FRAME GRABBING AND RECORDING IN SPACE

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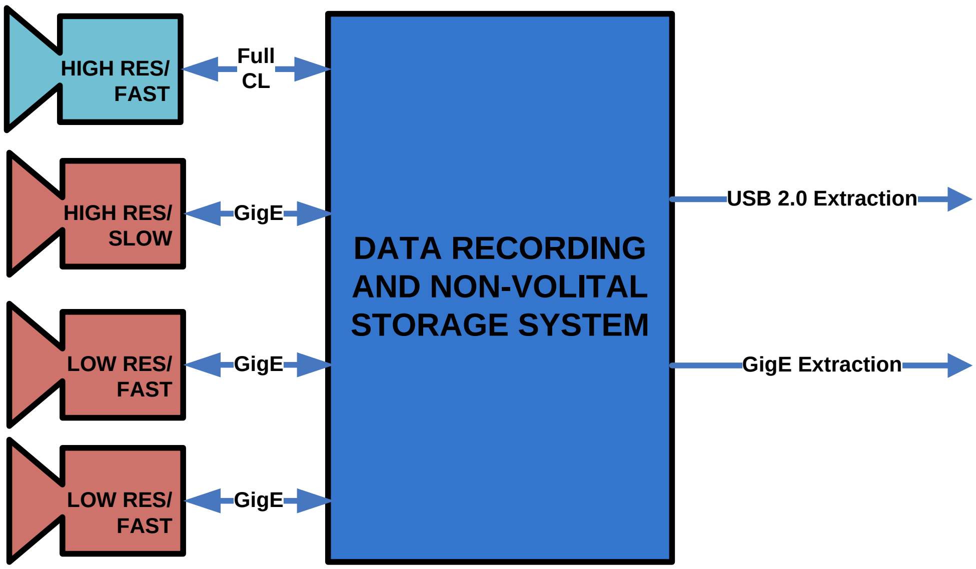
NASA'S SHUTTLE RECORDING REQUIREMENTS

There are extreme environments where shock, vibration, heat, and lack of air cooling are the norm. One such place is on board the space shuttle and it is here that NASA is considering solutions to upgrade one of its existing vehicle video/ camera recording systems. The system requirements are high frame rate, imaging from multiple cameras, and recording the video and data to a nonvolatile media which can be recovered and read out. An example use of the system would be to mount the cameras and recording system in the top of the shuttle's solid rocket boosters (see image below) and point the cameras back at the vehicle to monitor its health and status much like the small analog cameras currently installed. This example is one of many military and commercial applications that require ruggedization or militarization of a high speed frame grabber/recording system. The recording system must tolerate extreme vibration, high G shock, and lack of air cooling, while simultaneously providing high data rate recording and storage, despite power loss, over a reasonable time period.

The NASA system requirements (diagrammed below) include, unattended operation, recording for roughly 2 minutes during lift off, followed by 4 minutes of recording during the free-fall back to earth. The camera system will contain one camera operating at full camera link speeds (~500 MB/s), and two gigabit Ethernet cameras each operating at up to 75MB/s, for a total of 725MB/s. The recording must be non-volatile as the system will lose power before recovery. Furthermore, the system must tolerate power loss and power return, and restart recording, until power is lost at the end. It must have enough memory to record for 6 minutes or at least 270 gigabytes of memory. Also the system must be able to control the cameras to compensate for the varying lighting during the recording. During recording extraction after recovery, the system must support multiple methods of extraction and various computers which may not use the same operating system.



DESIRED NASA RECORDING SYSTEM

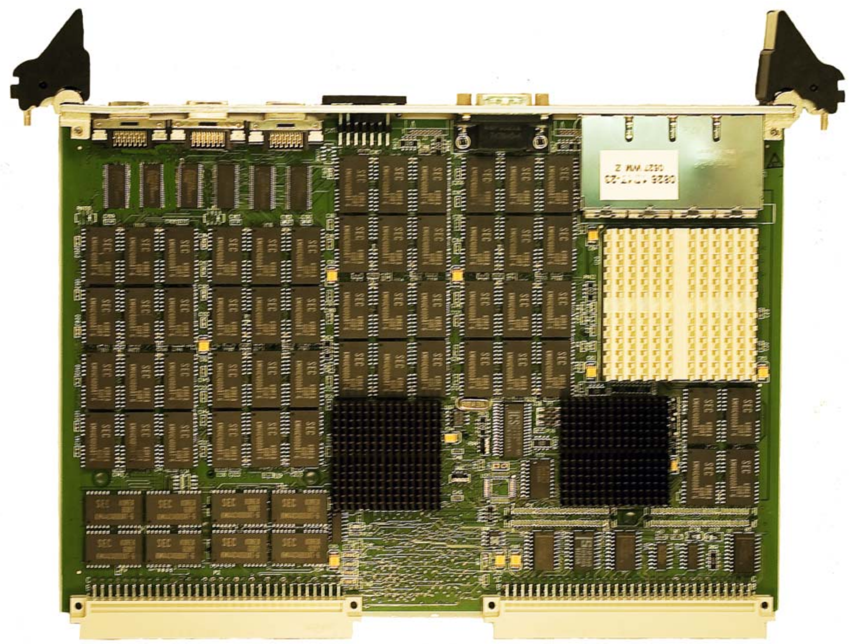
To summarize the desired recording system should be:

