Novel Satellite Random Access E-SSA Receiver with SIC – Simulation and Prototyping

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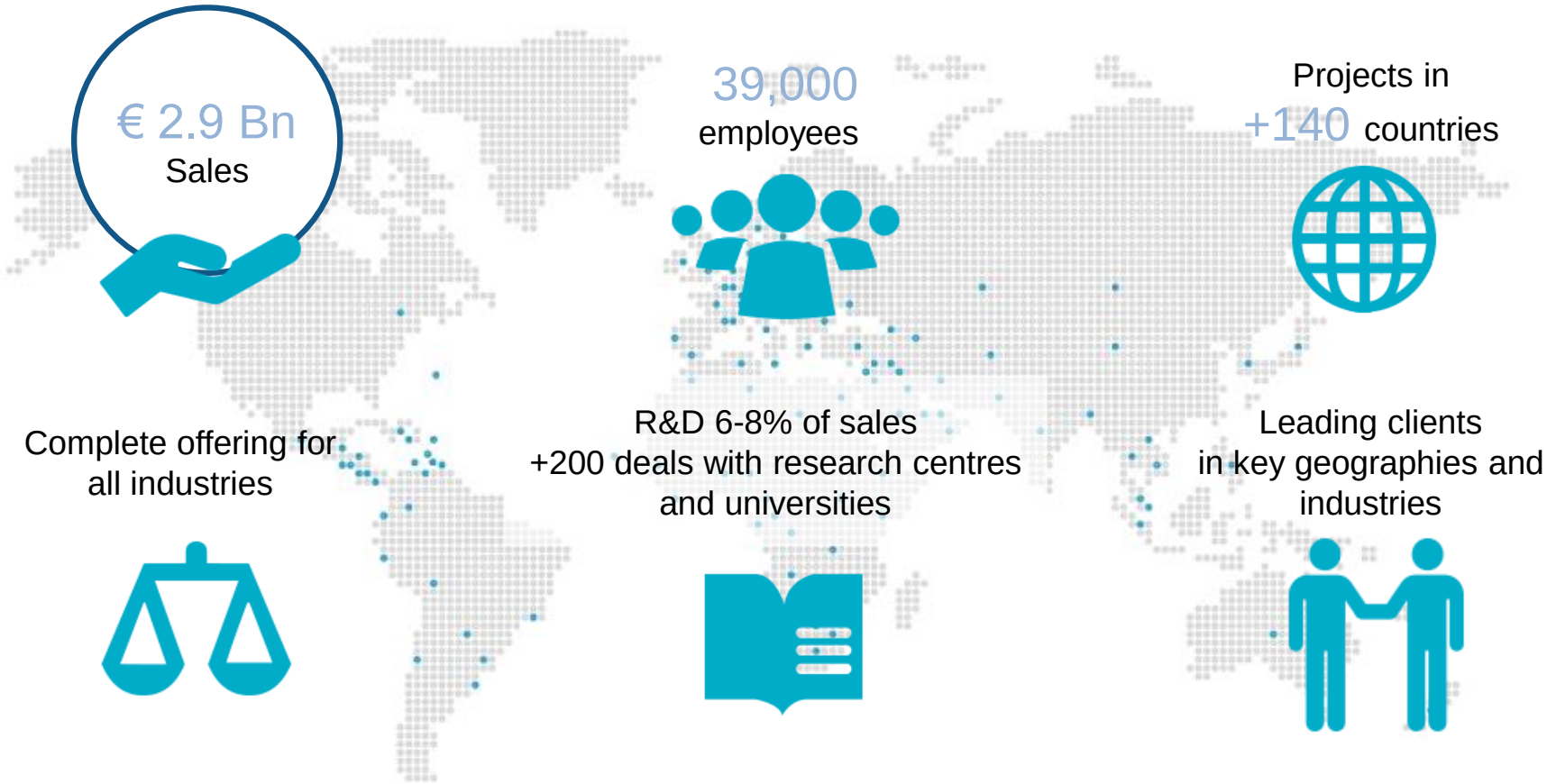
Key Takeaways

1. Time-consuming algorithms progamming tasks reduced to the minimum
   - Focussing on the Innovative Algorithms Design and Evaluation
   - Minimising Design Phase
2. Same system models used for
   - Algorithms Detailed Design
   - Performance Analysis
   - Assisting Prototyping and Verification
3. MATLAB used in all project phases (not only during the design phase)

Introduction to Organization and Business (I)



€ 2.9 Bn
Sales

39,000
employees

Projects in
+140 countries

Complete offering for all industries

R&D 6-8% of sales
+200 deals with research centres and universities

Leading clients in key geographies and industries

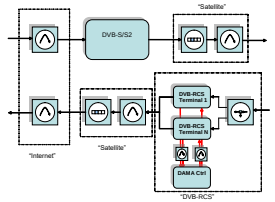
Sectors

- 16% Energy and Industry
- 16% Financial Services
- 12% Telecommunications & Media
- 17% Public Administration and Healthcare
- 23% Transport & Traffic
- 16% Security & Defense

Introduction to Organization and Business (II)

- **Space division** is part of the defense & security market
- **Satellite communications** is one of the business unit within space division focused on:
  - Engineering and technical consultancy on satellite communications systems
  - Satellite systems simulation and emulation, from physical to network layer, in house simulation/emulation tools
  - Design, development and manufacturing of satellite communication equipment
  - Specification, design, integration and deployment of satellite communication networks, fixed and mobile
- Broad experience in SatCom projects for different customers worldwide, such as ESA, civil administration or military

