

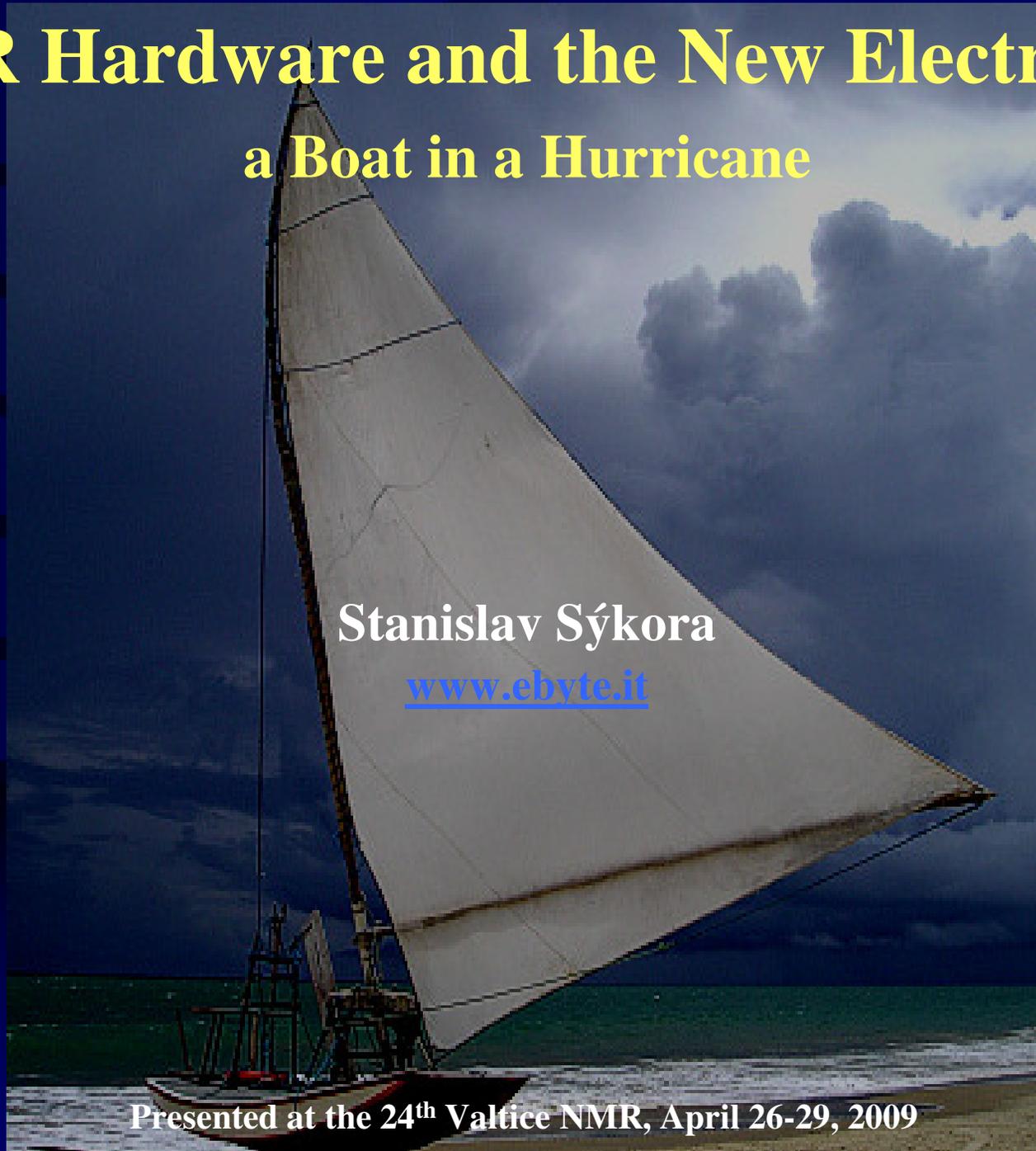
# NMR Hardware and the New Electronics

## a Boat in a Hurricane

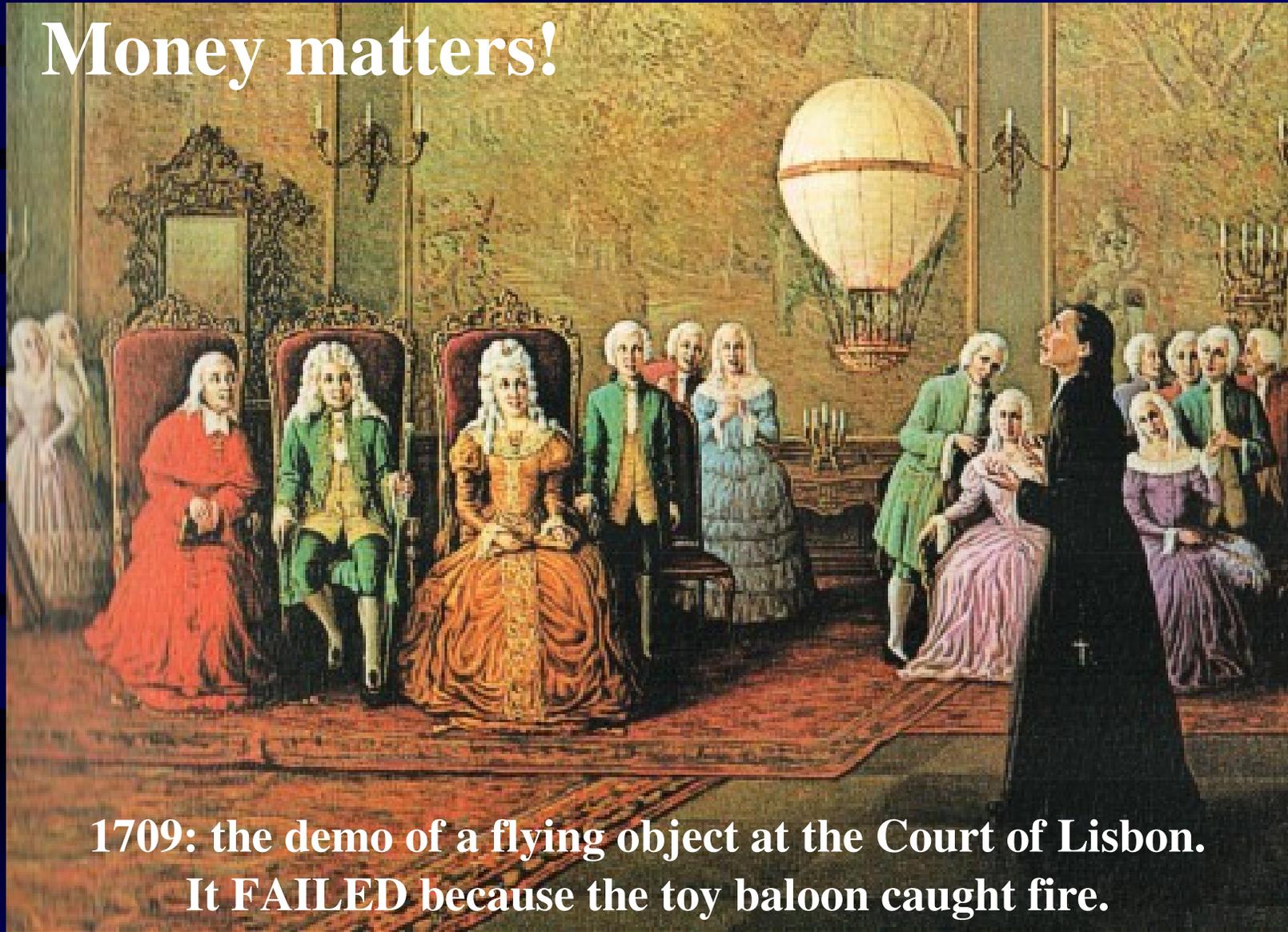
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# Money matters!



1709: the demo of a flying object at the Court of Lisbon.  
It FAILED because the toy baloon caught fire.

