Video Camera for Harsh Environments in Nuclear Energy Applications (SBIR Phase IIB)

Advanced Sensors and Instrumentation (ASI) Annual Program Webinar (Oct – Nov 2023)

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Project Overview

Technical Objective: Develop and test *high-frame rate* video sensor and camera that is capable of operating high radiation environments. The video camera will improve the state of the art of cameras available for nuclear energy research.

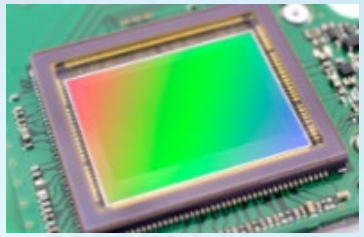
In the field of nuclear-heated transient testing, one of the experiments needing this type of camera is “reactivity-initiated accident simulation with video observation of coolant transient boiling”.

According to a Technology Expert: *“The main benefit from a very high frame rate and extreme radiation hardness camera would be that for the first time some of the unknown mechanisms could be seen and better understood. One of the mechanisms is the coolant transient boiling phenomena. Seeing this boiling requires very fast camera placed at harsh reactor environments.”*

Ph IIB Goal: Alphacore will optimize the DOE Nuclear Energy SBIR sponsored advanced camera for a commercial launch.

The optimized larger pixel count camera is called Falcon-RH-SXGA.

Alphacore will be working with a partner from the nuclear energy industry.



Motivations:

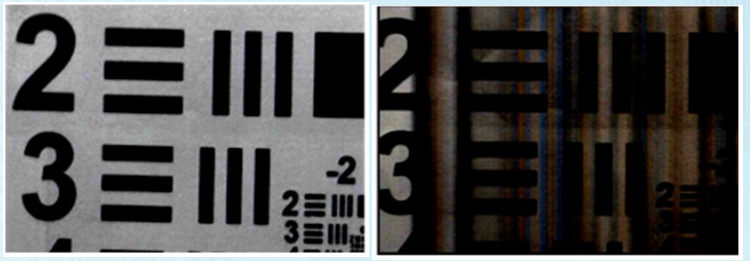
1. Frame Rate

Selected Pixel Array Configuration	Falcon-RH-SXGA (200 Mrad)	Diakont D40 (200Mrad)
1024 x 1280	375 fps	30 fps (eff.) for 728 x 492 (eff.)
640 x 512	1,500 fps	
512 x 512	1,880 fps	
384 x 384	3,330 fps	
320 x 256	6,000 fps	
256 x 256	7,500 fps	

Note that the frame rate is programmable, e.g. 30 – 375fps for the highest resolution.

2. Radiation Hardness

Radiation hardness of high-frame rate commercial cameras is poor



a) b)

- **Figure a)** COTS high-speed camera image at 0 krad(Si).
- **Figure b)** Same sensor, after 3.2 krad(Si). Image degradation was seen already at 900 rads(Si).
- Custom-hardened cameras are needed for imaging in radiation environments.

3. Upgrading Old Technology

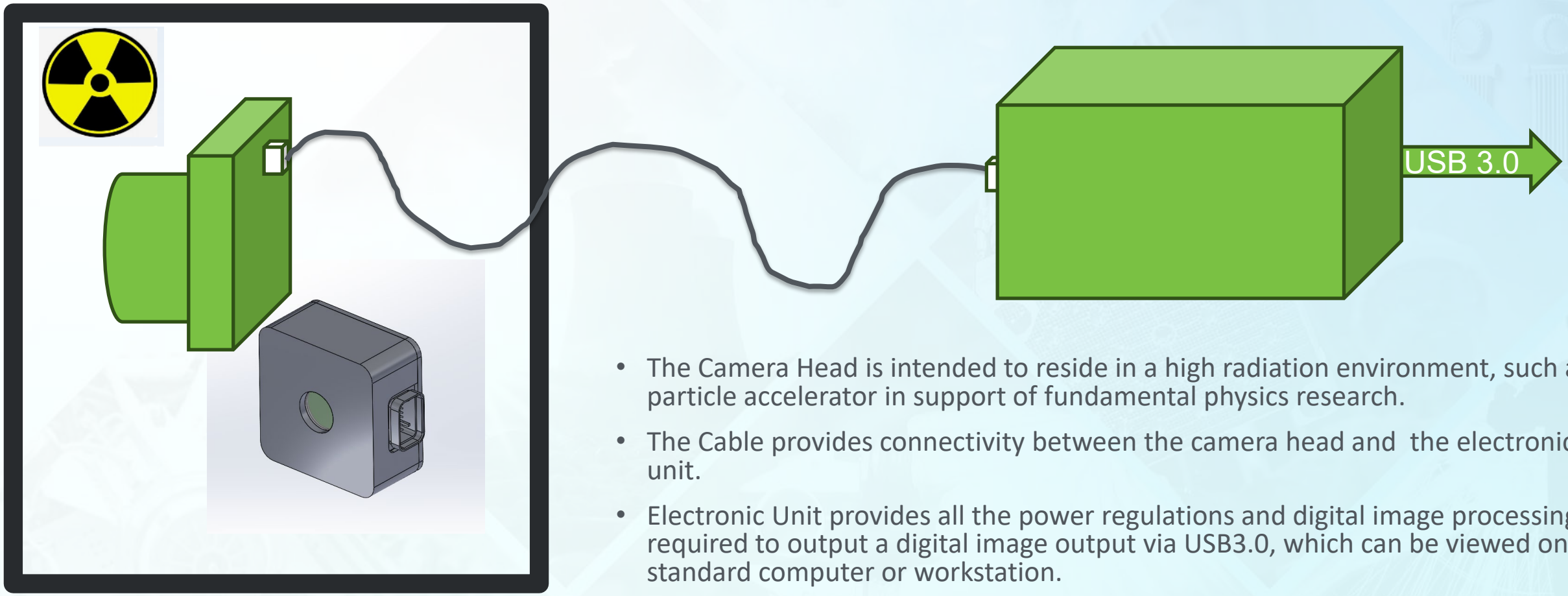
Vidicon Tube used in Radiation Hard Cameras