IMBU – TT&C



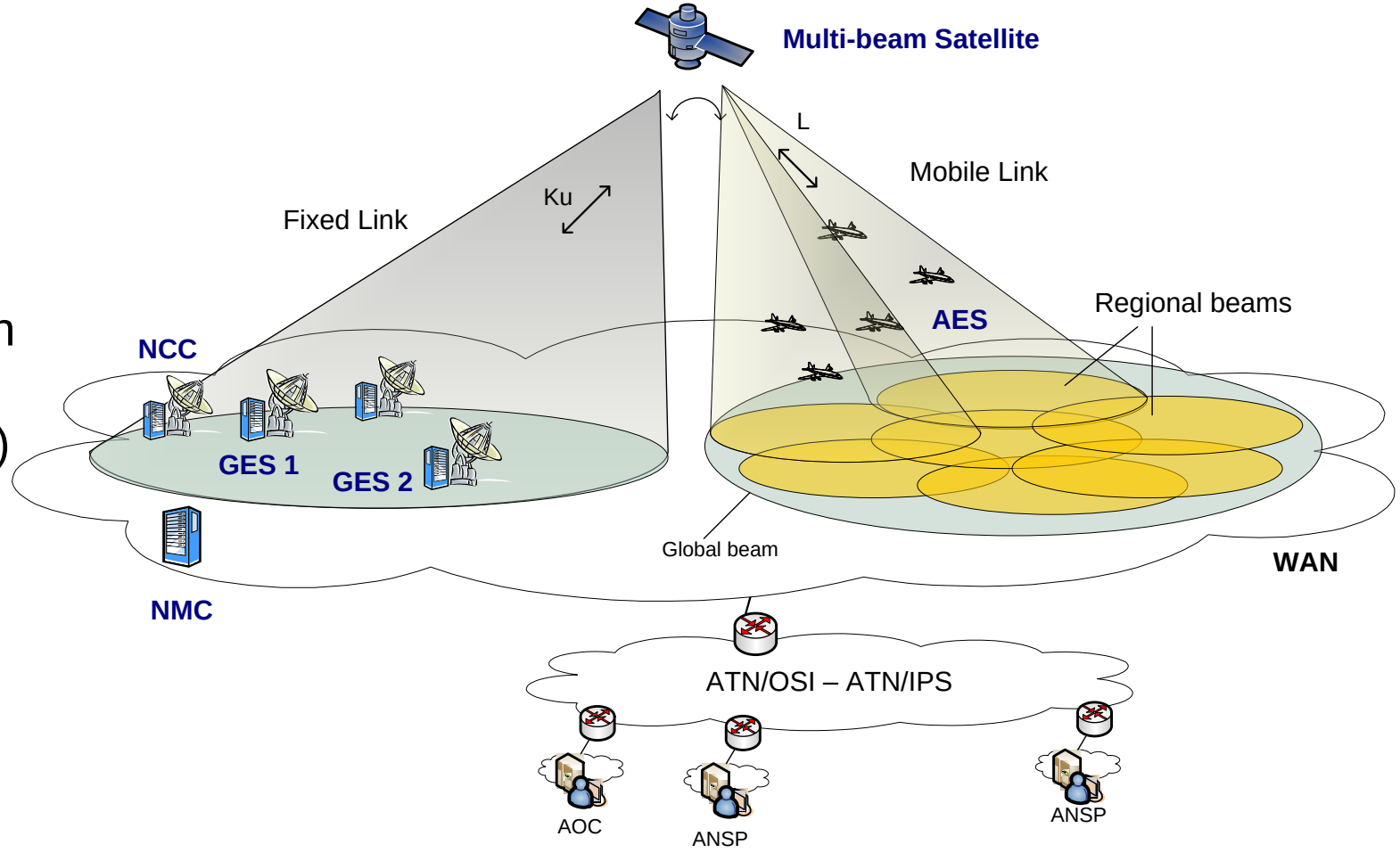
AINE

QoS Enforcer

Innovation Challenges and Achievements (I)

- The European Space Agency (ESA), in coordination with Eurocontrol, initiated the Iris programme to design a satellite-based communication system able to cope with future Air Traffic Control (ATC) communication needs

- Work carried out in the frame of the ESA Iris ANTARES project – consortium of more than 15 participants

