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THE MODEL-DRIVEN DEVELOPMENT APPROACH & FORMAL SPECIFICATION FOR AIR-TRAFFIC CONTROL SYSTEM OPERATIONS: PRACTICAL COMMENTS AND CASE STUDIES

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Agenda

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- Motivation
- Introduction - Models
- BridgePoint - xtUML
- Formal Verification – FDR3 & AutoFocus3
- MDD Issues
- Conclusion

Motivation

Corporations want systems that work!

... as fast as possible,

as cheap as possible and

as easy to change as possible...

System development is difficult!

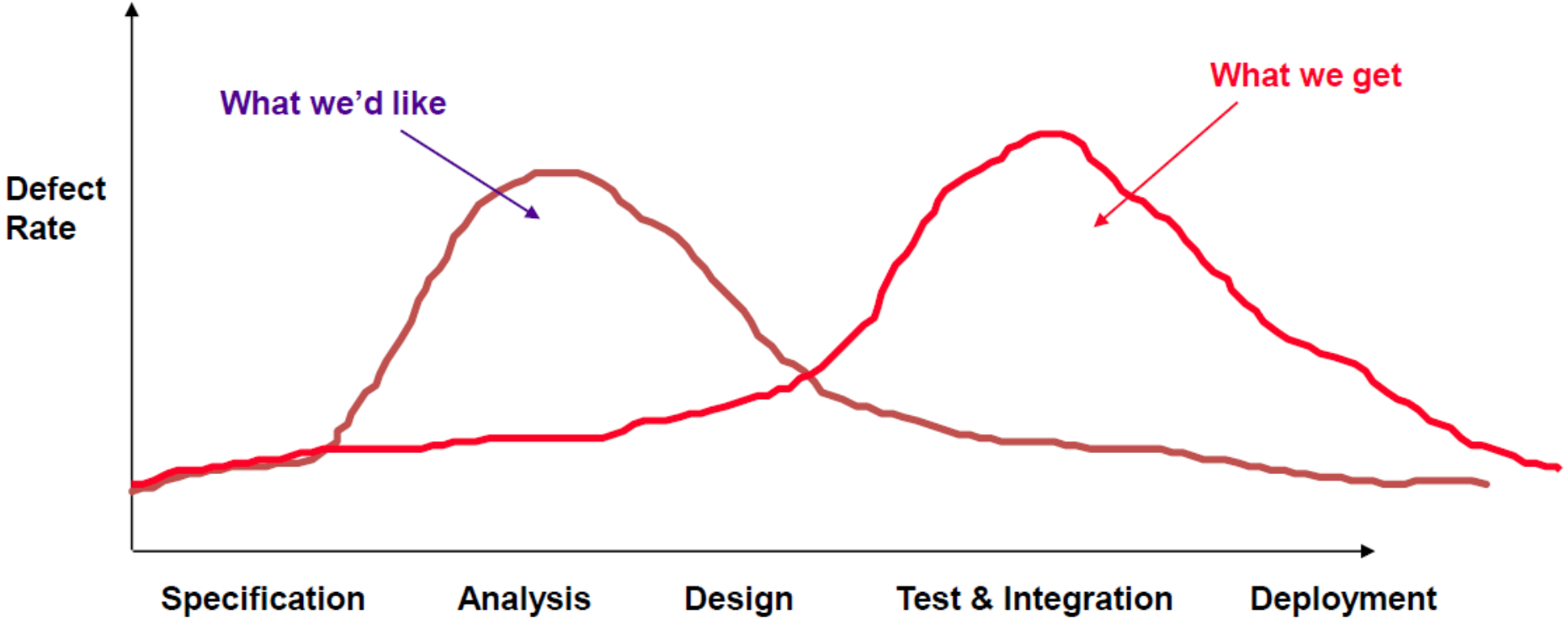
- take overlapping and conflicting requirements
- invention of good abstractions from those requirements
- fabrication of an efficient, cost-effective implementation
- clever solutions
- succesful conclusion at the lowest possible cost in time and money

(Balcer & Mellor, 2002)

Cost of fixing the defect	**Detection of defects**				
Introduction of defects	Requirements	Architecture	Construction	System Test	Post-Release
Requirements	1x	3x	5-10x	10x	10-100x
Architecture	-	1x	10x	15x	25-100x
Construction	-	-	1x	10x	10-25x

(MCCONNELL, 2004) *Code Complete: A Practical Handbook of Software Construction.*

- Systems are difficult to test—and it occurs too late.
  - Wasted effort in constructing wrong code
  - Late discovery of problems and delayed delivery



Motivation

“The lack of an integrated view often forces developers to implement suboptimal solutions.” *– Douglas C. Schmidt (2006)*

“***Model to have a conversation***.” **–** Craig Larman and Bas Vodde

Motivation

"***The sciences do not try to explain, they hardly even try to interpret, they mainly make models***. *... The* ***justification of such a mathematical construct is*** *solely and precisely* ***that it is expected to work***."
— John von Neumann

Motivation

Air Transportation domain:

- **Software** intensive
- Computationally **distributed**
- Great **complexity**
- Represents great potencial for **accidents**

Safety-critical systems

Intro – *From Document-centric to Model-centric*

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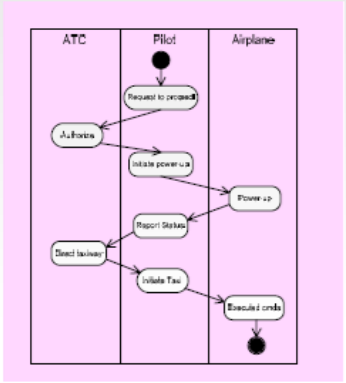
Past

- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

Future



*"The underlying motivation for MDD is to **improve productivity."** –* Atkinson (2003)

Models

"*Separate those things that change from those things that do not*" – IBM-Rational Software Group (2008)

- Things that change rapidly:

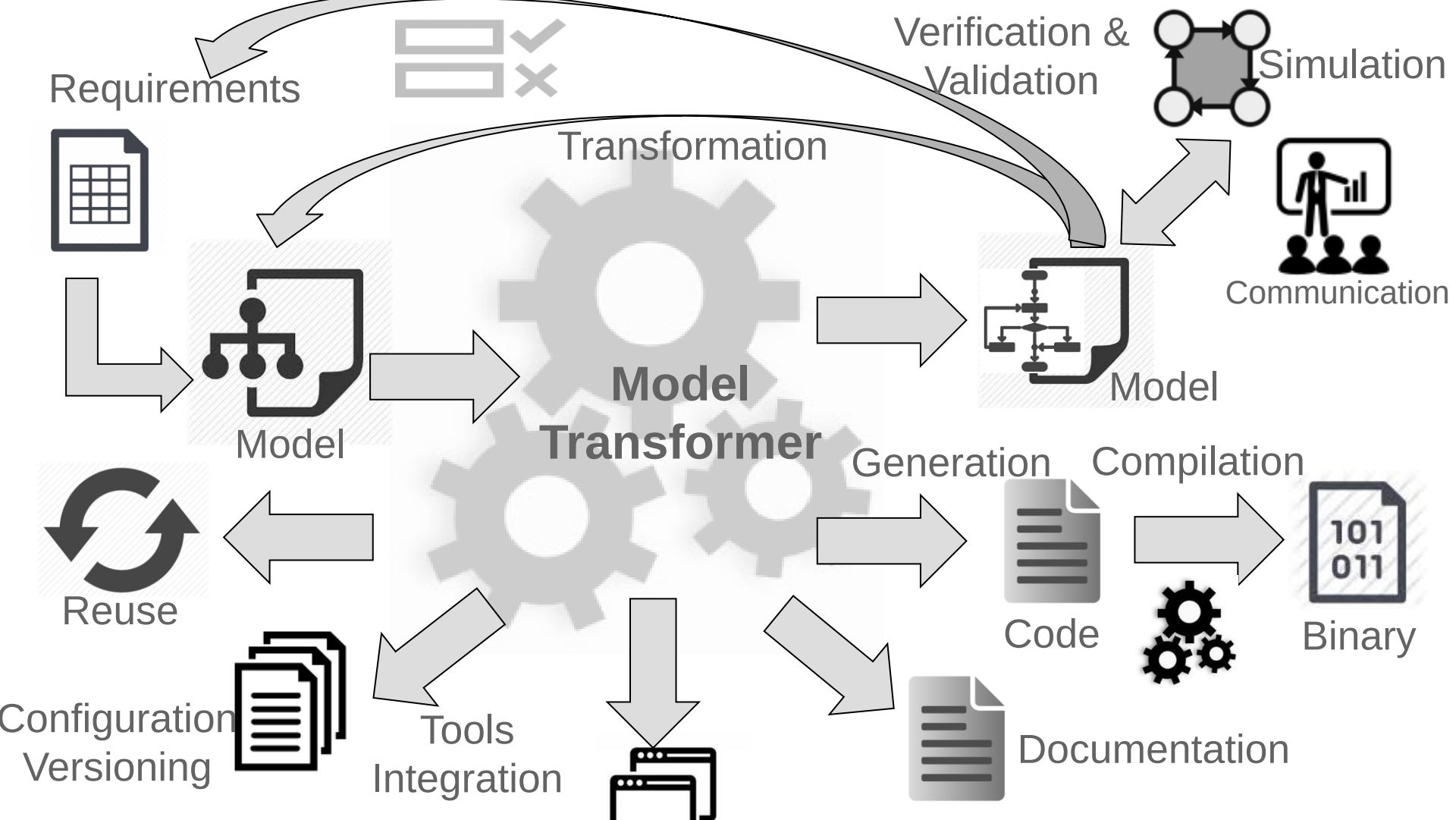
  Technology, Hardware Platforms, Sensor Technology,
  Operating environments, Connectivity

- Things that do not:

  Problem Domain semantics,
  Relations among domain concepts

"Free architecture from implementation details – conceptual architecture and technology decisions are decoupled, making both easier to evolve"

(Volter, 2010)


Requirements
Verification &
Validation
Simulation
Transformation
Communication
Model
Model
Transformer
Model
Generation
Compilation
Reuse
Code
Binary
101
011
Configuration
Versioning
Tools
Integration
Documentation

Mentor Graphic's BridgePoint
(ver.4.1.8Demo)

It is a composition of...

- Open-source UML model editor
  - xtUML Modeling Language (UML profile)
- a verifier (providing simulated execution capability)
  - Model debug
  - Animated features during model execution (simulation)

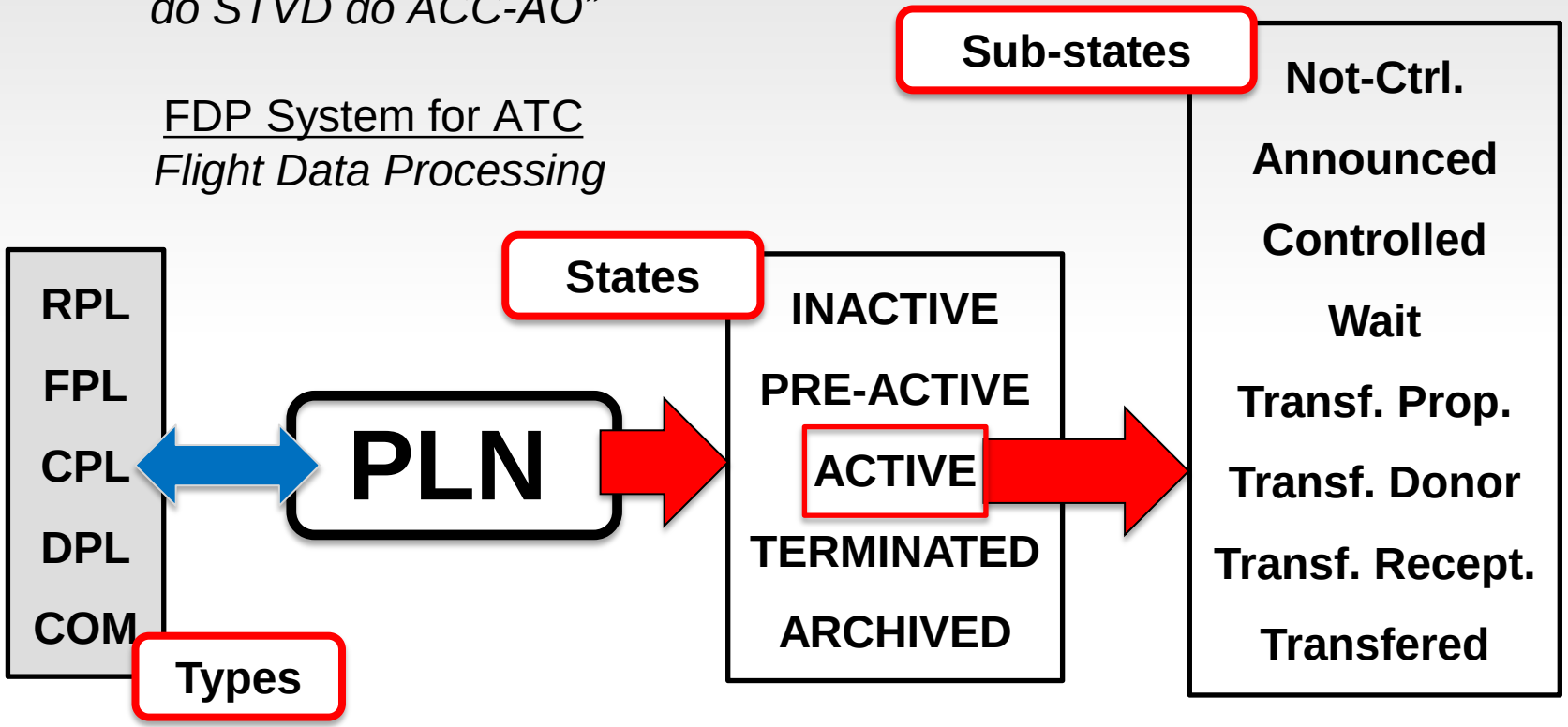
    providing early model verification
  - allows integration with external code
- set of model compilers (providing translation)

