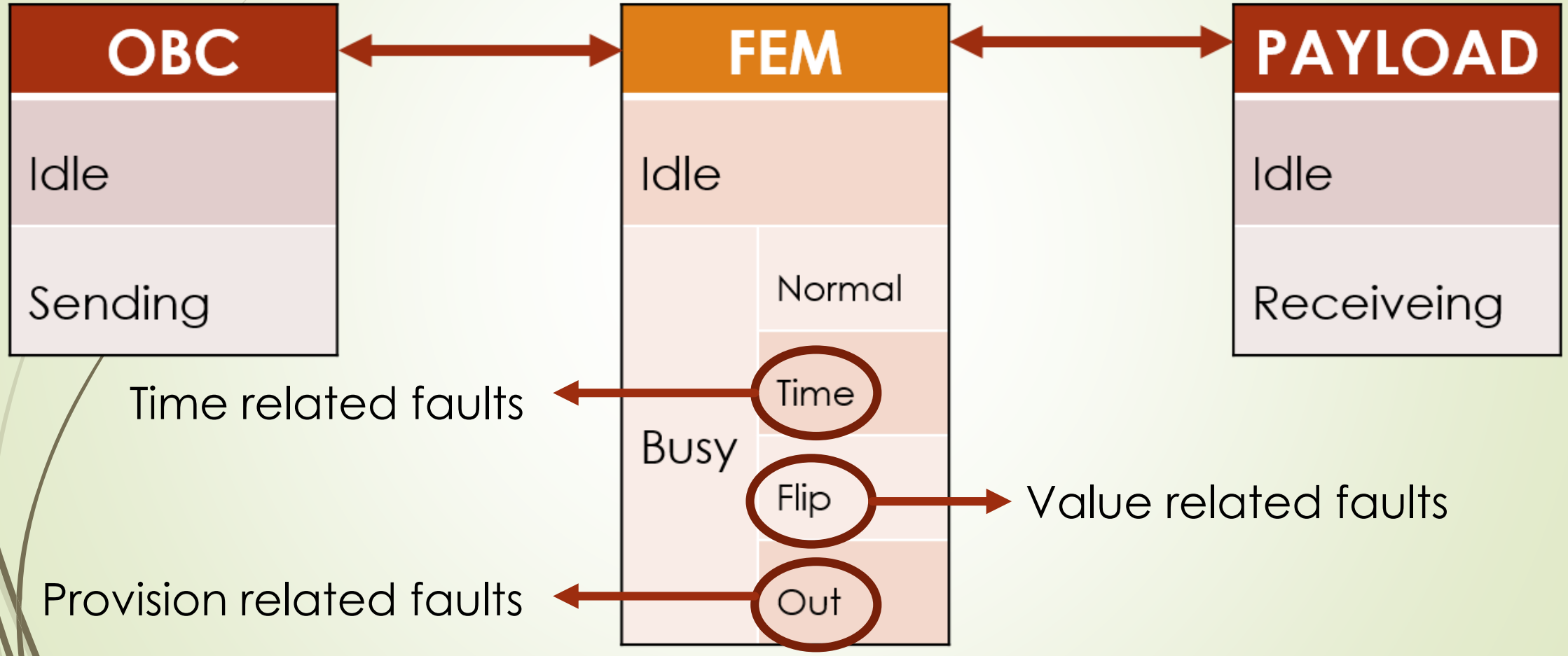
Development : Model



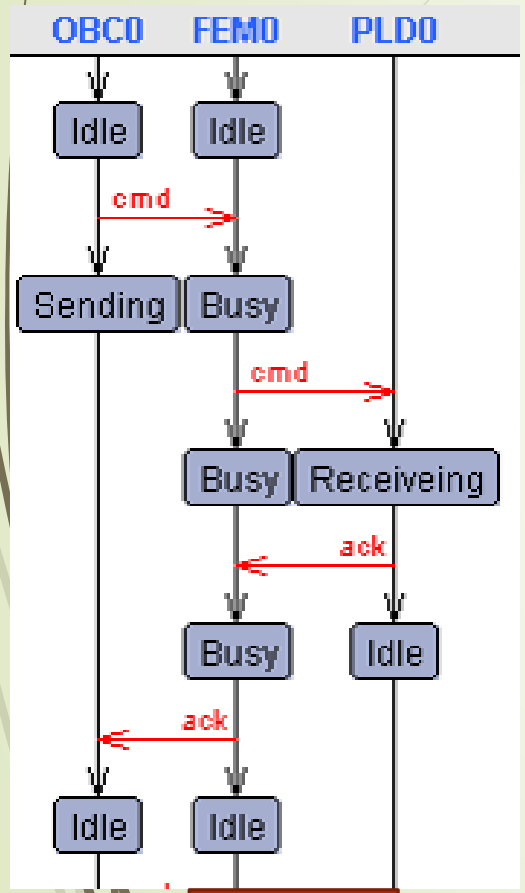
Development : Model



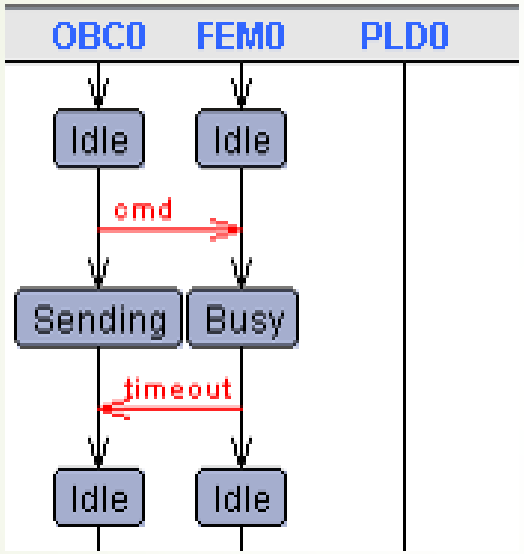
Development : Model