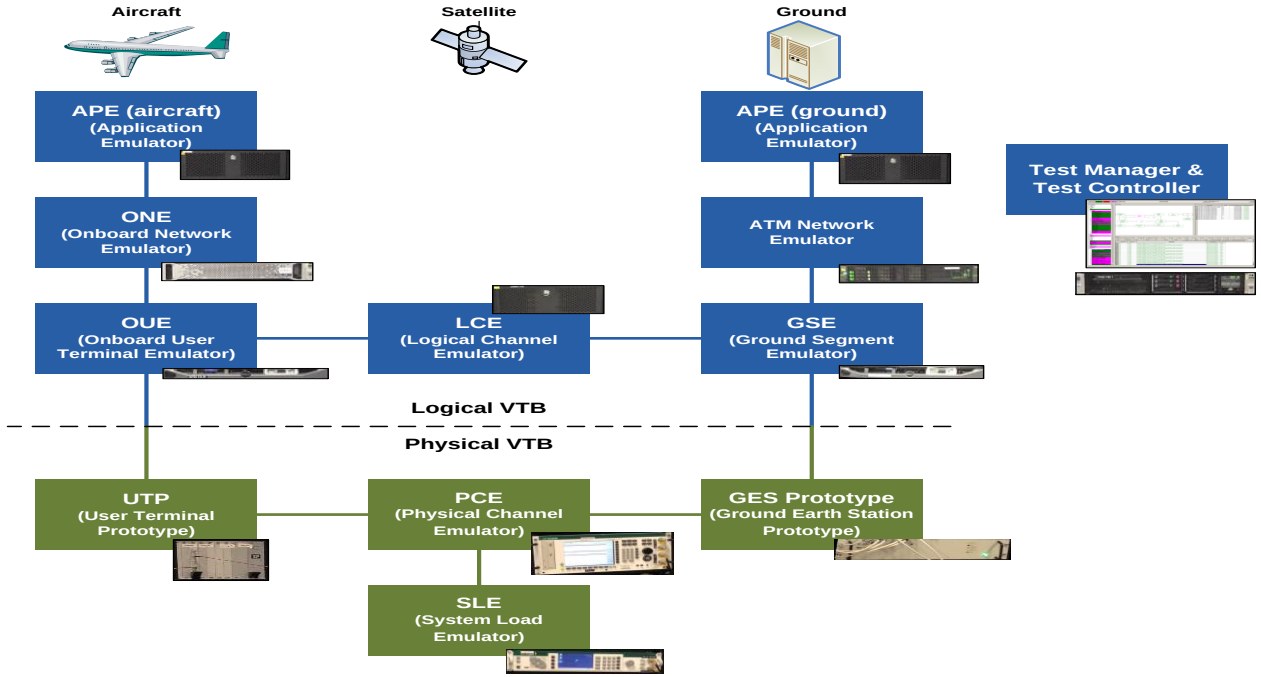


Innovation Challenges and Achievements (II)

- A key design decision was the selection of the Return Link multiple access scheme which, finally, was based on Asynchronous-CDMA Random Access.
- On the ground segment, a novel receiver (E-SSA), using state-of-the-art interference cancellation techniques, was used to improve the overall return link spectrum efficiency.
- MATLAB was the key tool used in the simulation, prototyping and verification of the innovative E-SSA receiver.

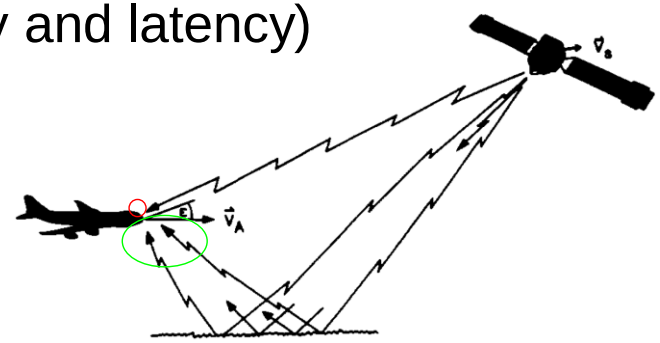
Approach

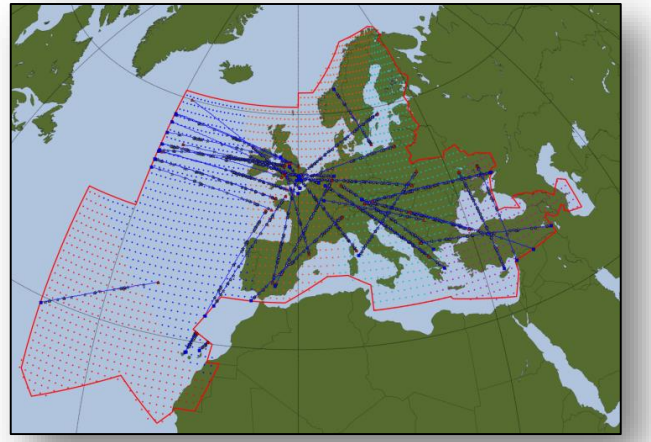
- Approach to prototyping the access schemes and, in particular, the ground segment receiver:
  - Trade-off of several multiple access schemes and selection of the most appropriate one
  - Design of the access scheme, involving extensive simulation campaign
  - Prototyping of key elements, being the most critical one the ground segment receiver
  - Verification of the performances in a Test Bed



Design Constraints

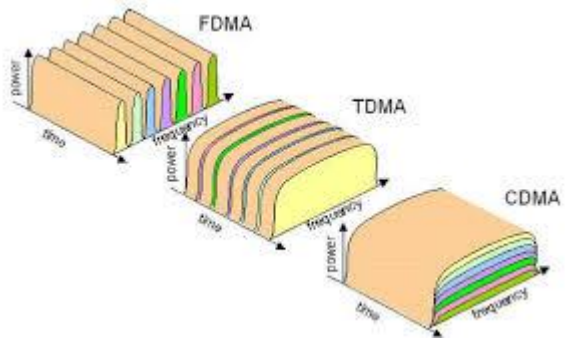
- The Return Link multiple access scheme, the waveform and the receiver was designed taking into account the following constraints:
  - Stringent Class-of-Service requirements (continuity, integrity and latency)
  - L-band aeronautical propagation channel
    - Multipath, Doppler, etc.
  - Limited L-band spectrum resources
    - High system spectral efficiency required
  - Bursty traffic generated by a large population of aircrafts
  - Support for fixed and rotary-wing aircrafts

