Draft Study on

SEXTANT²

"*Susceptibility of Electronic Systems To Atmospheric Neutrons: from Test to Technology*"

1) Rationale

Over the last 30 years, citizens have trusted in electronics and electronic systems with a confidence that these systems are becoming more and more present in our everyday surrounding, either visible or embedded – heading to the creation of an ambient intelligence, and manage most of the safety critical applications (from energy to health and transportation). Considering the technology trends of future electronics, there is a vital need for the preservation of this confidence to ensure that all the efforts (research and industrial) put in these technologies will be applicable at the best cost-effective ratio.

The **SEXTANT² Working Group** addresses the key problem of the **sensitivity of electronic components and systems to the adverse effects due to the interaction of atmospheric neutrons** with devices, effects that are bound to become more and more important considering the roadmap of electronic systems.

Where do atmospheric neutrons come from and what effects on machines?

Atmospheric neutrons are end-products of the interactions of cosmic rays with our atmosphere. The cosmic rays interact with air nuclei to generate particles comprising protons, neutrons, etc. The radiation intensity is maximum at 20km (≅60.000 feet) and then drops off to sea level at which the neutron flux is significant. At aircraft cruising altitude (≅10km) the radiation is several hundred times the ground level intensity.

These particles have been recognised for more than 10 years to be responsible for incidents ("Single Event Upsets", or SEU; more generally "Soft Errors") in on-board electronic systems of aircrafts and railway engines. On machines, effects range from corrupted code or data, to destruction of electronic components.

Why now?

Developing an information society for all, is of **crucial importance for competitiveness and growth in Europe**, through a knowledge-based economy, the increase of the capabilities of computing technologies and the development of intelligent transport systems enhancing road safety. Most of these developments are based on the development of faster, smaller and more efficient electronics. In this context, reliability and robustness are as vital as performance and integration: this is true for every scale, from mere components to subsystems to complete systems. **Each new CMOS generation** allows more performing devices (processors, larger and larger memory banks, Systems on Chip) which are **roughly 5 times more sensitive** to soft errors rate. However, robustness to environmental constraints is not the primary concern of semiconductor industry.

So, now is the time to cope with this problem in a concerted manner.

Why Networking at the European level?

This radiation is already taken into account for people aboard aircrafts, as reflected in an **EU directive**, effective May 2000, whereby annual radiation doses in excess of 1 milliSievert must be estimated and controlled. This "cosmic" radiation essentially consists of neutrons and affects electronics as well.

Research in the field of effects of atmospheric neutrons on electronics has been carried out in the US and Japan since the late 80's, both by industries (*TI, IBM, Intel, Fujitsu, NEC, Xilinx*), and academics. Punctual studies were achieved in Europe in the late 90's, but this topic needs an integrated mode of research and development to release a new secure and usable electronics technology in Europe over the present decade.

2) Objectives

The SEXTANT² Working Group aims at improving by several orders of magnitude[1] the robustness of present and future electronics technologies to the effects of atmospheric neutrons, now and up to the 2010 horizon.

This will be achieved by providing end users as well as semiconductor industries and SMEs developing electronics based systems, with a new generation of electronic components together with hardware + software solutions. The resulting products and applications must be robust to the interaction of atmospheric neutrons and compatible with the roadmap of electronics, **without increasing cost and time-to-market penalties**.

The creation of a **methodology and standards**, ensuring the respect of different levels of the robustness of different products to atmospheric neutrons effects, will be one way to improve the state-of-the-art.

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3) The proposed approach

Current situation and risks

A few numbers can recall the pervasion of the issue: in EU, 400 million citizens use more than 200 million cars, trucks and planes, an average of 100,000 people travelling by plane at any daytime time), more and more patients cured by proton therapy, patients with today's heart implants (such as pacemakers), defibrillators, internal medication distribution and future bioartificial prosthesis.

SEU are encountered in **many different domains**: avionics, railways, automotive, medical therapy and instrumentation, safety application and information technologies (e-society).

Concerning avionics, SEU is experienced by sensitive electronics in aircraft systems, because of the increasing radiation flux with altitude. A significant effort has gone into monitoring the environment and analysing operational systems for SEU. Upset rates of about 1 per 200 hours were measured in the Boeing 777 autopilot: this is much higher than the tolerances required by the aircraft manufacturers' directives (10^{-6} upset per hour). These error rates might have important consequences if the flight lasts several hours..

Personal and vital risks require a very high level of confidence in the equipment, not only with respect to electromagnetic compatibility (EMC) but also **against natural radiation fluxes whatever the circumstances**: aircraft travels, living in altitude, even in time of solar eruption, and also sporadic therapy sequence. All these risks must be asserted, updated along the technology and society, and the emerging ones quantified.

The work-programme: a joint programme of activities

The work-programme will be organised around **3 main themes**: Simulation and Testing (S&T), Components (Co), Systems and Products (S&P), each producing information or tools utilised by the others, as follows[2].

Theme 1: Simulation and Testing (S&T)

This theme will settle the necessary theoretical basis on which the other themes will rely, to provide products or services coherently with the objectives of the Integrated Project. It will be divided into several sub-themes, centred on the development of accurate and broad spectrum simulation tools.

The largest ground level event on record occurred in February 1956 when enhanced neutron rates of a factor 50 were observed in England, and much higher in altitude. In theme 1, simulation will be oriented to establishing the influence of Space Weather to the SEU rates from sea level to high atmosphere.

The accurate modelling of neutron environments critically depends on the data from ground-level and altitude monitors, taken at various latitudes and altitudes. An increasing body of data on upsets in avionics systems is already being accumulated. There is a real need for the same **data collection** in other **application domains** because of the different and sometimes specific environments.

Theme 2: Component level (Co)

The development of **new components and/or new technologies, robust to atmospheric neutrons**, is going to become the **key problem** of this central theme. Data and experience on the sensitivity of present and future electronic components and technologies to atmospheric neutrons are to be provided. The components have to be characterised and simulated. Gathered data will also be used with themes 1 and 3, in order to end the loop.

The importance of analysing the behaviour of a component within its electronic environment (processor, memory, sensor, power electronics, etc), including software, when a SEU occurs, is worth noting: this feature, too, is to be developed.

Theme 3: Systems and Products (S&P)

This is the level where **hardware and software solutions**, new technologies or new designs, will be developed to solve real problems. It is probable that robustness will be achieved through different solutions for each domain: **"good practices"** will then be provided and rules for safety margins developed.

Standardisation will be a key issue of this theme: the real impact of the IP on the citizen will be measured by the will of the main actors of the electronics industry to apply the robustness standards developed.

4) Milestones and Future Work

The SEXTANT² Working Group is currently composed of a board and informal participation. Its first action has been to answer a Call for Interests of the European Community in June 2002. Labs, Universities, SME, Technology Providers and Industrial End-Users joined the Board and constituted the **SEXTANT²** initiative for

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building up an **Integrated Project** in the sense of the **6th Framework**[3] of the European Community. The **SEXTANT² Working Group** is becoming perennial. Any interest and participation in the field is welcome. Please contact the Board, through jean-luc.leray@ieee.org or fabrice.auzanneau@cea.fr, or and visit the website http://sextant2.ieeenpssfrance.org.

3Framework intended for structuration of the European research