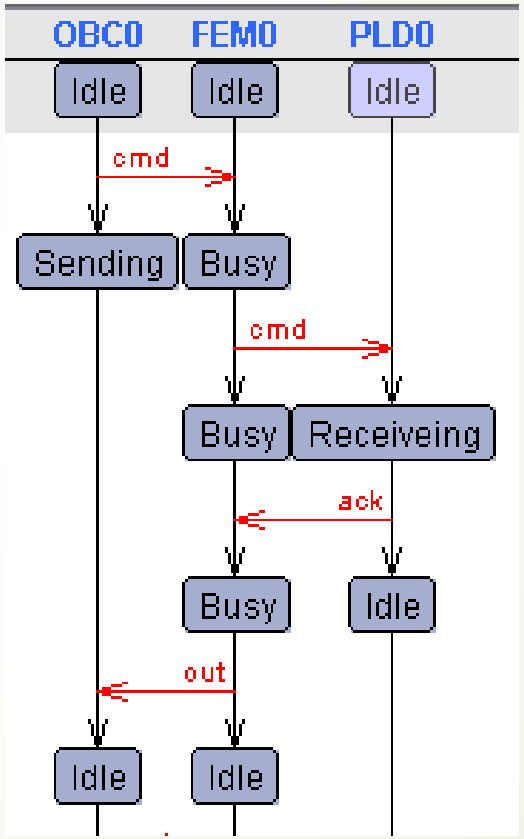
Development : Model



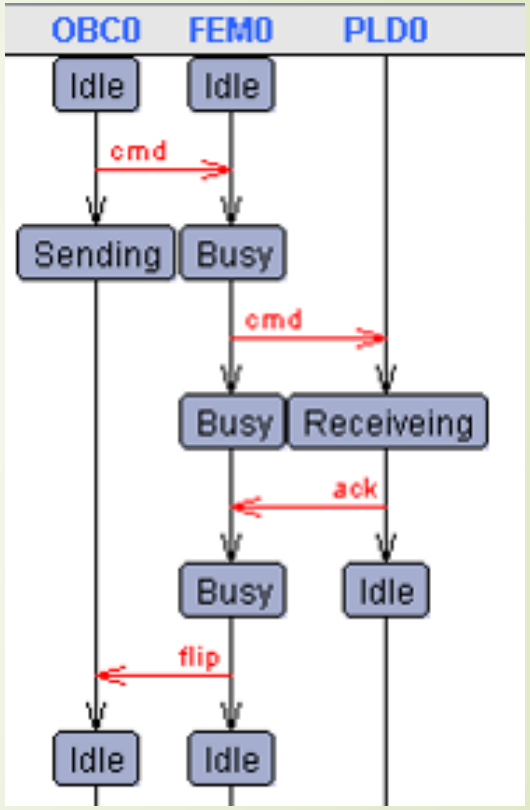
Normal



Timeout

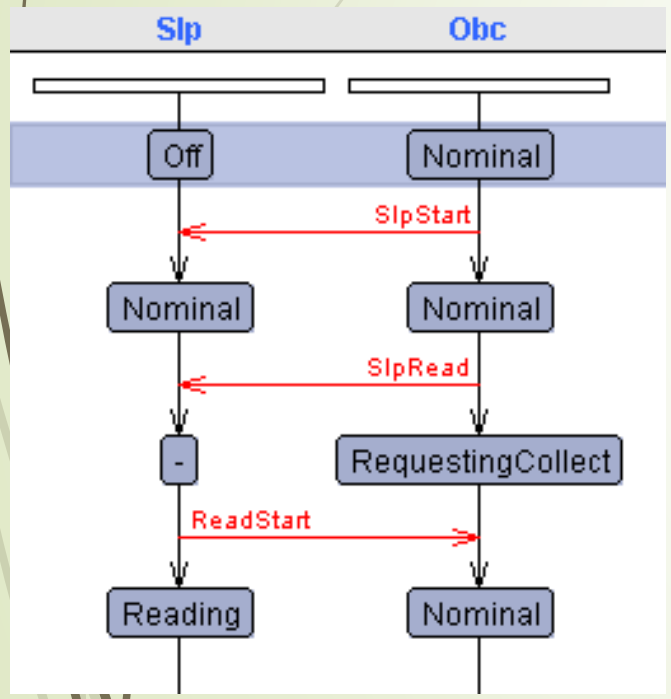