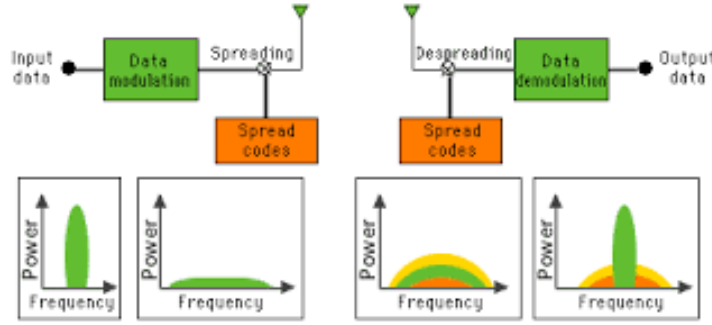




Asynchronous CDMA for the Return Link

- Random Access scheme based on **Asynchronous Code Division Multiple Access** (A-CDMA)
  - Several transmitters send information simultaneously over a single communication channel taking advantage of Spread Spectrum techniques

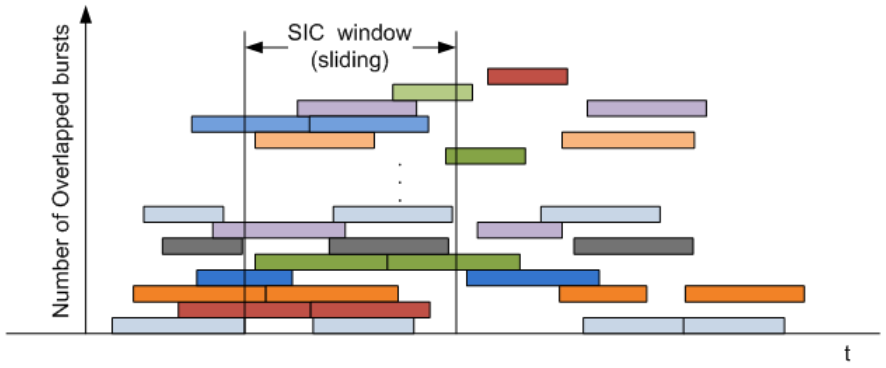




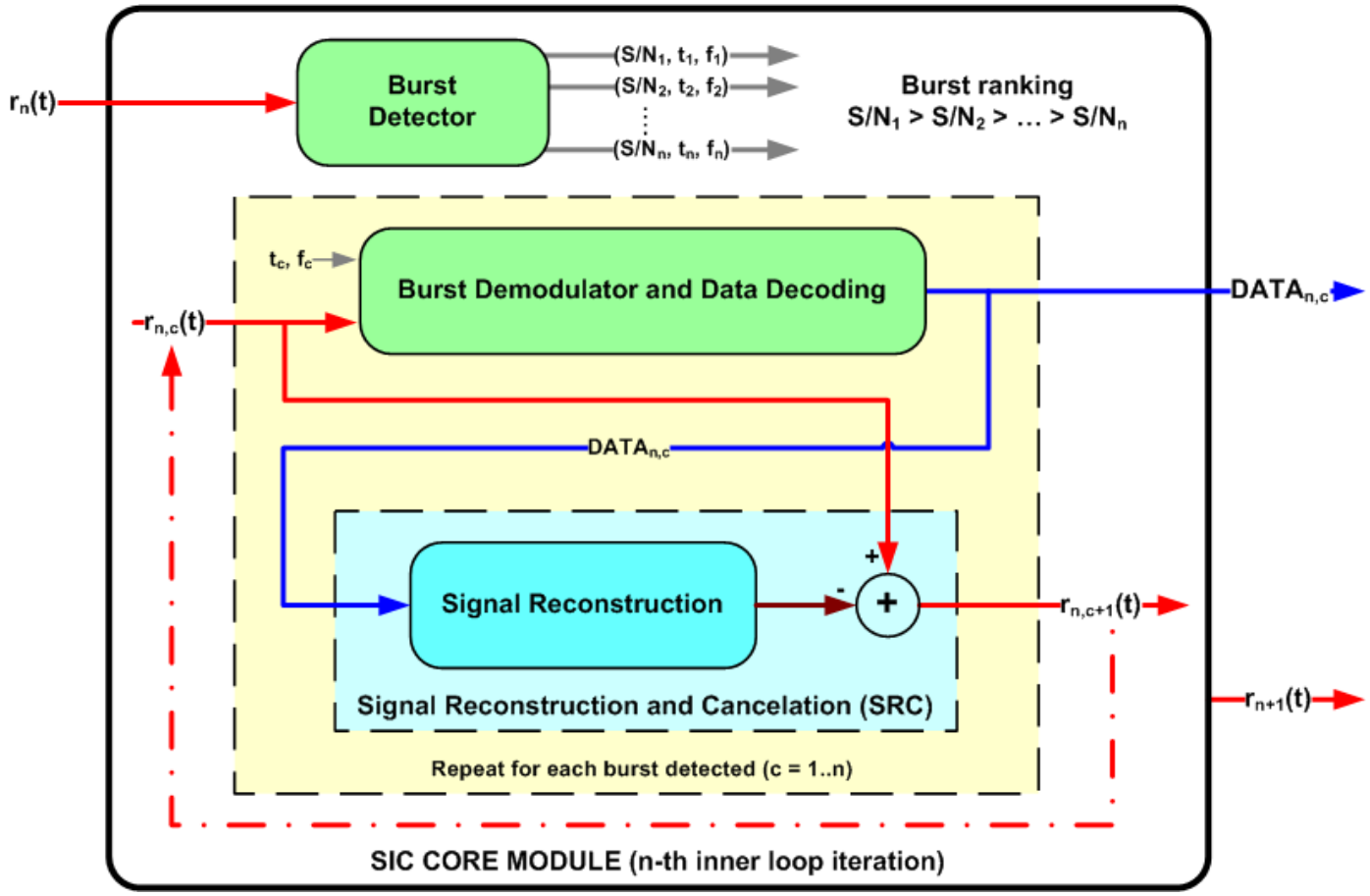
  - No need for network synchronisation → Simple transmitter (low-cost)
- **Enhanced Spread Spectrum ALOHA** (E-SSA) receiver
  - Combination of Spread Spectrum ALOHA (SSA) with **Successive Interference Cancellation** (SIC)