Code generation functionality into C, C++, System C, Java

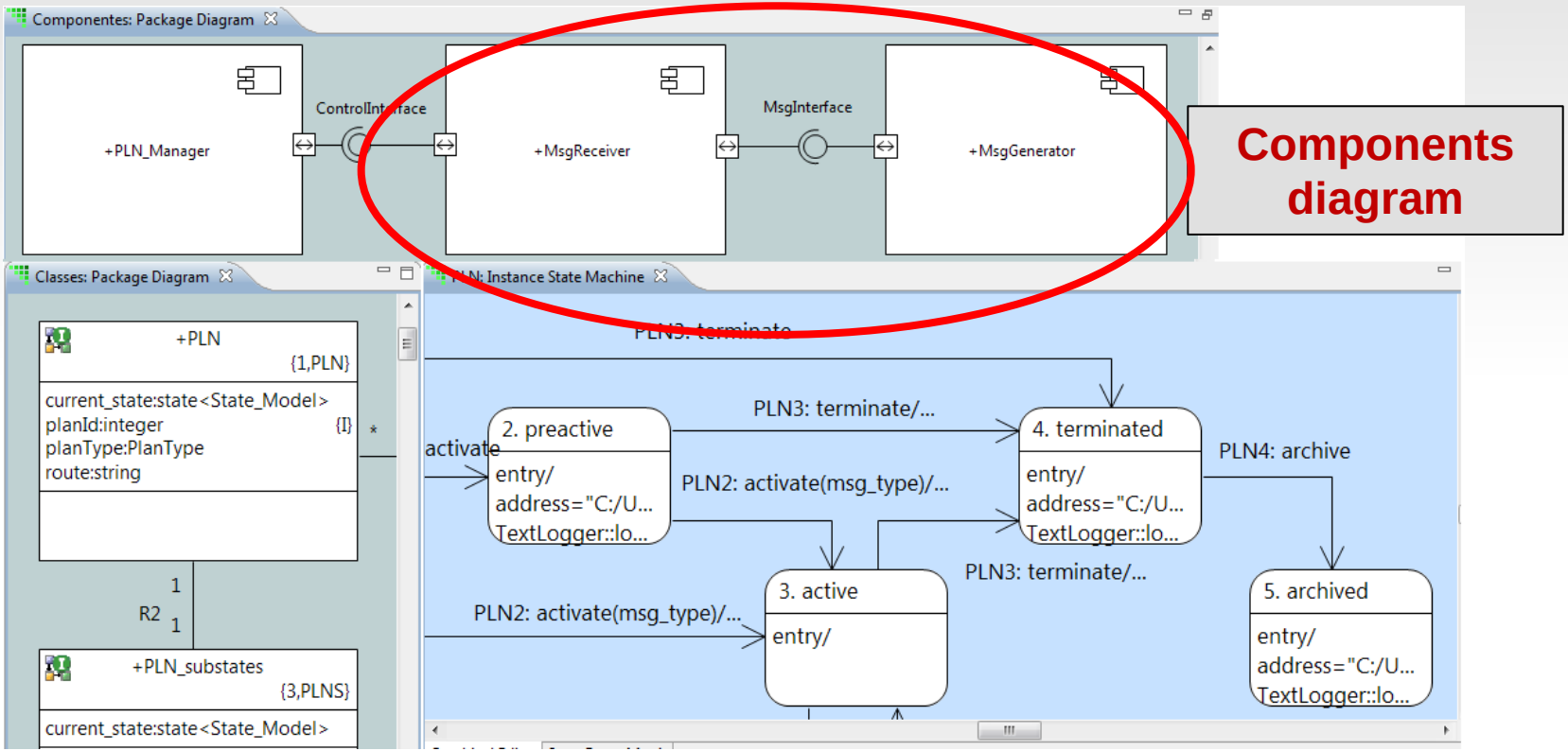
Mentor Graphics®

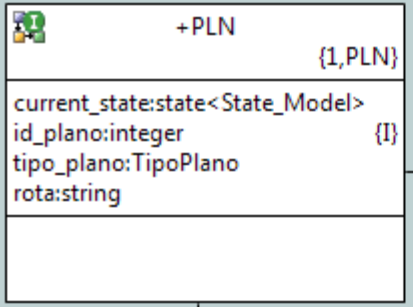
“*Especificação de Requisitos de Sistema do STVD do ACC-AO*”

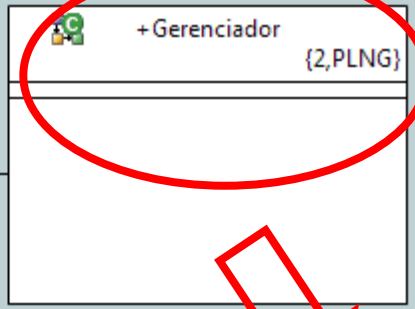
FDP System for ATC
Flight Data Processing



