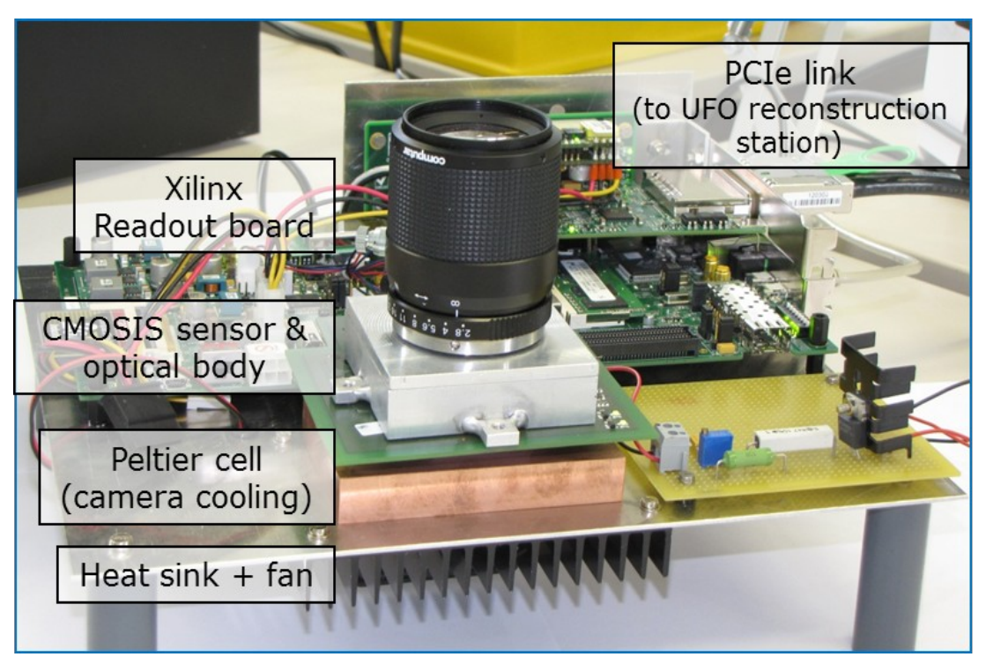
Karlsruhe Institute of Technology

ALPS – Advanced Linux PCI Services

for Rapid Prototyping of PCI-based DAQ Electronics


PCIe link
(to UFO reconstruction station)
Xilinx Readout board
CMOSIS sensor & optical body
Peltier cell (camera cooling)
Heat sink + fan