E-SSA Receiver with SIC

- It provides exceptional performances in scenarios with many transmitters sending asynchronous bursty traffic

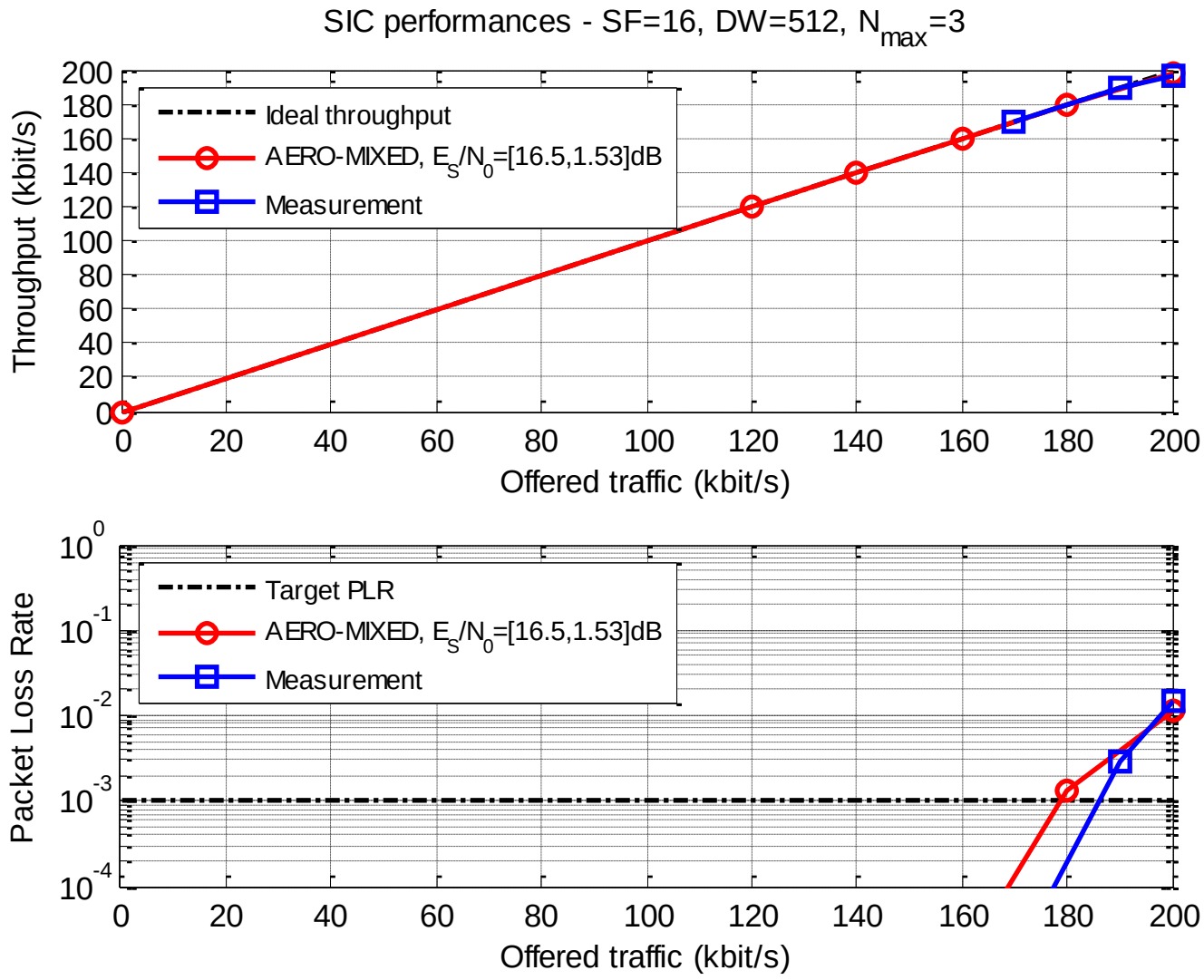


- The receiver iteratively detects, demodulates, decodes, regenerates and cancels bursts from the received signal, starting with those with highest power
- Robust to power unbalance