Modeling Tools - BridgePoint

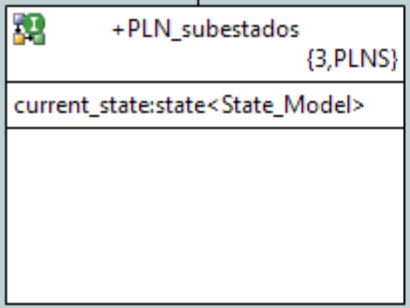




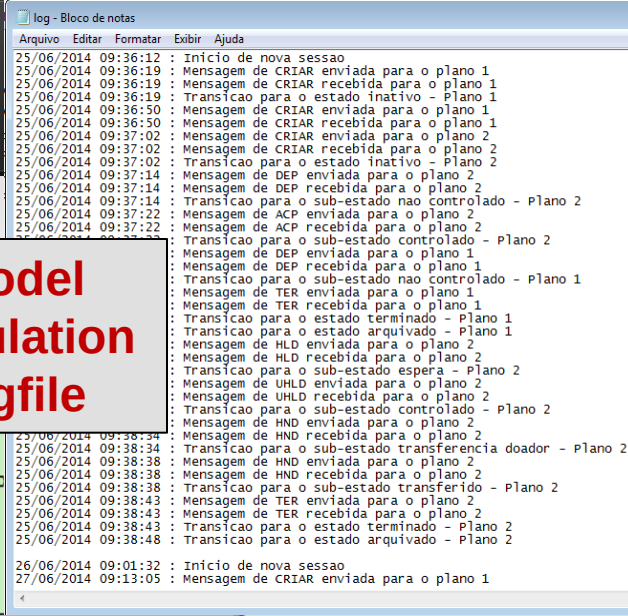


R1 * 1

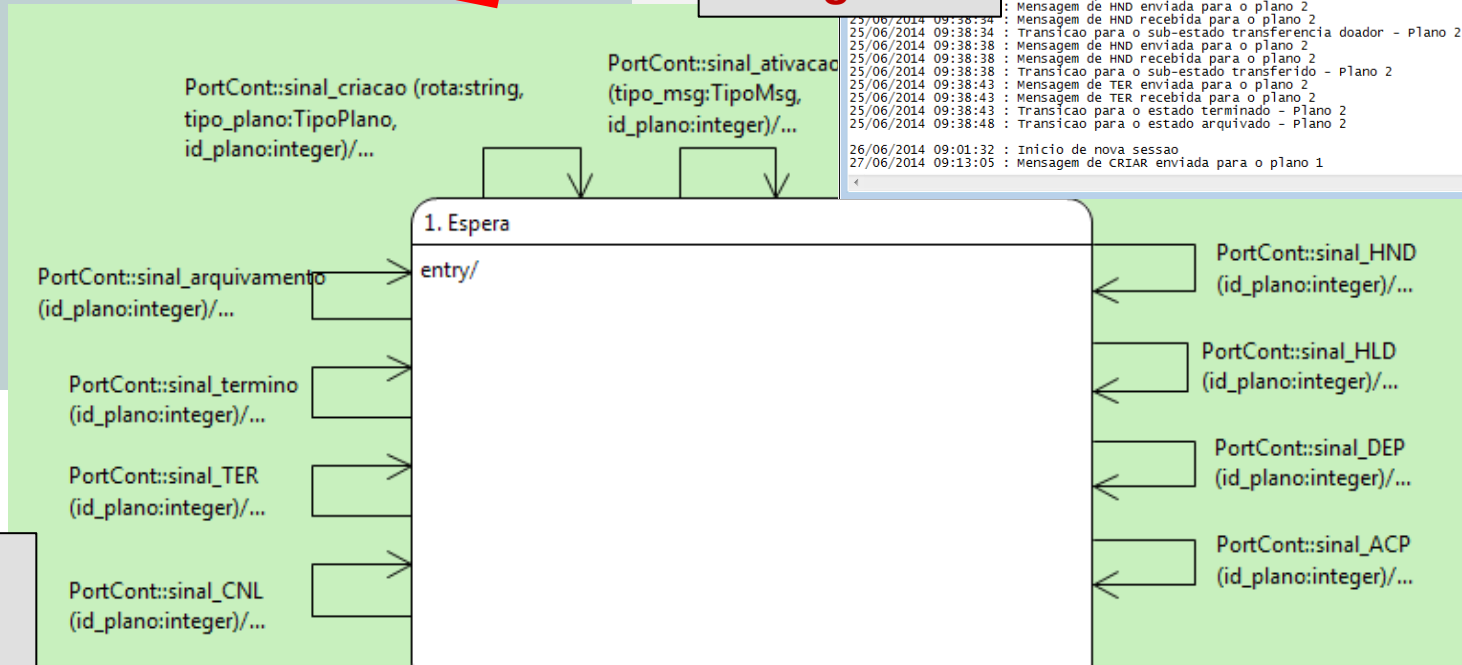
R2 1 1



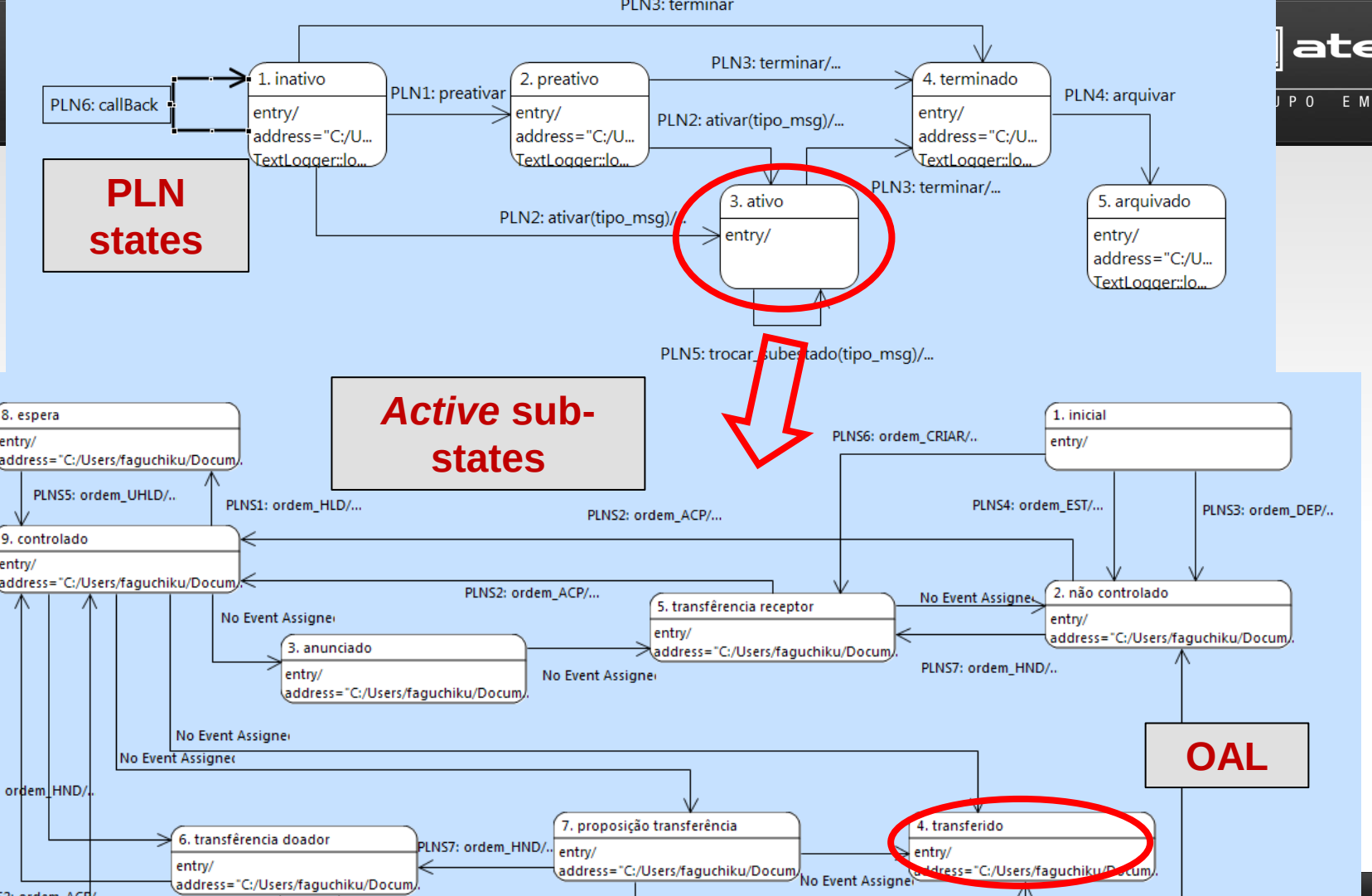
Class diagram



Model simulation logfile



Gerenciador **State-Machine**


PLN3: terminar
PLN6: callBack
1. inativo
entry/
address="C:/U...
TextLogger::lo...
PLN1: preativar
2. preativo
entry/
address="C:/U...
TextLogger::lo...
PLN3: terminar/...
4. terminado
entry/
address="C:/U...
TextLogger::lo...
PLN4: arquivar
PLN2: ativar(tipo_msg)/...
PLN3: terminar/...
PLN2: ativar(tipo_msg)/...
3. ativo
entry/
5. arquivado
entry/
address="C:/U...
TextLogger::lo...
PLN5: trocar_substado(tipo_msg)/...
PLN states
Active sub-states
8. espera
entry/
address="C:/Users/faguchiku/Docum...
PLNS5: ordem_UHLD/..
PLNS1: ordem_HLD/...
PLNS2: ordem_ACP/...
PLNS6: ordem_CRIAR/..
1. inicial
entry/
PLNS4: ordem_EST/...
PLNS3: ordem_DEP/..
9. controlado
entry/
address="C:/Users/faguchiku/Docum...
PLNS2: ordem_ACP/...
No Event Assigne
5. transferência receptor
entry/
address="C:/Users/faguchiku/Docum...
No Event Assigne
2. não controlado
entry/
address="C:/Users/faguchiku/Docum...
3. anunciado
entry/
address="C:/Users/faguchiku/Docum...
No Event Assigne
PLNS7: ordem_HND/..
No Event Assigne
No Event Assigne
OAL