1. Rugged or militarized to tolerate vibration, and shock at high G forces.(preferably non-mechanical)
2. Record multiple hundreds of megabytes per second over an extended period, i.e. minutes.
3. Store and retain data despite power loss.
4. Provide camera control
5. Have the ability to be downloaded afterwards via common data interfaces, e.g. GigE or USB2.0 to computer systems running any OS, without the installation of special software.

NON-VOLATILE HIGH-SPEED DATA RECORDING AND STORAGE

When NASA contacted Alacron to determine the suitability of any of Alacron’s products to provide part or all of a solution to the system requirements listed above, it so happened that Alacron had previously developed data recording system for a previous customer which satisfied similar requirements.

The original challenge was to develop a rugged VME form-factor frame grabber/recording system that provides the best characteristics of solid state recording, without the extra overhead and disadvantages of disk drives, disk controllers, disk protocols and disk drive bulk, in a ruggedized board level product. The Alacron product is called Fast-Vault.

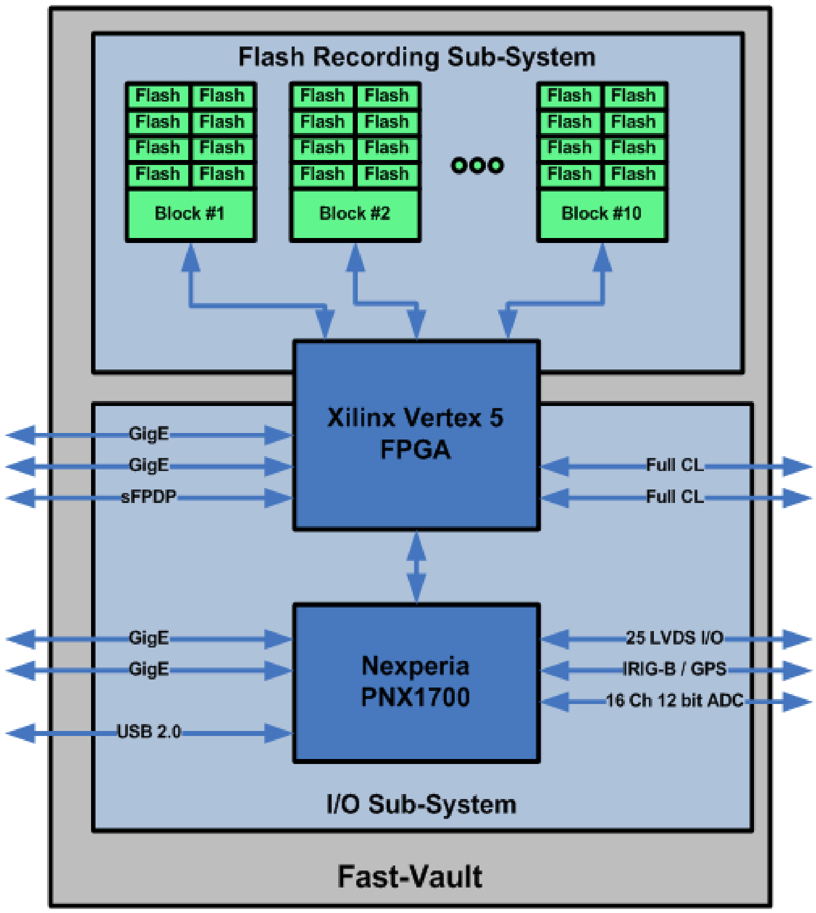


FAST-VAULT

The Fast-Vault is a combination of two on-board systems into a 6U VME form factor board, a high speed, 320 GB flash memory system, and an I/O subsystem which provides interfaces to multiple Camera Link and GigE cameras, along with analog and digital inputs.

The Fast-Vault memory system is organized as an array of ten 80MB/s recording blocks, each containing two chains of four flash memories operating at 40 MB/s. The complete system contains 80 flash chips, each containing 4 Gbytes of Micron flash memory. The recording blocks do striped recording overlapping data writes with data transfers. The recording blocks are striped by a Virtex 5 FPGA which provides an average recording rate of over 800 MB/sec to the I/O system. Writing to the flash system is performed using a write leveling algorithm to increase the life of the flash chips, error correction coding, and a defective page substitution list to prevent data loss during recording. The front panel connectors support one full camera link, two gigabit Ethernets ports, and a LVDS I/O connector. Analog inputs and serial I/O are connected to P2, with two gigabit interfaces, and the second full camera link interface on the P0 connector. The VME bus is not used by the Fast-Vault; only its power is used.