Out of Range

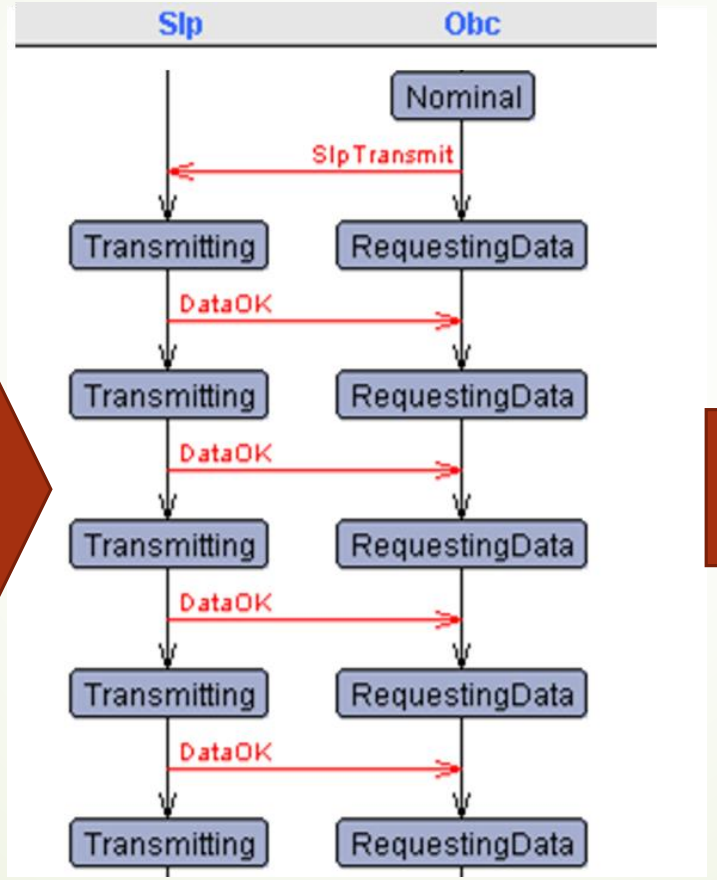


Bit-Flip

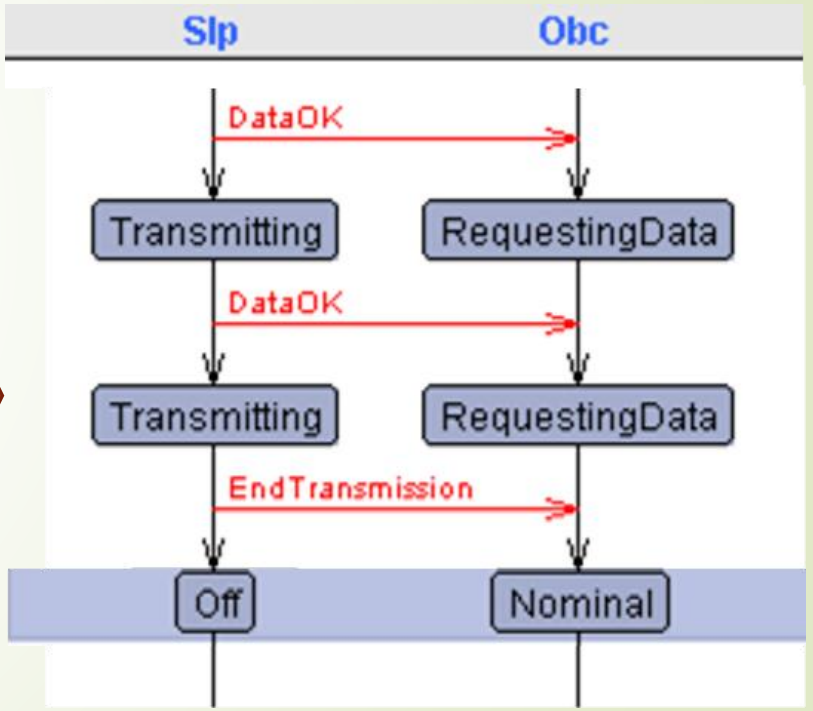
Development : Model



OBC cmd SLP Start

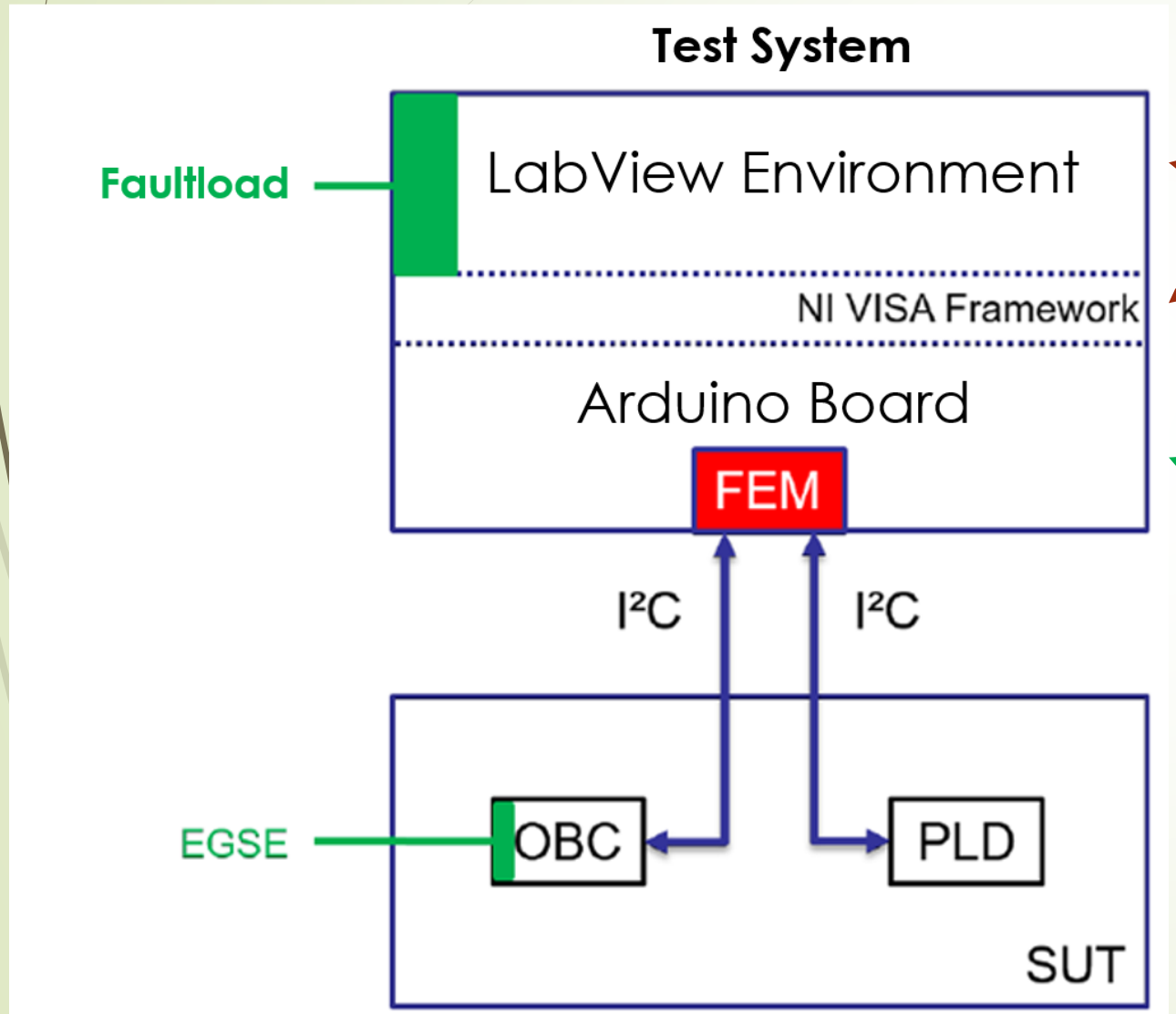


