National Aeronautics and Space Administration

FY24 Topic Areas Research and Technology Development (TRTD)

# Investigating Spacecraft Guidance Navigation and Control (GNC) and Vision Control Element (VCE) implementation on a Next-Gen Multi-Core Processor

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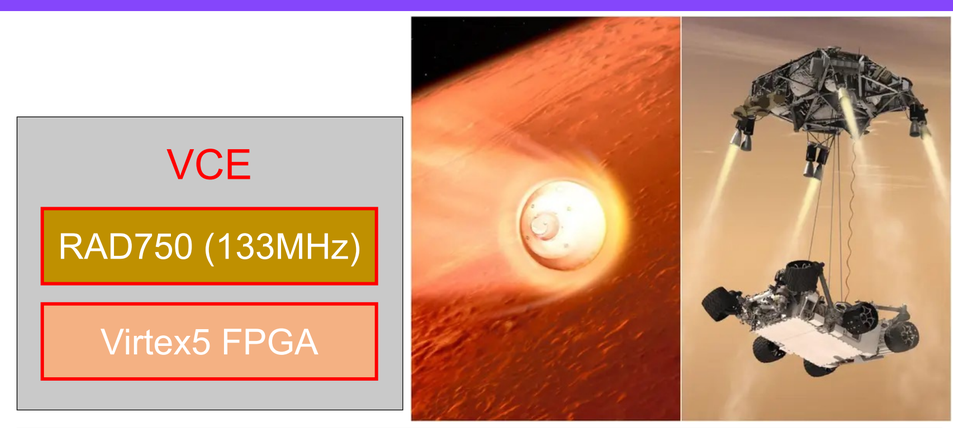
**Strategic Focus Area:** Precision Landing

**Objectives**: The Overall Objectives of the task are to study the feasibility of implementing the GNC and Lander Vision System (LVS) algorithms in VCE on a next-gen multi-core processor, and to investigate the reliability of the GNC/VCE on the multi-core processors to perform real-time object recognition and tracking operations.

**Background:** The spacecraft has a critical component – GNC. If the GNC is not functioning as intended, the mission is lost. As a part of the GNC processes, the Entry, Descent, and Landing (EDL) system is implemented on a RAD750 CPU and a Virtex5 FPGA coprocessor in a VCE that weighs 5.7 Kg and consumes ~ 36W power. The RAD750 is at its end of life. We have an opportunity to explore how more computational capability can significantly enhance the VCE function and its ability to host future GNC applications, while reducing its size and weight. NASA has invested into the High Performance Space Computing (HPSC) processor as the next generation space computing platform. JPL's Mars Helicopter has employed the COTS Qualcomm Snapdragon processors as it's on-board processors and successfully demonstrated the operations on Mars. Other COTS processors such as Nvidia Jetson GPUs and Xilinx VERSAL FPGAs also have potential in fulfilling certain space computing functions. The goal of this task is to research the best next-gen computing platform for reliably implementing real-time GNC and LVS functions and to develop fault tolerant strategies in multi-core processor architectures.




## Approach and Results:

**Task 1: Identify Key GNC and LVS Algorithms**: Completed

Selected LVS and GFOLD as the key computational algorithms in both the GNC and LVS current working models; Identified the source code, test data, and performance in current implementations.

**Task 2: Investigate the Next-Gen Multi-Core Processor Development Environment**: Completed and exceeded

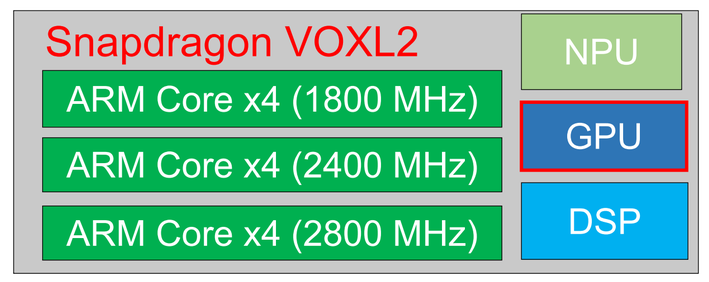
Selected two processor platforms (instead of one): Snapdragon and AMD Xilinx VERSAL.