The on board, I/O system contains four gigabit Ethernet ports, a serial Front Panel Data Port interface, two full camera link interfaces, which can be split into various configurations down to 6 base camera link configuration, 16 single ended channels of 200KHz analog to digital converters with +/-10 volt inputs, and 25 LVDS input or output bits. The I/O system is controlled by a Nexperia PNX1700 processor. The on board I/O system supports extraction of the data from flash to gigabit Ethernet, or USB 2.0



BLOCK DIAGRAM OF THE FAST-VAULT

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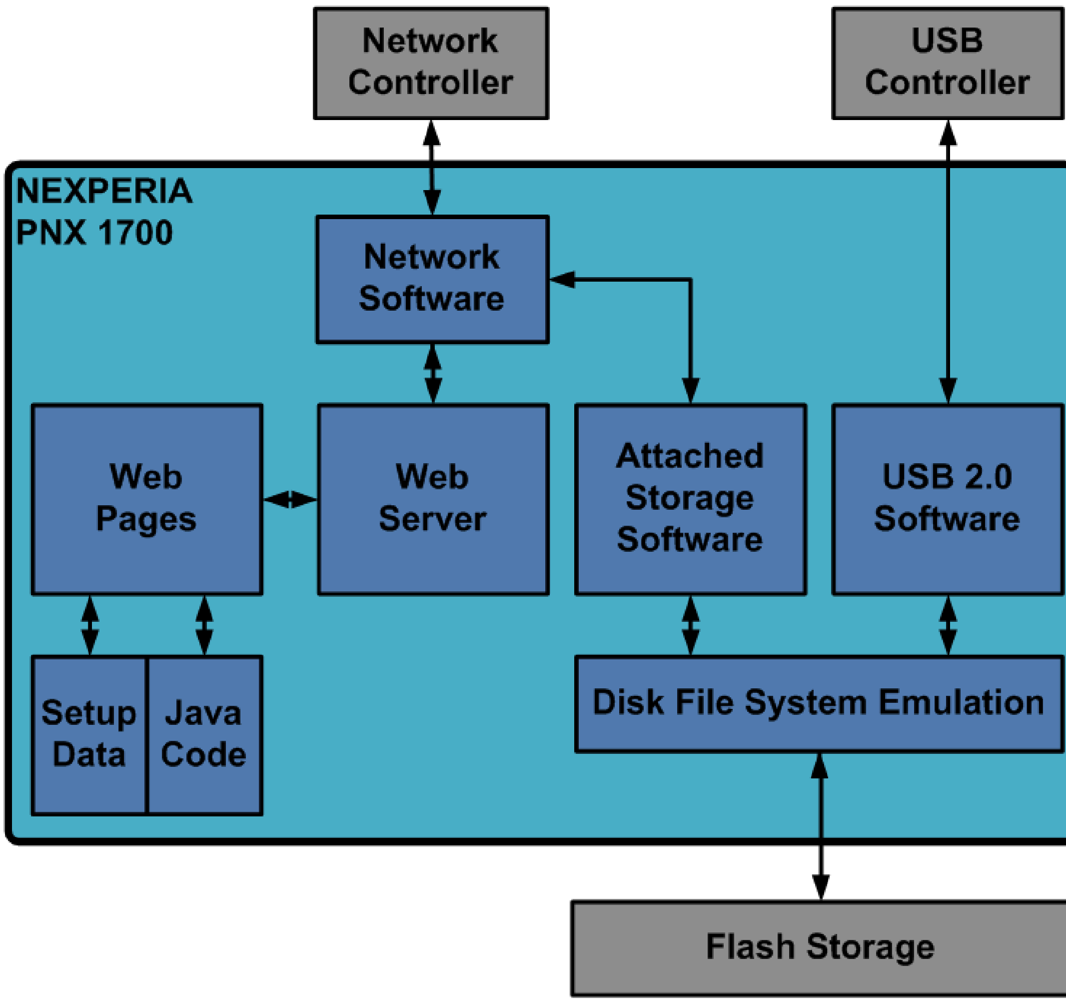
The software architecture of the system is shown below and is a Nexperia PNX1700 application. The PNX1700 supports a web server for configuration and control allowing the recording system to be configured from any workstations running any OS. Internally the Fast-Vault uses PSOS, which is not exposed to the user. The system operates as a network appliance which records high speed data sources, such as video from high resolution fast cameras, slower GigE cameras, and various analog and digital sources.