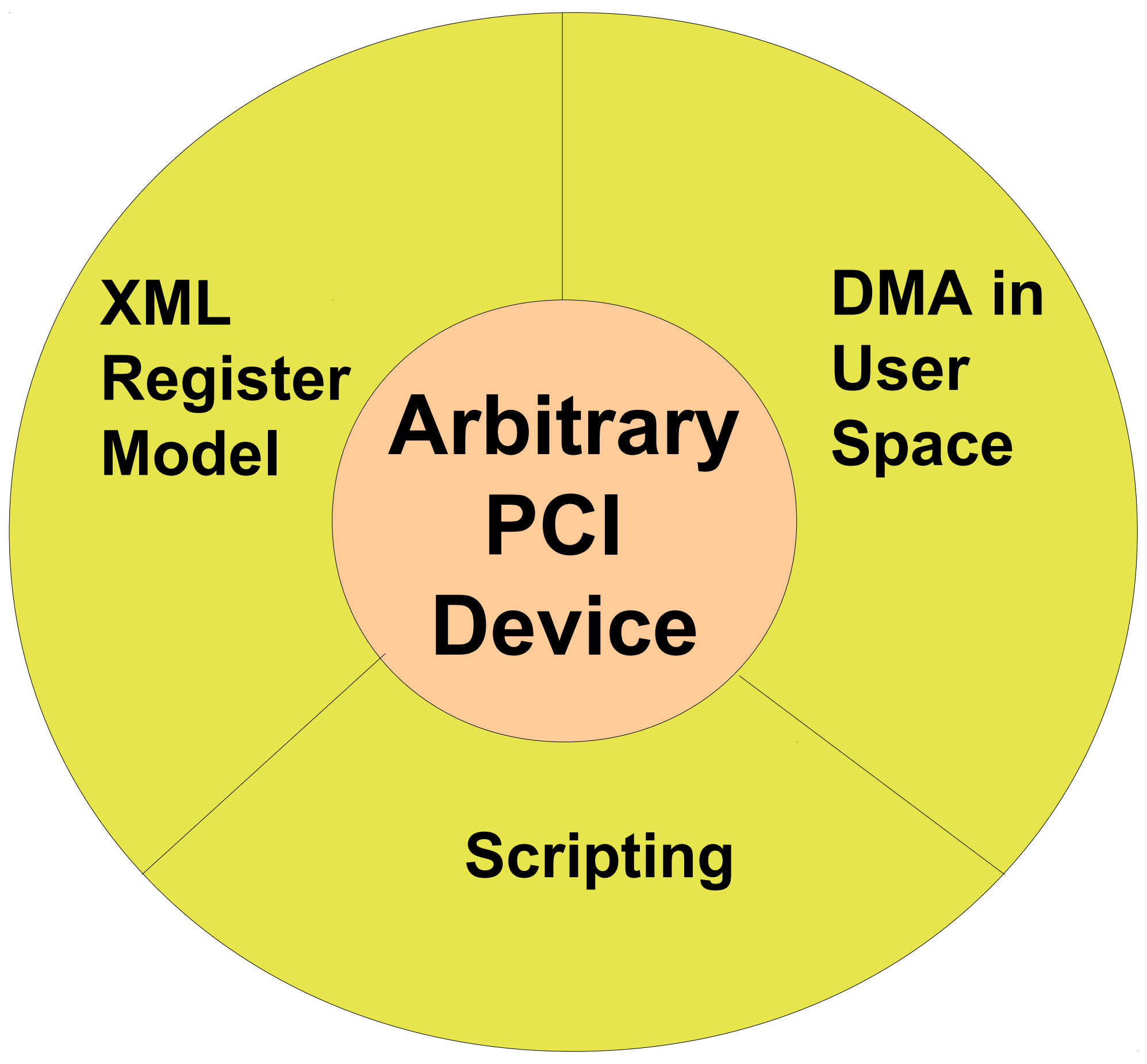
S. Chiligaryan, M. Caselle, A. Kopmann, U. Stevanovic, M. Vogelgesang

Karlsruhe Institue of Technology, Karlsruhe, Germany

ALPS (Advanced Linux PCI Services) are a flexible toolset to prototype and debug new PCI-based DAQ hardware using an universal driver.

Motivation

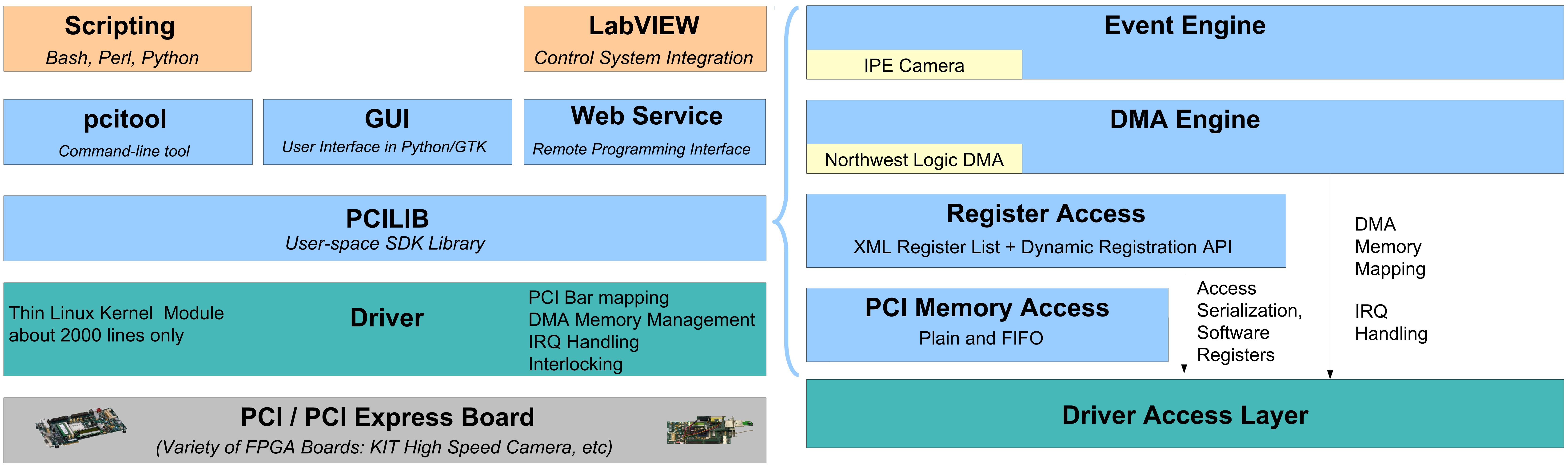
Writing stable and performant drivers and keeping them up to date with the latest Linux kernel is a complex and tedious task. It is especially difficult to synchronize parallel development of hardware and software. However, many components of PCI driver are standard. Basically, in development phase hardware engineers often only need access to the device registers and the ability transfer data between device and host memory in few different modes. This functionality may be provided uniformly for most devices by a universal driver. So, the hardware design is not blocked by missing or malfunction software and no software modifications are required for hardware debugging.