**Bartoleu Lourenco de Gusmão** was denied the grant  
and nobody tried flying again for the next 70 years

# **What to do when money is scarce ?**

**Buy [much] more for [much] less:**

**Electronics consistently offers  
every 3 years twice the performance at half the price!**

**Performance/Price ratio grows about  
100 times every 10 years !**

# New electronics

( last 10 years )

- ✓ Totally new ways of developing digital control/evaluation hardware
- ✓ Continuing reduction of development times: from years to weeks
- ✓ Continuing reduction of development costs: from >100 k\$ to <10 k\$
- ✓ Incredibly cheap memories (this has far-reaching consequences)
- ✓ Availability of high capacity FPGA's (Field Programmable Gate Arrays)
- ✓ Clock rates rapidly approaching 1 GHz (currently about 500 MHz)
- ✓ Ample availability of development software and low-cost IP core libraries
- ✓ Improving quality and dropping costs and sizes of analog devices such as ADC's, preamplifiers and RF amplifiers

# Emerging new concepts

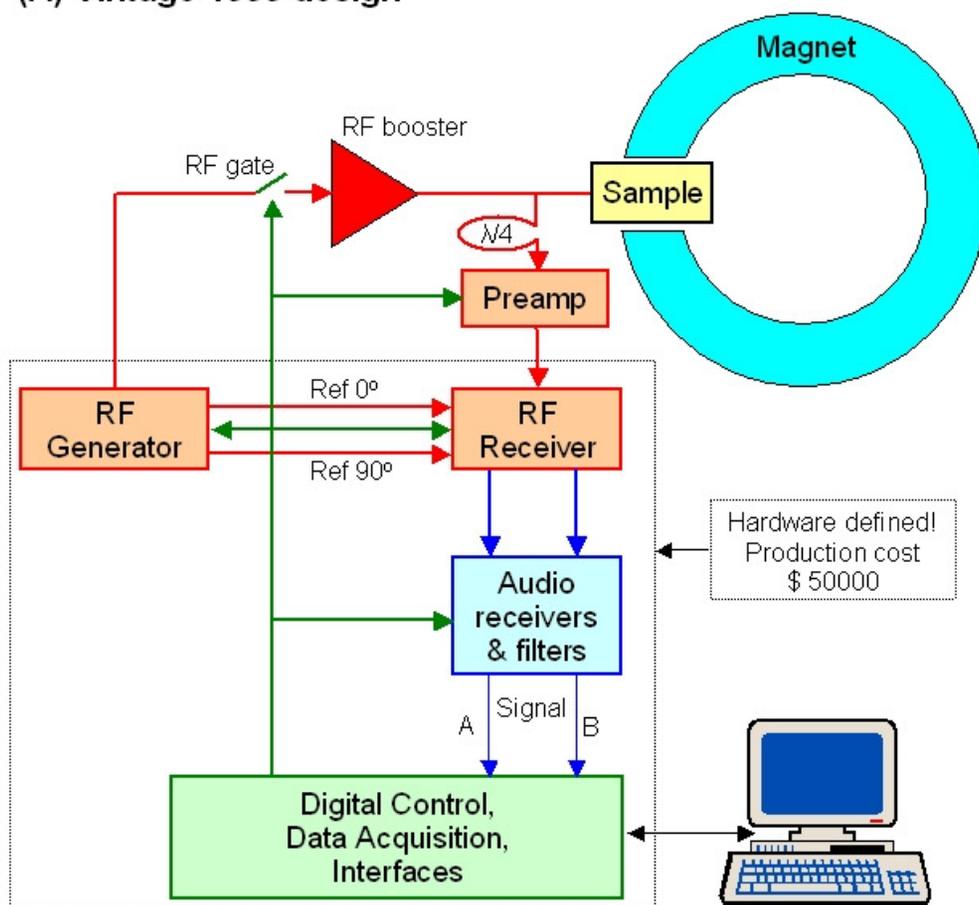
- ✓ Hardware re-programmability (even at run-time)
- ✓ Data acquisition:
  - Beyond Nyquist: multiple-rate sampling and irregular sampling
  - Direct RF sampling (no interfrequencies and/or phase detectors)
- ✓ Extensive hard-wired pre-processing, such as:
  - Artifacts removal/avoidance (algorithmic/neural)
  - New methods of averaging, delayed averaging, etc
  - Early standard pre-processing (such as integral transforms)
- ✓ Virtual instrumentation:
  - Software-based instrument differentiation (virtual front-panels)
  - Majority of hardware is shared (using hardware re-programming)