OBC request data



SLP end transmission

Development: Architecture



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
Receiveing...       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
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
Cammands

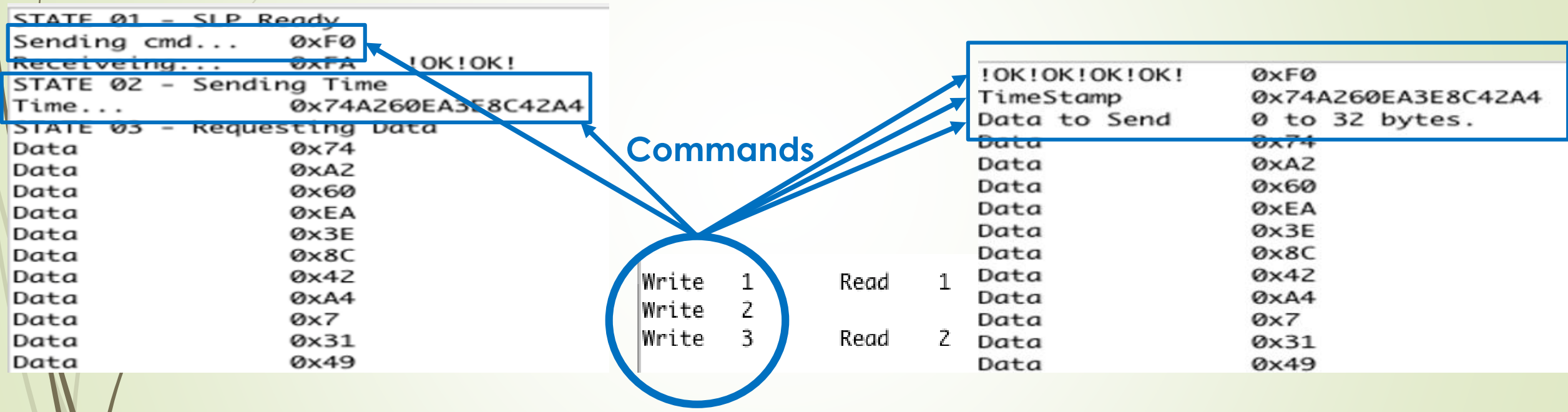
FEM Serial Monitor
Busy Mode
Normal Activ
Monitoring