During data extraction the Fast-Vault appears as a USB disk drive or network attached storage. The PNX1700 presents the recordings in flash as a file system which contains files that contain the flight recordings. These files may be up loaded to the network, as raw files, or in the case of image recording files may be converted to AVI or MPEG files, using a Java application, down loaded from the imbedded web server to a user's computer.



SOFTWARE ARCHITECTURE

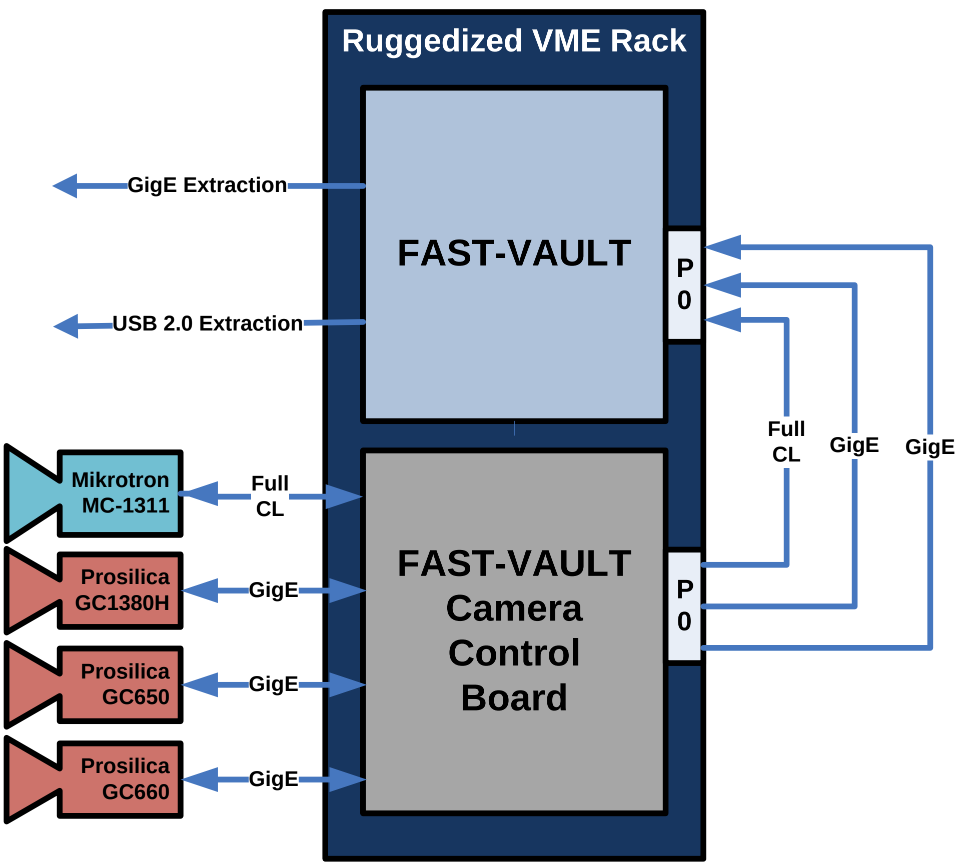
PROPOSED ALACRON SOLUTION

The proposed Alacron solution includes two Fast-Vault boards, one without flash memory. The second board provides frame grabbing, camera control, and extracts information from the images before posting them to the second Fast-Vault board used as a recording system.

As the system must operate autonomously, the proposed solution to the NASA application requires the system to start a script at power up and wait for a signal to begin recording and executing the timed events in the script. When the launch system switches to internal power a possible brief power failure can occur, which the system must tolerate.

The recording system executes a script and monitors inputs adjusting camera exposure, and frame rate during the various phases of the lift off. Various cameras are being considered such as, the Silicon Imaging SI-1920HD, Mikrotron MC1311, and Prosilica GC Series Models GC650, GC660, and GC1380H. Also, the latest cameras using Gig-E and Camera Link standards are being considered.

After the flight, the recording system is recovered, it is connected to a network and recordings are extracted. Java applets, running on the user's workstation, convert the data from raw format to AVI, MPEG, or custom formats. The Java code is obtained from the embedded web server of the Fast-Vault. The formats of the raw files are open so customers may convert them as they require. All data is time stamped and the system supports input of IRIG-B or GPS for absolute time stamping. A diagram of the complete recording system is show in the figure below.



INITIAL PROTOTYPE CONFIGURATION

CONCLUSION

The proposed Fast-Vault solution provides for all of the requirements of this NASA imaging application. While this is no guarantee that this solution will be adopted by NASA beyond the prototype stage, it does fulfill the basic requirements of a Shuttle recording system. Additionally this solution can be modified to perform equally well in many other challenging airborne, space, ocean, or land based applications.