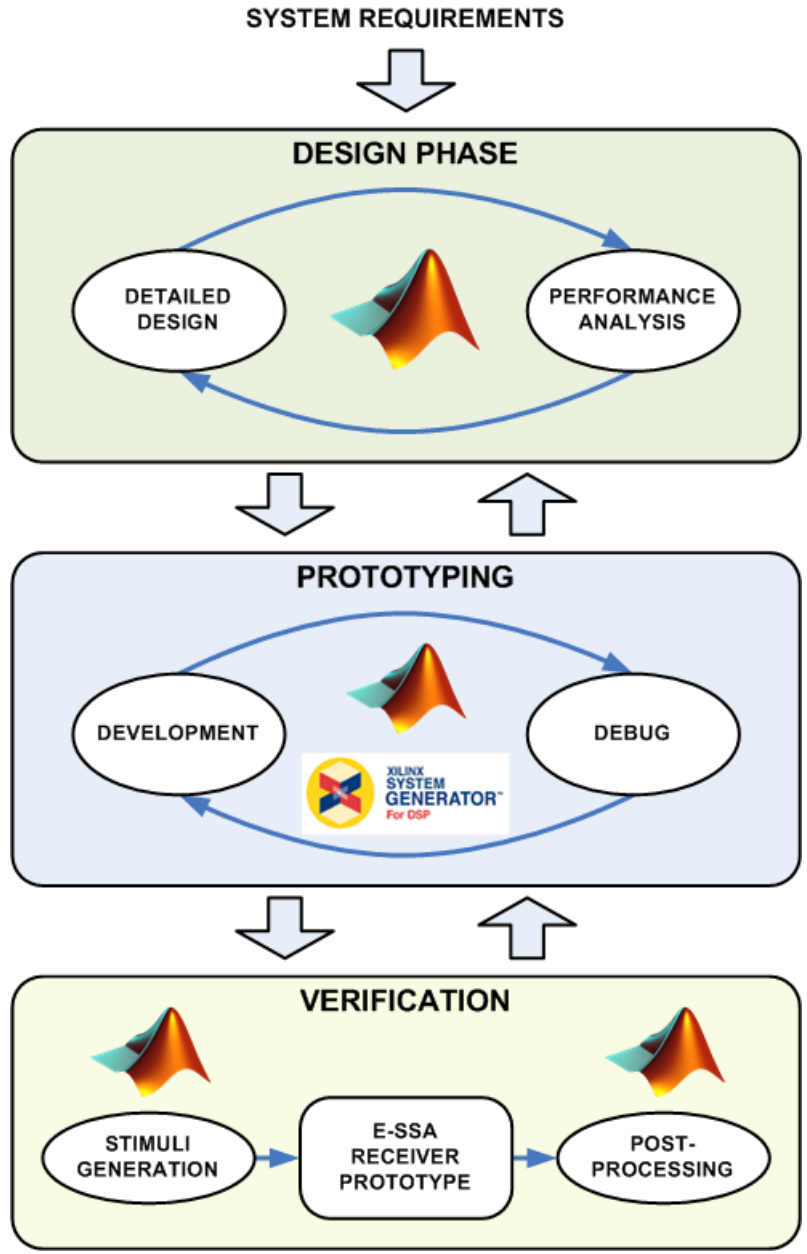
Performances of E-SSA Receiver

- SIC Efficiency of 95% even in severe aeronautical channels
- Low Packet Loss Ratio even with high throughputs
- Spectral efficiency above 1 bit/s/Hz
- Full frequency reuse is possible improving the system efficiency even further
- Performances reached with the final test-bed (blue lines) matched those from early project phases simulations (red lines)