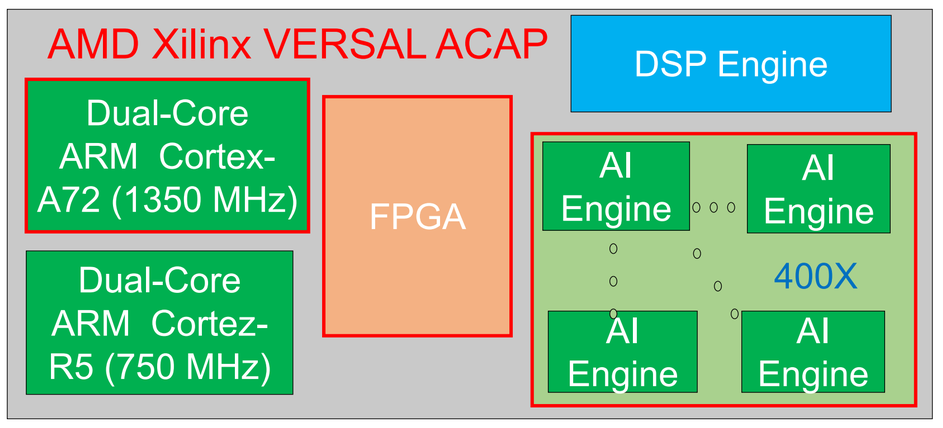
**Task 3: Implement GNC/LVS programs in a Multi-Core Processor Board**: Completed and exceeded

The GNC/LVS codes have been converted and ported to three platforms instead of one: the Snapdragon VOXL2, VERSAL and an HPSC Emulator. The input and output data have been compared to the current system to verify and validate the implementation.

**Task 4: Investigate SWaP Reductions and Speed Gains of the Board**: Completed and exceeded

Ran the GNC/LVS programs with input data, measured the SWaP of two evaluation boards instead of one. Compared the SWaP data to the current VCE system.




| | Functions | VCE | VOXL2 | VERSAL |
|---|---|---|---|---|
| LVS | Forward FFT* | 107 ms | 14 ms 7.6x | 6.79 ms 15.8x |
| LVS | FFT Correlate* | 153 ms | 27 ms 5.67x | 23.45 ms 6.52x |
| GNC | GFOLD (400**) | 0.8 s | 0.003 s 266x | 0.015 s 53x |
| GNC | GFOLD (2200**) | 7.52 s | 0.03 s 250x | 0.15 s 50x |
| | Size (mm) | 296x197 x109 | 166x75*** | 100x160x25 **** |
| | Weight (kg) | 5.7 | 0.078*** | 0.5 **** |
| | Power | ~40 W | 12.5 W max*** | 4-25W **** |

*Image Size: 1024x1024
**Solution Variable Size
***SRH ECM Avionics Solution
****AlphaData VB630 Versal AI Edge for Space Board.

## Significance/Benefits to JPL and NASA:

This task has shown the improvement of performance of GNC/LVS from 5x to 266x in speed on next-gen processors. The VOXL2 and VERSAL boards can save up to 75% size, 97% weight, and 60% power over the current VCE box. It will enable improved autonomous on-board GNC capabilities that leverage real-time computer vision, and are relevant to future missions having challenging requirements and goals. It will be a breakthrough in developing a new general purpose high bandwidth GNC computer. The success of this research will enhance the capabilities of missions Mars Science Helicopter, Venus Balloon Missions, Autonomy Small Body Explorer (e.g., DARE), Small Body Sample Return, and many more.

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RPD-107 Clearance Number: CL#24-5095



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