PLNS7: ordem_HND/..
6. transferência doador
entry/
address="C:/Users/faguchiku/Docum...
PLNS7: ordem_HND/..
7. proposição transferência
entry/
address="C:/Users/faguchiku/Docum...
4. transferido
entry/
No Event Assigne

BridgePoint – *The benchmark problem*

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Achievements:

- Data structure was devised to emulate many instances of flights
- Verifier functionality tested (*Model Debbuger*)
- Testing: automatic and man-in-the-loop
- Logging Interface (Java *External Entities*)
- User Interface (Java *Realized Component*)
- Code Generation (compiled & tested)

Formal Specification

Specification of a system properties, using a language defined by mathematical logic

- Improve system reliability
- Based on:
  - process algebra,
  - first order logic,
  - temporal logic,
  - set theory...
- Each language represents a view of the system – languages are complementary
- Formal Verification

Formal Verification

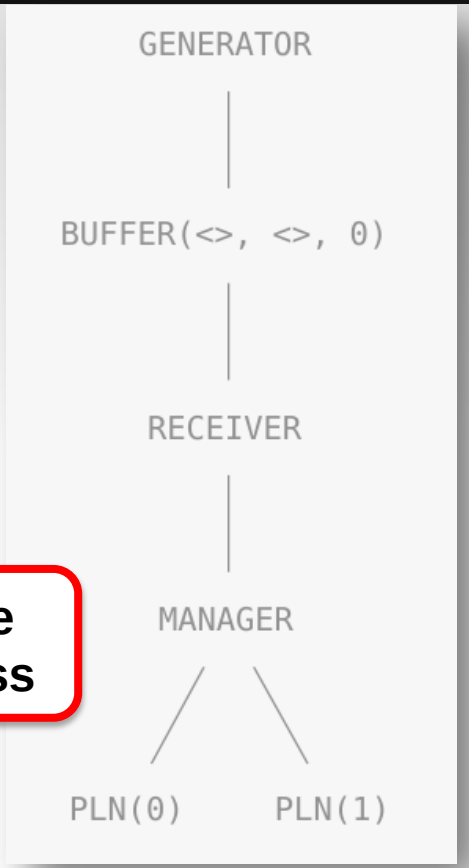
Communicating Sequential Process (CSP) – process algebra:
Description of programs or processes that communicate events, from a set, within an environment

FDR3 - Failures Divergence Refinement (a refinement checker)

Constructing equivalent refinement checks (models)
- traces
- failures
- failures-divergences