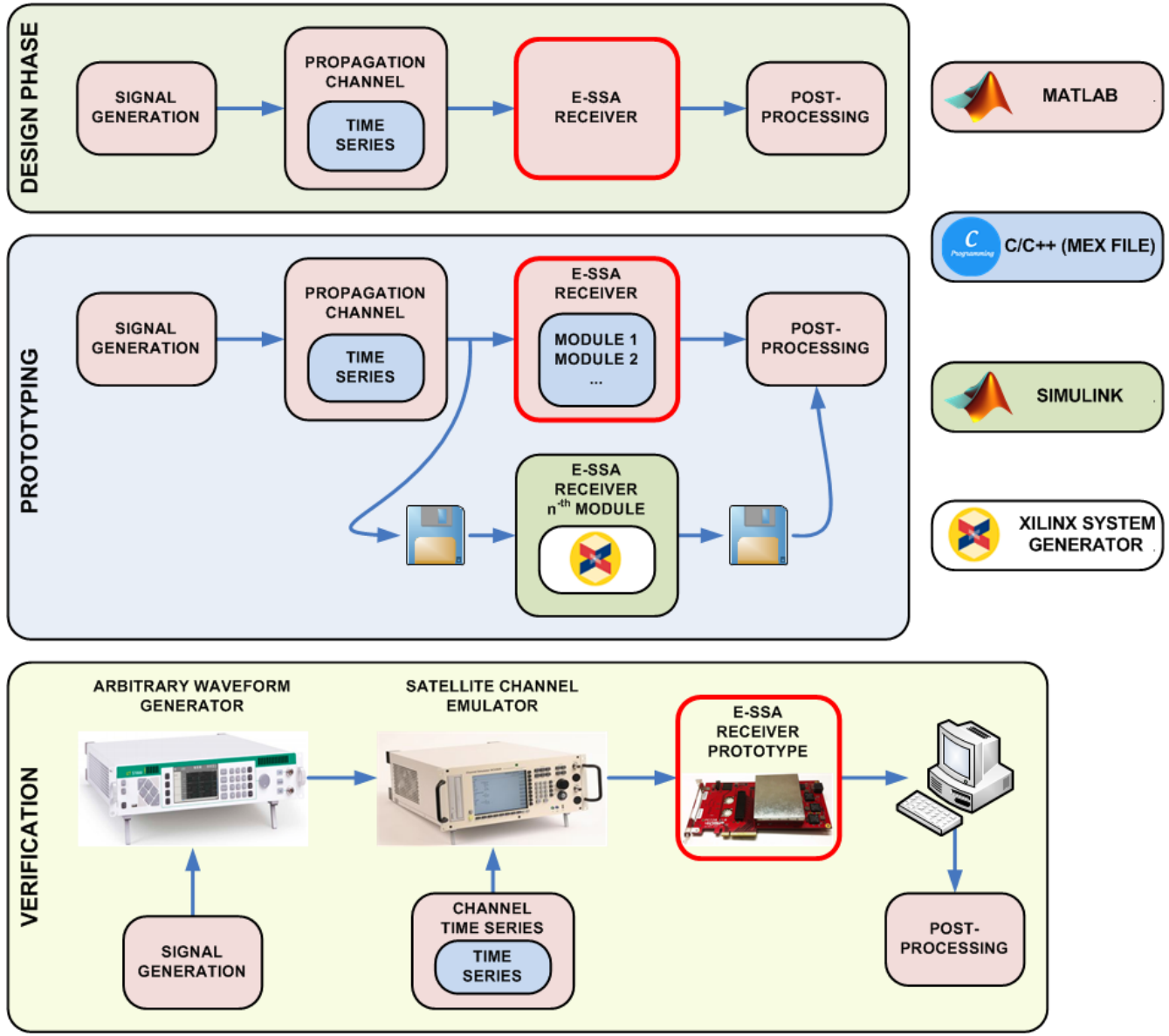
E-SSA Receiver Workflow

- Design Phase
  - Receiver detailed design completed in very few months thanks to new algorithms programming with MATLAB
  - MATLAB allowed us focusing on the innovative algorithms design and evaluation
- Prototyping
  - FPGA FW development was assisted by MATLAB and Simulink + Xilinx System Generator
- Verification
  - E-SSA receiver prototype verification and tested assisted by MATLAB tools to generate input stimuli and post-process receiver output



Simulation Models

- MATLAB has been used in all project phases
- Many MATLAB modules reused in each phase
- MEX files: C/C++ subroutines called as if they were built-in functions
  - Reuse existing C/C++ code
  - Used to validate VHDL coding of critical receiver modules during Prototyping
- Simulink + Xilinx System Generator also used to speed up development of some receiver modules



MathWorks Tools

- MATLAB toolboxes used in all project phases
  - Communications System Toolbox
  - DSP System Toolbox
  - Signal Processing Toolbox
  - Fixed-Point Designer
  - MATLAB Compiler

- Simulink + Xilinx System Generator used for Prototyping
  - Development and debugging of key receiver modules