SLP Serial Monitor
Received
Confirmation
Data

First Results

MASTER

SLAVE



OBC Serial Monitor
States
Requests
Cammands

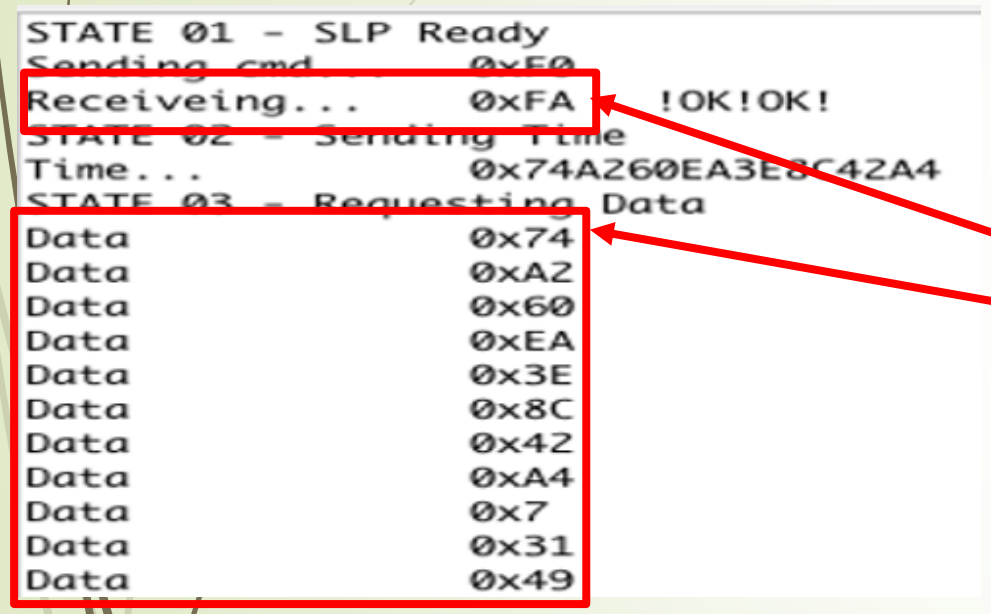
FEM Serial Monitor
Busy Mode
Normal Activ
Monitoring

SLP Serial Monitor
Received
Confirmation
Data

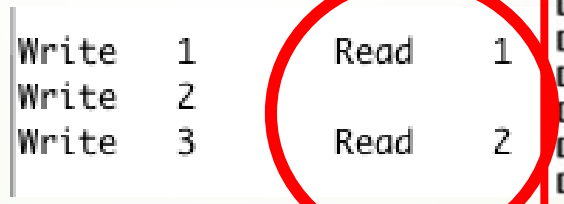
First Results

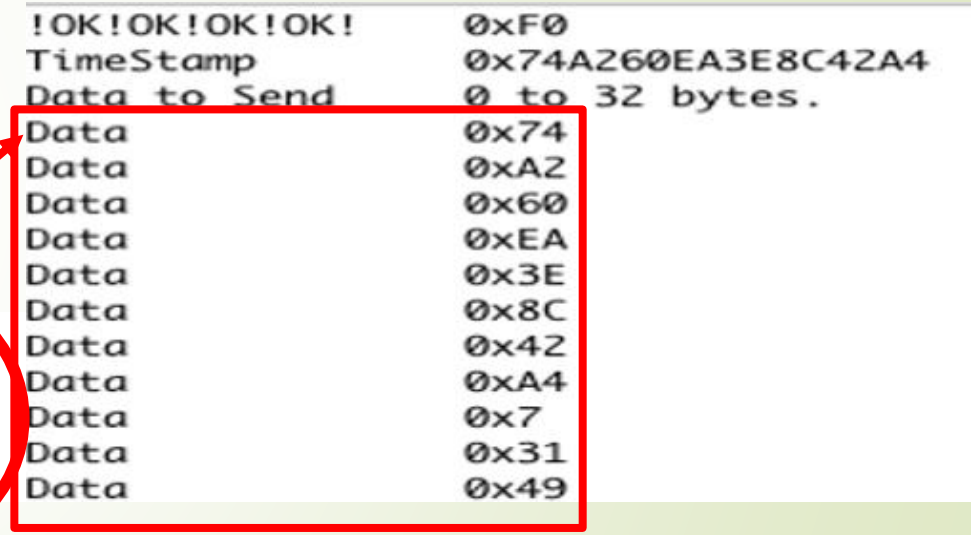
OBC (master)