# Single-board MR consoles and double-board hybrids

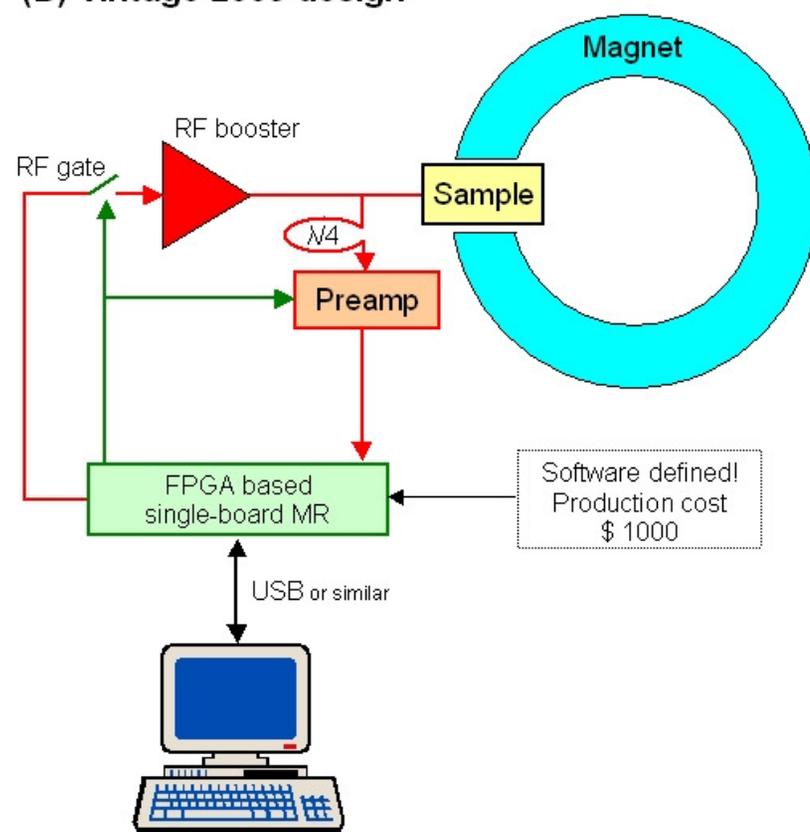
- ✓ One can fit many full-fledged NMR/MRI systems onto a single large chip or a simple machine (such as a routine 400 MHz) on a **single \$50 chip**
- ✓ Possibility to start with low-cost (or even zero-cost) development kit boards and **ridiculously low capital investment** (a few k€)
- ✓ Development is now fully in the reach of any individual – **what matters is only the developer's know-how**

## Layout of a basic single-channel NMR Instrument

(A) Vintage 1999 design



(B) Vintage 2009 design



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# New NMR-related concepts

- ✓ Totally digital RF sources (DDS)
- ✓ Obsolescence of many old features such as:
  - hardwired pulser/sequencers, hardwired data-samplers, etc
- ✓ Digital receivers: potential advantages ...
  - ... and some funny start-up errors made by many Companies  
(don't ever literally "translate" old analog designs into digital form)
- ✓ Easy digital generation of RF and AF waveforms of any complexity
- ✓ Acquisition of phase/modulus to combat magnetic field noise
- ✓ Novel data sampling strategies
- ✓ Novel data accumulation strategies

# The rest of NMR hardware

- ✓ Continuous evolution of RF power amplifiers  
(pulsed 1kW in a box half the size of a PC tower)
- ✓ Digital probes (currently spreading in MRI but soon to become universal)
- ✓ Acquire-all multi-channel probes
- ✓ Electric detection probes, particularly those integrated into silicon chips
- ✓ Cryogen-free high-resolution supercon magnets
- ✓ Innovative, portable high-resolution permanent magnets
- ✓ ...

# Let's launch an Open MR initiative

to develop and share the know-how to build good-quality  
MR consoles for less than 1000 €

## OMR should:

- ✓ Follow the management principles of open-source software projects like Linux, SourceForge projects, Scilab or R
- ✓ Maintain a master repository of open-access MR IP cores
- ✓ Maintain a master repository of MR firmware & software
- ✓ Promote Virtual Scientific Instrumentation in general
- ✓ Promote MR instruments for undergraduate education
- ✓ Promote MR instruments in developing countries
- ✓ Promote cost-sensitive MR applications

# Thank you for your attention

and, to follow the evolution of OMR, keep visiting

[www.ebyte.it](http://www.ebyte.it)

Let a new era start !

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