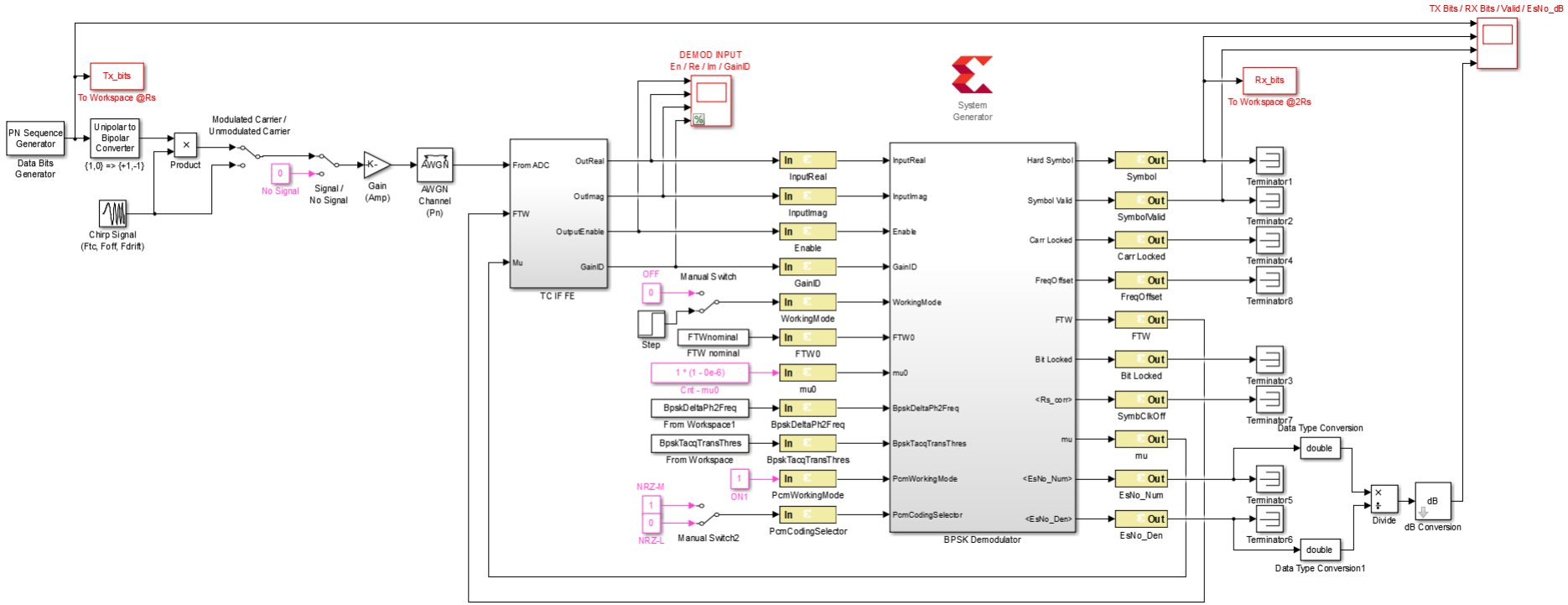
Identified Best Practices and Learnings

- Reuse models as much as possible
  - In all project phases
  - Among different projects and teams

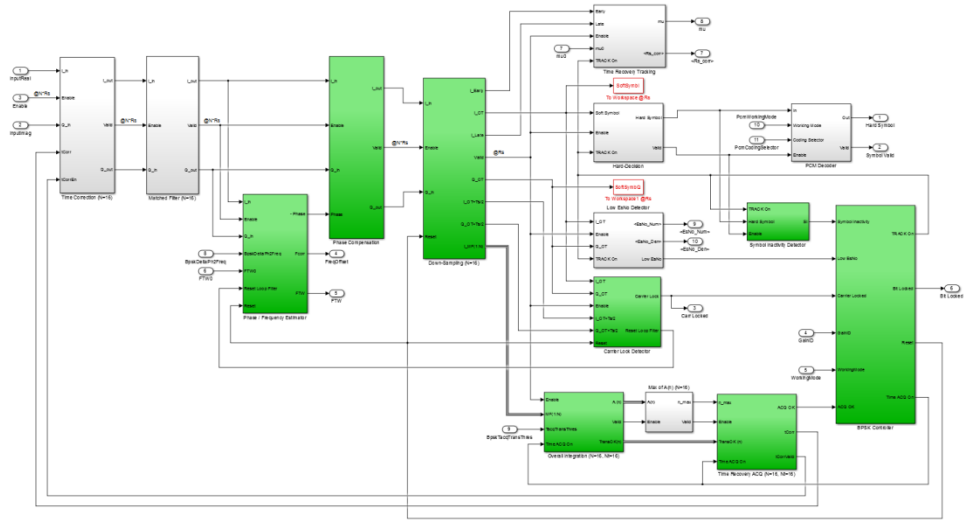
- Exhaustive simulation with in-depth performance analysis during the design phase
  - Speeds up prototyping and verification phases
  - Minimizes risk of unexpected issues at later project stages

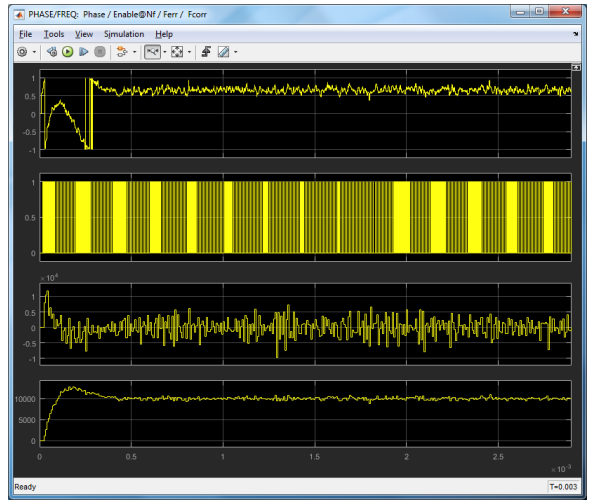
Forward-looking Plans (I)

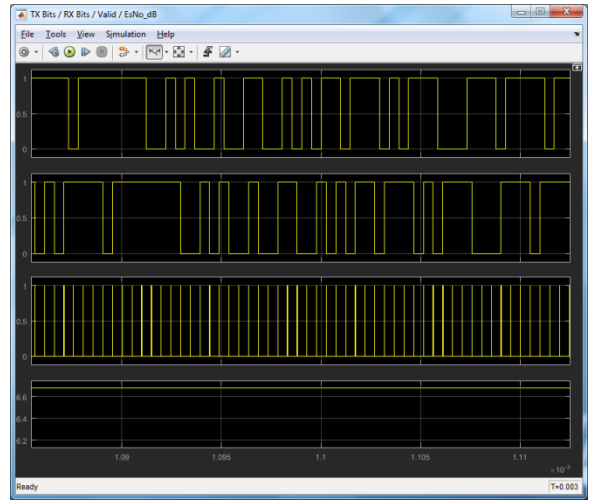
- Incorporate **Simulink** during Project Design Phase
- More intensive usage of **Simulink + Xilinx System Generator** during Prototyping (already put in practice in on-going projects)



Forward-looking Plans (II)







- Explore the advantages of using
  - **Parallel Computing Toolbox** in projects requiring intensive simulations
  - **System Objects** to speed up simulations that process large streams of data in segments
  - **HDL Coder** to generate VHDL or Verilog code for FPGA from MATLAB functions or Simulink models

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