SLP (slave)



Requests





OBC Serial Monitor
States
Requests
Cammands

FEM Serial Monitor
Busy Mode
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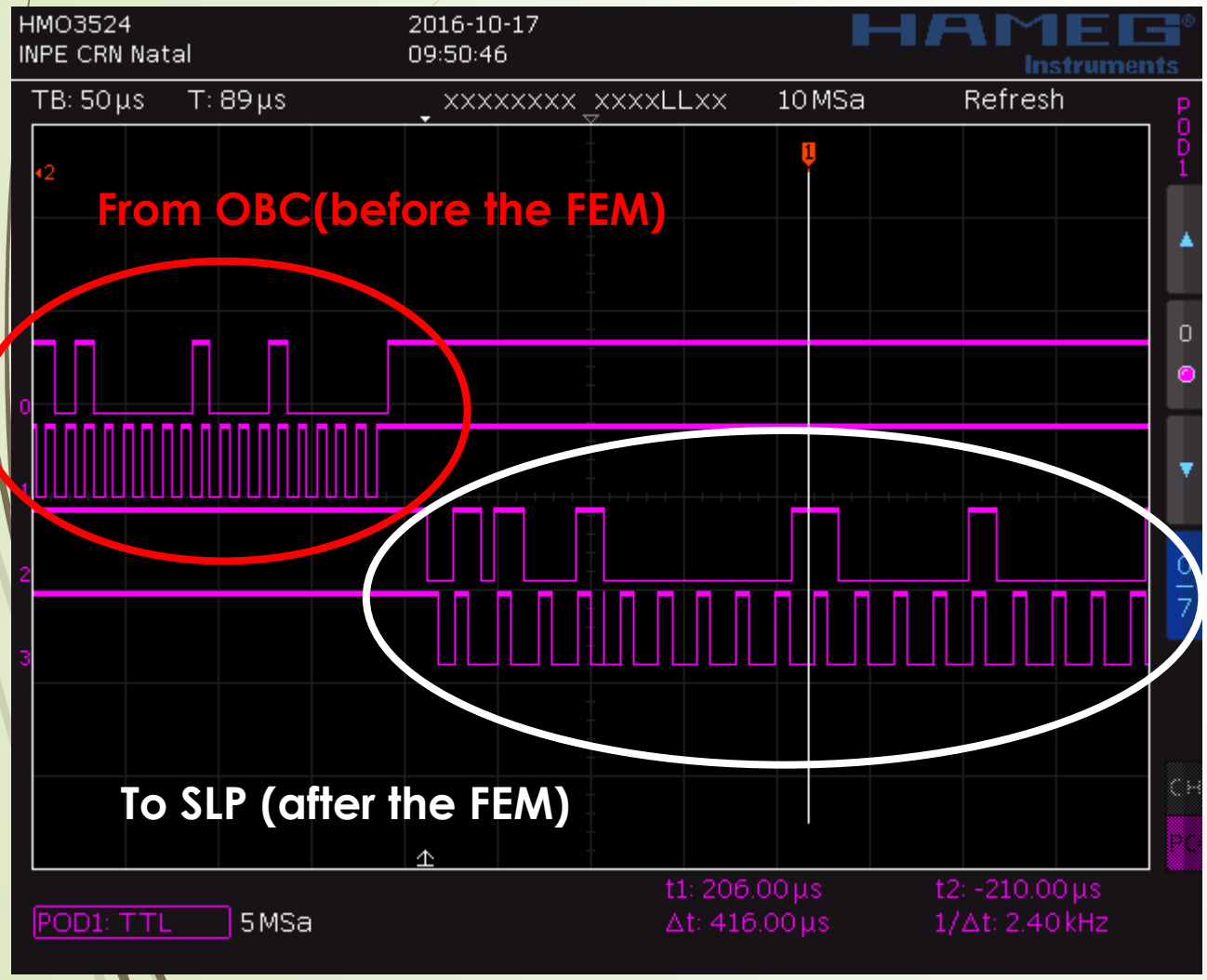
SLP Serial Monitor
Received
Confirmation
Data

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

LabV&Vsis

Thank you!

Questions ?

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