

High Performance Processors for Space Environments- A Subproject of the NASA Exploration Missions Systems Directorate "Radiation Hardened Electronics for Space Environments" Technology Development Program

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Abstract: *Implementation of challenging Exploration Systems Missions Directorate objectives and strategies can be constrained by onboard computing capabilities and power efficiencies. The Radiation Hardened Electronics for Space Environments (RHESE) High Performance Processors for Space Environments project will address this challenge by significantly advancing the sustained throughput and processing efficiency of high-performance radiation-hardened processors, targeting delivery of products by the end of FY12.*

Keywords: microelectronics; processors; high performance processing; NASA; RHESE; radiation effects

Project Description

Capabilities that can increase the effectiveness or the efficiency with which Exploration Systems challenges are addressed can be data processing intensive. Among these capabilities are autonomous systems involving spacecraft operations, surface mobility, and entry, landing and descent. Whereas numerous systems with these capabilities have been deployed, their requirements and implementations are typically constrained by data processing throughput, power resources, and radiation effects.

The RHESE High Performance Processors for Space Environments (HPP) project will expand the capabilities of data processing-intensive spaceflight systems by significantly advancing the sustained throughput and processing efficiency of high-performance radiation-hardened processors. Deliverables are targeted for FY12.

The need for high-performance radiation-tolerant processors and the required peripherals required to implement functional systems is not unique to NASA; this capability could also benefit systems deployed by commercial aerospace entities and other governmental agencies that utilize space-based assets. This task therefore intends to leverage to the extent possible, relevant processor development efforts sponsored by other

organizations, and prior work funded by NASA. This project seeks to deliver a processor with the performance metrics defined in Table 1.

Table 1. High Performance Processor Performance Metrics

Objective	Key Performance Parameters	Performance Targets	
		Full	Minimum
Provide Radiation Tolerance	Total Dose Radiation Tolerance (Krad (Si))	100	100
	Single Event Effects (errors/bit-day)	1.0E-12	1.0 E-10
Improve Processor Performance	Sustained Processor Performance (MIPS)	2000	500
Improve Processor Power Efficiency	Sustained Processor Efficiency (MIPS/W)	500	100

The HPP effort is addressed from a system-level perspective; meeting the objective will require peripheral devices that exhibit performance and environmental characteristics consistent with the processor. This task is therefore also ascertaining the availability and development status of components required to realize nominal high-performance spaceflight systems architectures. The task is also related to or dependent upon other RHESE projects; these projects include the Radiation Environmental Effects Modeling, the Radiation Tolerant Memory, and the Reconfigurable Computing projects.

Project Execution

The HPP project consists of several work elements:

Problem Definition (Element 1): The objective of this element is to identify NASA missions and measurements that require or whose execution could be enhanced by processing capability beyond that which is currently available, in development, or planned for future development. The missions and measurements will not be limited to those under the purview of the Exploration Systems Missions Directorate, but will also include those from other Agency directorates. This broad view will facilitate identifying potential opportunities for leveraged activities.

Solution Space Definition (Element 2): This element will derive methods of addressing the challenges identified during the problem definition phase. The technology readiness and other risk factors inherent in the potential solutions will be analyzed, but will not immediately disqualify approaches from further consideration. The missions and measurements that can be enabled or enhanced by the infusion of these solutions into flight systems will instead be the major driver for this element.

Identification of Current and Planned Relevant Efforts (Element 3): The project team will identify relevant current technology, technology under development, and technology planned for development within NASA, across industry, academia, and within other government agencies. Development risks and risk mitigation factors associated with each effort will also be identified.

Identification and Analysis of Technology Gaps (Element 4): The objective of this element is to identify technology and funding gaps existing between the approaches identified in Element 2 and current or planned efforts identified in Element 3.

Strategies and Recommendations (Element 5): The project team will identify candidate technologies with potential for having significant impacts on high-performance flight systems, and based on the gap analysis of Element 4, devise strategies on how these technologies could be designed, adapted, or productized for relevant spaceflight environments. The criteria used in formulating recommendations will include, but not be limited to factors such as cost and time to infusion, mission need dates, cost sharing and partnership opportunities, and development risk factors.

Project Status

This project was initiated during the first quarter of FY06. The evolving nature of Exploration Systems requires multiple HPP projects elements to be executed simultaneously. Systems architecture studies are ongoing; potential processing architectures and capabilities will be derived from these studies. Concurrently, the HPP project has been surveying relevant existing and planned technology developments internal and external to NASA.

An essential component of this task is establishing traceability between ESMD mission and measurement requirements and the high performance processing technologies that will be funded. To that effect, a significant portion of this project has focused on attempting to understand the major ESMD technology drivers, ascertaining the data or signal processing capabilities required to enable or enhance missions and measurements.

Several processing options are under consideration; they include general purpose, system-on-a-chip, and various numeric coprocessor implementations such as multi-core digital signal processors and field programmable gate arrays. A single architecture will not be relevant to all of the needs identified during the project investigation. The project team will however, consider all relevant factors in determining candidates most traceable to NASA requirements.

Challenges

Several challenges must be addressed to fully realize project objectives. Some of these challenges and initial plans to approach them follow.

Emerging Technologies: Technologies that have potential to significantly increase computing performance and power efficiency are becoming fairly commonplace in terrestrial applications. One of these technologies is multi-core processors. The effective increase in performance that can result from this architecture is highly application and software dependent, however. Whereas multithreaded applications or separate applications running concurrently are well suited to this architecture, it is yet to be established that common NASA-centric applications will benefit.

Software Development Support: Hardware only addresses one aspect of high performance computing; software tools that can support the end-to-end systems development must also exist. The HPP project is primarily targeting hardware development; requisite software tools compatible with HPP hardware must already largely exist.

Deliverables Productization: Deliverables from the HPP project must be readily available for use by NASA and the larger aerospace community. To this end, other issues such as software development tools (as previously stated), and product sales and technical support must be appropriately addressed to fully meet project objectives.

Conclusion

The RHESE High Performance Processor for Space Environments project intends to enable or enhance the capabilities of Exploration systems by significantly advancing radiation tolerant processor performance and power efficiency. This task intends to leverage to the extent possible, relevant processor development efforts sponsored by other organizations, and prior work funded by NASA. Deliverables are targeted for FY12.