Features

- Tiny and easy to support kernel module
- XML-based register model
  - Access by address or name
  - 8-64 bit little/Big-endian access
  - Support of bit-fields
- Data Transfers
  - Plain
  - FIFO register
  - High-speed DMA support
- Register/DMA scripting support
- Device specific functions using plugins
- Web service API (planned)
  - Binding to multiple languages

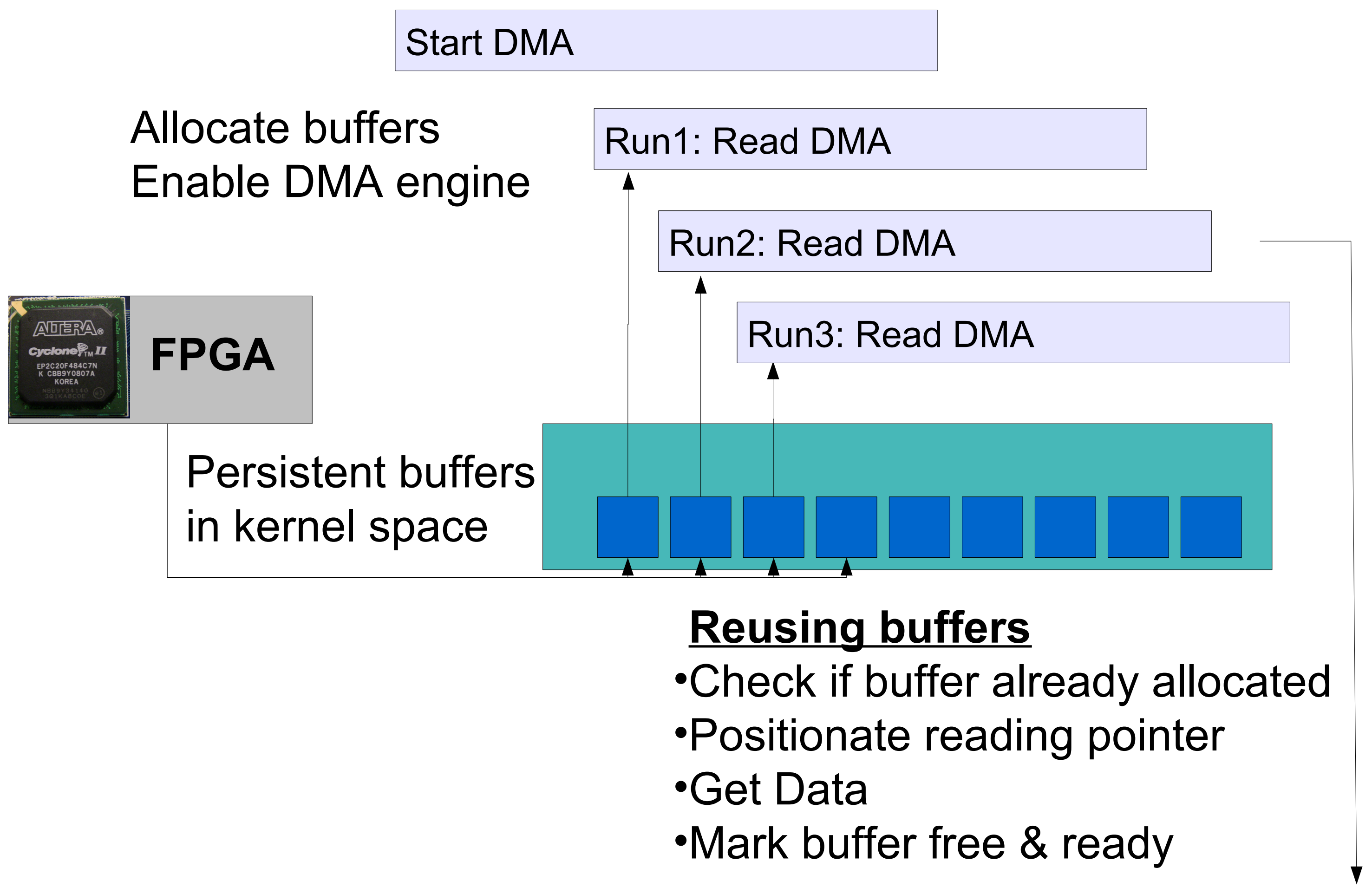
Architecture



ALPS consists of the tiny kernel driver, SDK library (pcilib), and command-line tool (pcitool). The GUI and Web Service interface are planned.

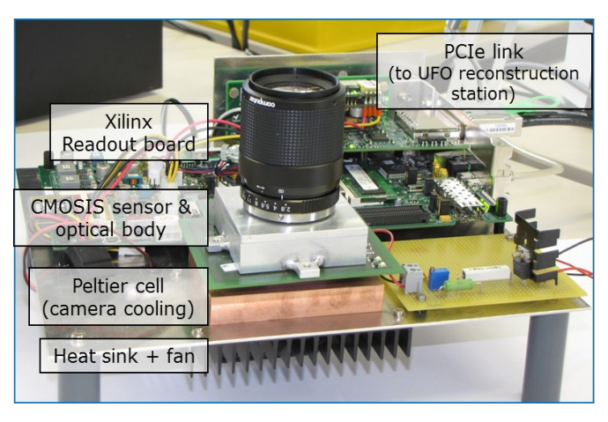
There are 4 layers in SDK library: raw access to the PCI I/O memory, register model, DMA engine, and device specific code.

DMA Engine in User Space


Start DMA
Allocate buffers
Enable DMA engine
Run1: Read DMA
Run2: Read DMA
Run3: Read DMA
FPGA
Persistent buffers in kernel space
Reusing buffers
•Check if buffer already allocated
•Positionate reading pointer
•Get Data
•Mark buffer free & ready

- DMA implemented in user-space
  - Tiny and easy to support kernel module responsible for synchronization and memory management
  - Easily extensible to new DMA protocols without kernel-level programming
- Persistent kernel buffers
  - Scripting and debugging support
  - Read/Write/Peek functionality
  - Page/Packet/Buffer access levels
- High performance
  - 1350 Mb/s camera is tested with real-time frame decoding

Example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KIT High Speed Streaming Camera

Resolution: 2048 x 1088 @ 10 bits:

Frame Rate: 300 fps

Data Rate: 1350 MB/s

```
pci --start-dma dma1
pci -g -o images.raw --run-time 60000000 &
pid=$!
for i in `seq 1 100000`; do