Properties
- **deadlock-freedom**
- livelock-freedom
- Determinism

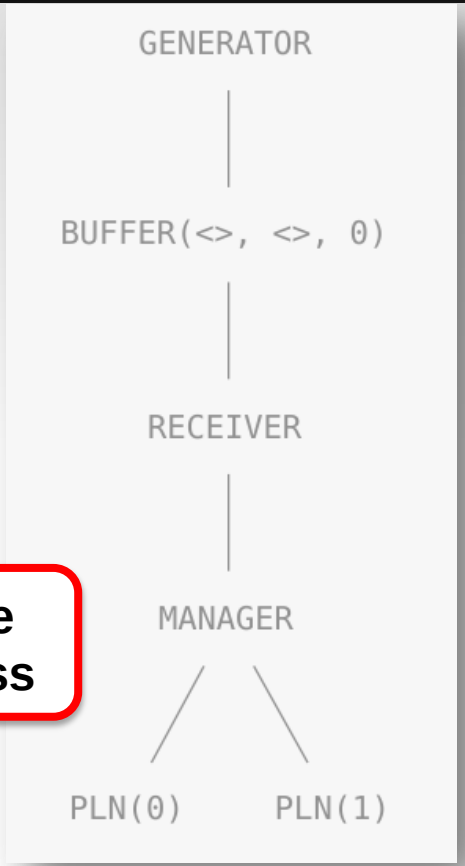
Single Process



Formal Verification

State Explosion Problem:

- Two Flight Plan processes;
- Three Buffer messages;



Single Process

Formal Verification

AutoFocus3

Funcionality:

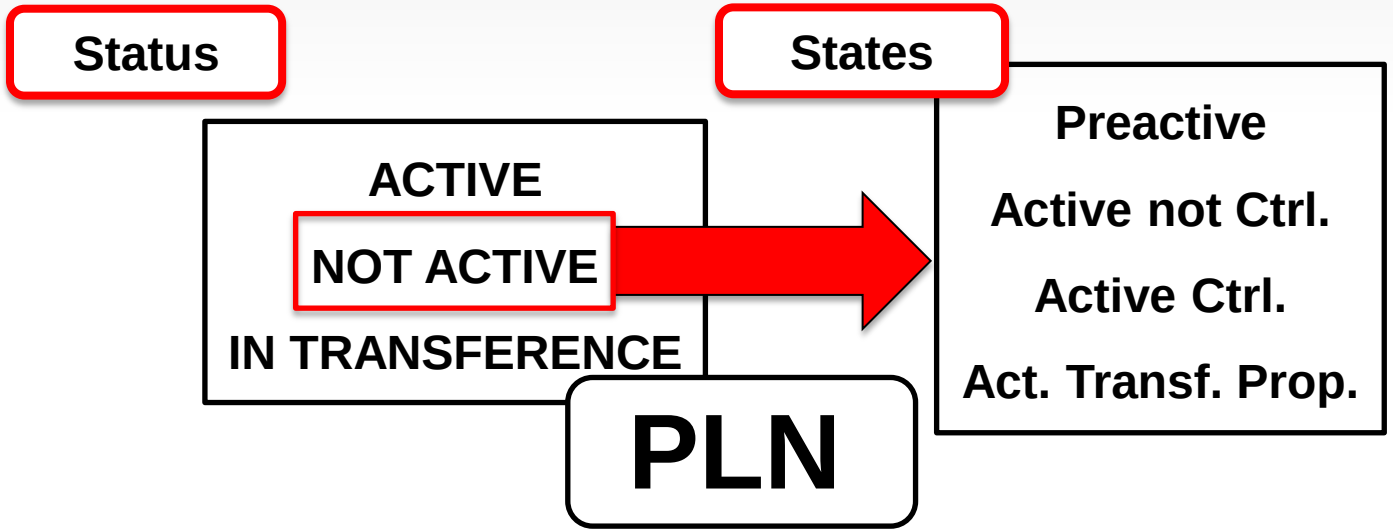
- Requirements Engineering
- Modeling and Simulation
- Code Generation
- Deployment
- Testing
- Formal Verification – NuSMV
    - Model Checking CTL/LTL property

Case Study

FDP System for ATC

Flight Data Processing

- Transferal of a flight plan from one ATC to another

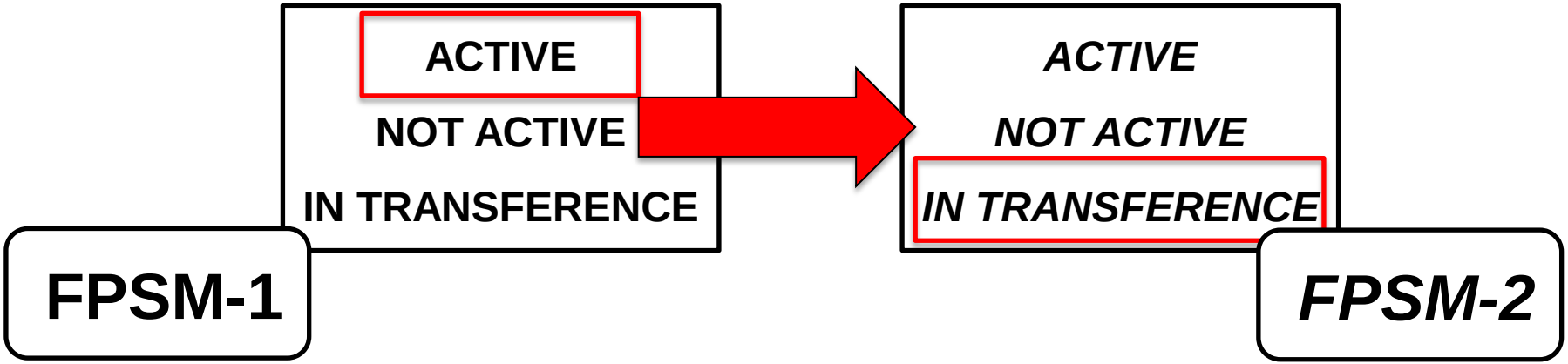


Case Study

FDP System for ATC

Flight Data Processing

- Safety properties:
  - Active x *Active*
  - Active - *In Transference* to Not Active – *Active*



