An Overview of Flight Computer Technologies for Future
NASA Space Exploration Missions

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ABSTRACT

1. INTRODUCTION

The development of advanced, high-performance flight computers designed and manufactured for long-term use in space, is of great interest to future NASA Space Science, Earth Science, Aeronautics, and Human Exploration and Development of Space applications. Moreover, highly integrated and embedded flight computers are an enabling technology for current and future commercial as well as strategic applications. In fact, it is expected that flight computing technologies will become an increasingly critical technology for a growing number of civilian applications that address commerce, communications, agriculture, energy, weather monitoring, science, education, etc.

That advanced computing technologies can revolutionize space applications should come as no surprise. Over the past several decades, computers have become increasingly ubiquitous on Earth, and have thus impacted every aspect of our lives. Some scientists compare the Information Technology revolution ushered by advances in computer technologies, with the agricultural and industrial revolutions.

There are several important impediments that delay the transition of this commercially driven technological revolution into space. Most notably are the extreme environmental conditions characteristic of space including: numerous radiation effects, extreme temperature conditions, absolute vacuum, and the combination of all the above. Furthermore, the remote and inaccessible and critical nature of the applications require special design, engineering, and manufacturing to enable high reliability, remote and online testability, self-diagnostics, fault-tolerance, and in many situations high-availability. Finally, given the inherent high cost of such reliable space computing systems, and the inherently small market for such applications, space systems must settle for both older technologies as well as the less frequent insertion of new generations of technologies into space.

In this paper, we present an overview of current developments by several US Government agencies towards high-performance single board computers for use in space applications. Three separate projects will be described; two that are based on the Power PC architecture, and one based on the Pentium processor. All three projects are
considering a local logical bus interface based on the commercial standard Peripheral Component Interface (PCI). Furthermore, all three projects are considering the design of single board computers based on the 3U Compact PCI (cPCI) mechanical interface.

In this paper, we also describe one approach to accelerate the insertion of advanced commercial computer technologies into space applications.

2. A Brief History of Space Flight Computers

Throughout the space exploration era, NASA has relied on the commercial sector to provide flight computers and associated high-reliability computer technologies. However, early research and development efforts such as the Jet Propulsion Laboratory Self Test And Repair Computer (STAR), as well as research at other national laboratories has guided the industry with target space requirements, space qualification testing, etc. Even so, it was not unusual for NASA engineers to develop unique components, modules, and electrical interfaces that were applicable only to very few space applications.

As it became evident in the early 80s that the commercial computer revolution was growing at an exponential rate, NASA made more explicit decisions to increasingly leverage developments in the commercial sector. Most notably, the Cassini project which launched in October 1989 and is now on route to Saturn, developed the first computer based on the Generic Very High Speed Integrated Circuit (GVHSIC) technology, as a contract to IBM Federal Systems. This four-chip computer chip-set was used as part of the Common Flight Computer (CFC), called so, because there was one flight computer common to all of the spacecraft subsystems.

The following generation of flight computer technologies was introduced by the Mars Pathfinder project, launched in December 1996. This project further pursued the approach of importing computer technologies from the commercial sector. The MPF Computer was based on the IBM R6000 architecture and developed by Lockheed Martin Federal Systems (x-IBM Federal Systems). A single-board computer was developed based on the VME commercial electrical and mechanical interface standard. Moreover, the computer was, for the first time, using the commercial VxWorks real-time operating system and the C programming language.

As discussed in the following section, NASA is currently developing another generation of computer technologies that will most likely set the tone for the first decade of the new millennium of space exploration.

3. Next Generation Space Flight Computers

NASA’s Outer Planets Program is currently in the final stages of completing the development of the X2000 System Flight Computer (SFC). This computer was originally designed as part of the X2000 Technology Program for the Europa Orbiter Project which was scheduled for launch in November 2003. Whereas this project is now scheduled for launch in March of 2008, the technology is still being completed on its original schedule,
and will thus be inserted into other earlier NASA missions. This computer is based on the Power PC 750 processor, and is being developed by British Aerospace Federal Systems. The electrical and mechanical interfaces are based on industry standards, including the local bus architecture of the Peripheral Component Interface (PIC), and the Compact PCI (cPCI) chasis.

4. Power PC Architectures

5. Power PC 750 System Flight Computer (SFC)

6. Power PC 603e Processor

7. Rad Hard Pentium (RHP) Project

8. Other Approaches for Space Flight Computers

9. Performance Measurements and Benchmarks

10. Looking into the Future of Distributed Computing

11. Conclusions