    old_size=`ls -la images.raw | cut -d " " -f 5`
    pci --trigger
    new_size=`ls -la images.raw | cut -d " " -f 5`
    usleep 100000
    if [ $old_size -eq $new_size ]; then
            echo "Incomplete frame..."
            killall -SIGINT pci
            break
    fi
done
wait $pid
pci --stop-dma
```

```
pci -r status
status = 0x80080000

pci -r 0x9000 -s 16 -a 32
9000:  00007300  00000000  00007300  00000000
9010:  000b7300  00000000  000b7300  00000000
9020:  00000004  00000000  00000004  00000000
9030:  00000004  00000000  00000004  00000000

pci –list-dma-buffers
Buffer     Status     Total Size
-----------------------------------------------------------
    0    U  FL      4 KB
  747    U  FL      4 KB
  748    U  F       4 KB
  749    U   L      8 B
  750               0 B
-----------------------------------------------------------
U - Used, E - Error, F - First block, L - Last Block
```

Example of script used for debugging of the high-speed camera to find a problem with camera trigger signals (left). The presented script initializes DMA engine and starts grabbing frames in the background process. The software triggers are send in the loop. If after trigger is sent, the size of file does not change within 100 milliseconds, the grabbing thread is killed and the script is terminated without stopping DMA engine. Then, hardware developer can investigate the status registers, state of DMA engine, etc (right). It is possible to see that the last DMA message has extra 8 bytes which could be the source of problem.

Contacts:

Suren A. Chilingaryan
Email: Suren.Chilingaryan@kit.edu
Phone: +49 7247 82-6579

Andreas Kopmann
Email: Andreas.Kopmann@kit.edu
Phone: +49 7247 82-4910

Institute for Data Processing and Electronics