Formal Verification

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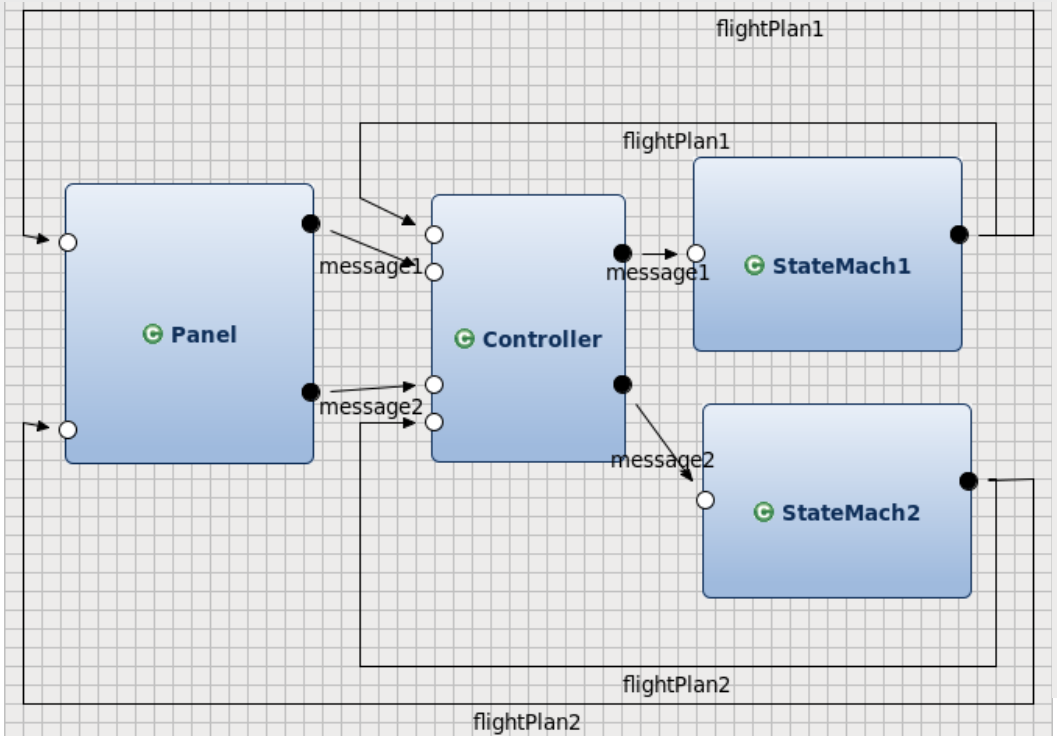
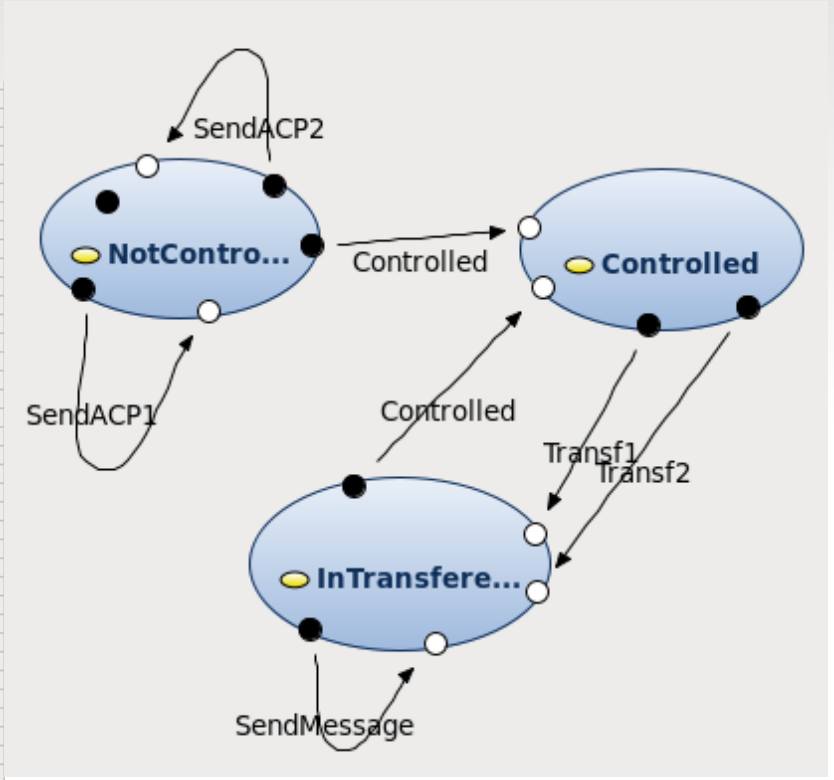
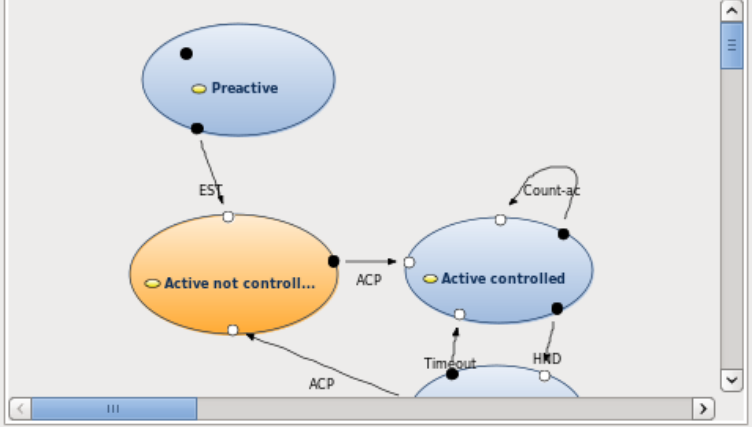
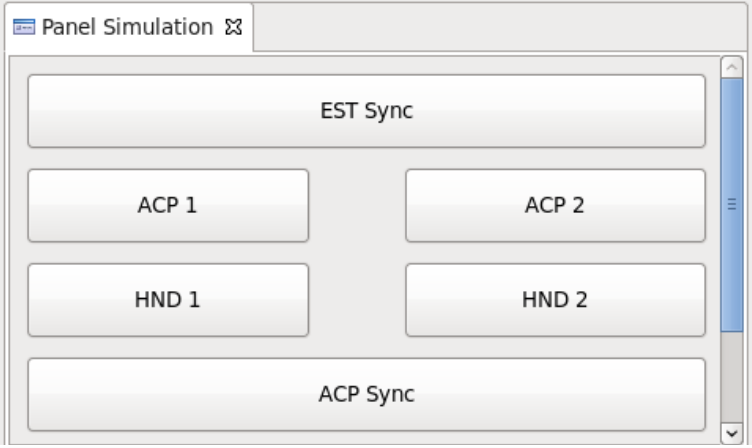
AutoFocus3

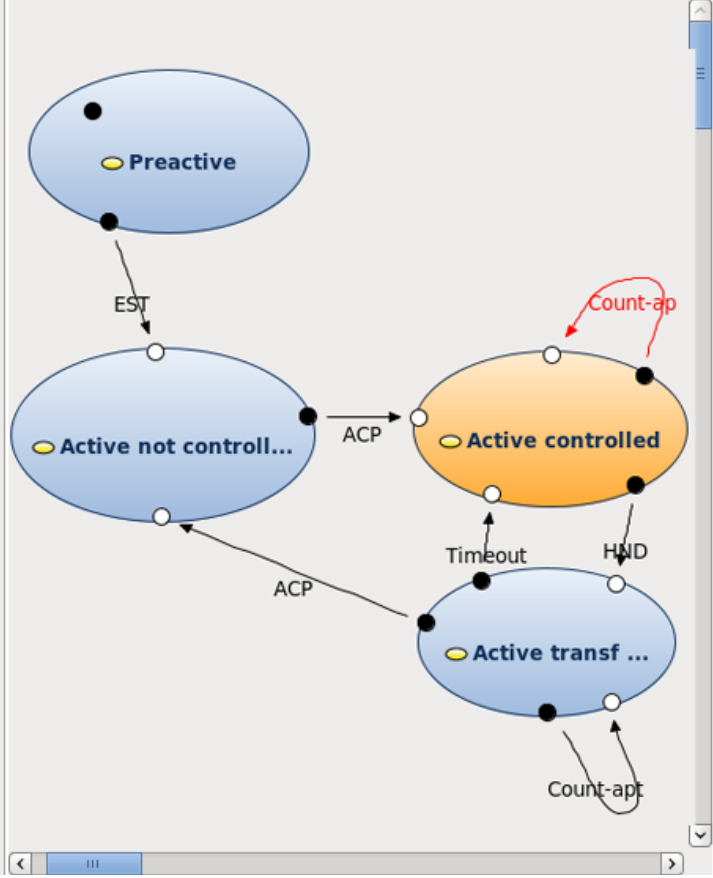




AutoFocus3
– NuSMV







Specification Atom	Verification c	Last check date	Last check result
Property 'flightPlanIn1 == Controlled( ) && flightPlar	Arch_v1	Wed Aug 26 11:25	SUCCESS
If '((flightPlanIn1 == Controlled( ) && flightPlanIn2 =	Arch_v1	Wed Aug 26 11:26	SUCCESS

MDD Issues

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"Some companies have reported great success with it, whereas others have failed horribly"
(Whittle, Hutchinson, Rouncefield 2014)

Issues related to MDD:

- UML – Abstraction level
- UML 2.0 – low acceptance
- Code generation

"*8 Reasons Why Model-Driven Approaches (will) Fail*" (DenHaan, 2008; 2009)

"*Model Driven Development Misperceptions and Challenges*" (Portier, Ackerman, 2009)

Conclusion

Gain from MDD:

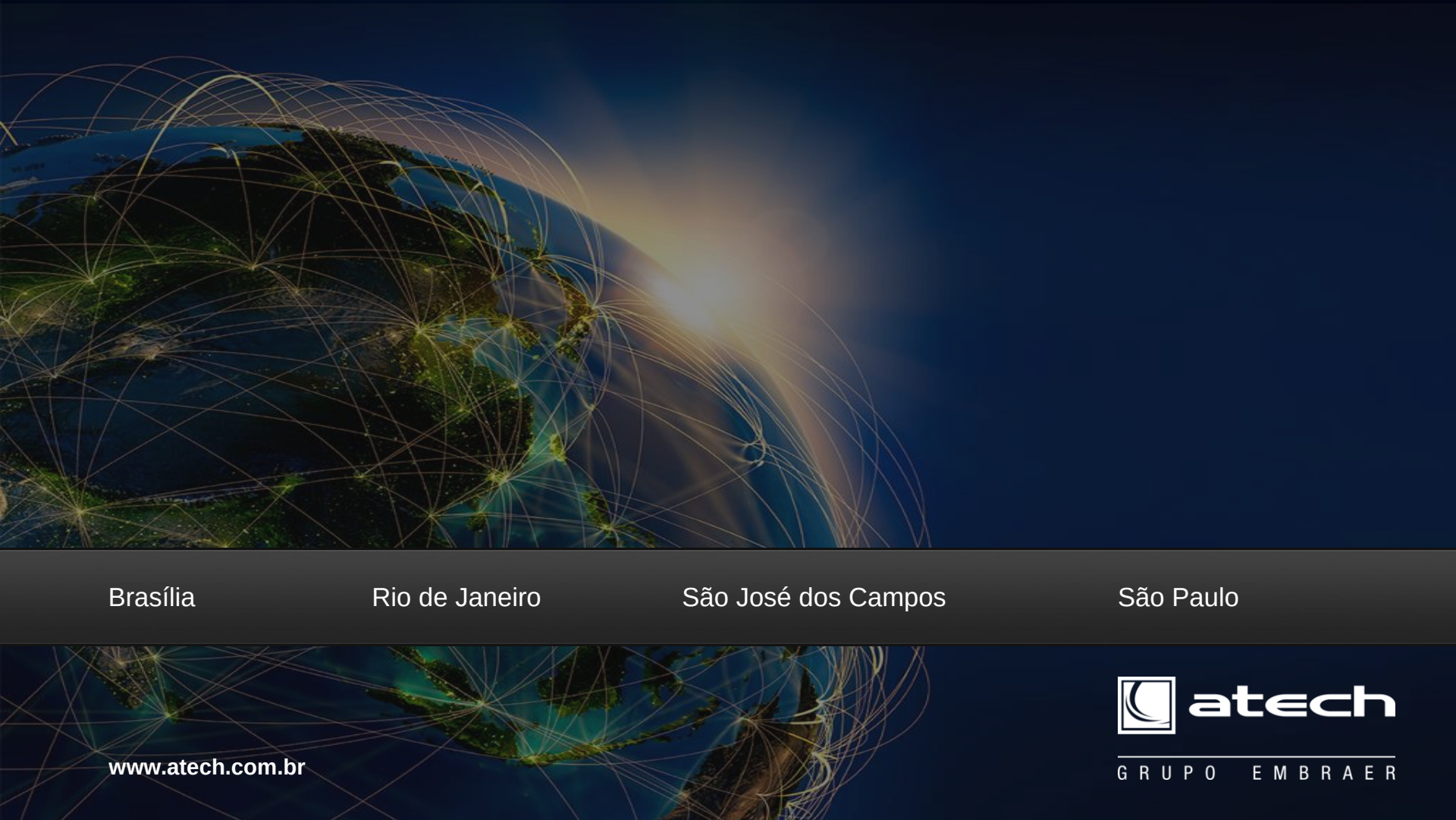
- Reuse
- Documentation
- Maintenance

Verification:

- Mapping of methods, modeling tools
- Model execution (simulation, debugging)
- Formal verification – model checking
  - Model refinement

“However, used in moderation and where appropriate, UML and MDA code generators are useful tools, although not the panaceas that some would have us believe”

(Thomas, 2004)



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