Technology Impact

- Through this Phase IIB program, we're building a higher resolution version of our Phase II Image Sensor, Falcon-RH (512 x 640), and this new sensor is called the Falcon-RH-SXGA (1,024 x 1,280)
- Alphacore's image sensor and camera provide *50X higher Frame Rate* than existing ultra-rad-hard cameras used in Nuclear Energy applications. It also provides *Array Resolution vs Frame Rate Programmability*.
- Optimized for higher temperatures (100°C with no cooling, 30°C with liquid cooling.
- Enables new types of tests/research in *Nuclear Reactor Research*.
- Novel CMOS Image Sensor will be offered to the *Nuclear Facility Inspection/Monitoring* market sector. Higher performance, higher radiation hardness, better manufacturability and lower cost than existing solutions.
- Image sensor with potentially the highest level of radiation hardness will be also offered to the booming *Space* market sector.

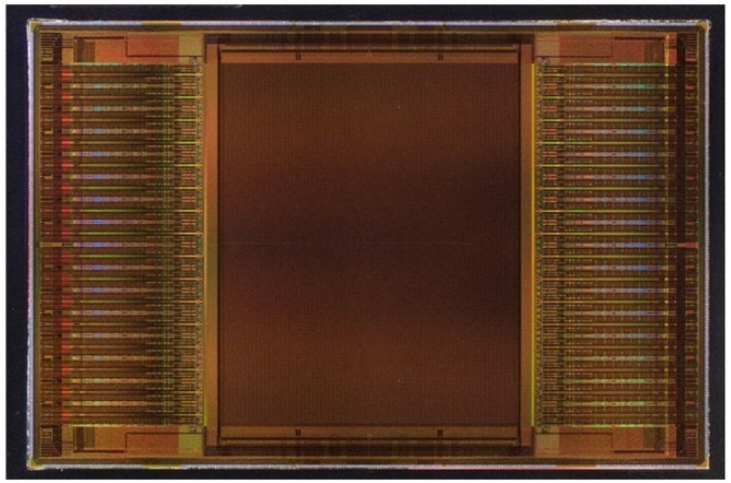
Results and Accomplishments: Falcon Camera System

- The Falcon Camera System consists of a Camera Head, Cable and Electronic Unit

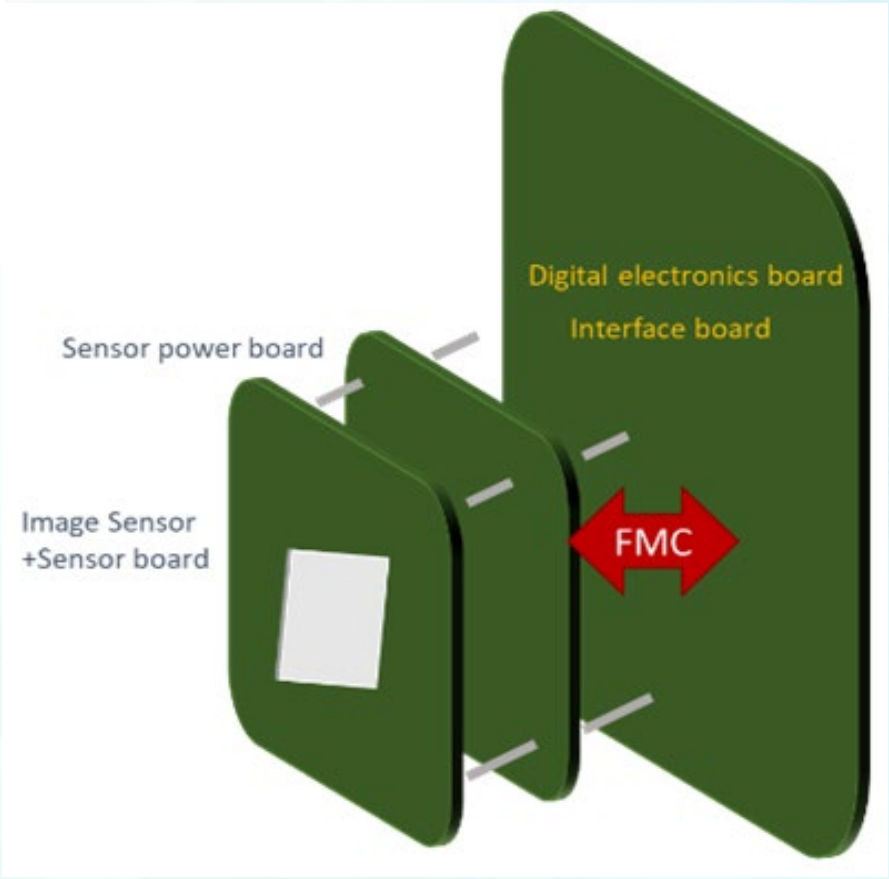


- The Camera Head is intended to reside in a high radiation environment, such as a particle accelerator in support of fundamental physics research.
- The Cable provides connectivity between the camera head and the electronics unit.
- Electronic Unit provides all the power regulations and digital image processing required to output a digital image output via USB3.0, which can be viewed on a standard computer or workstation.

Results and Accomplishments: Falcon Test Chip and Electronics



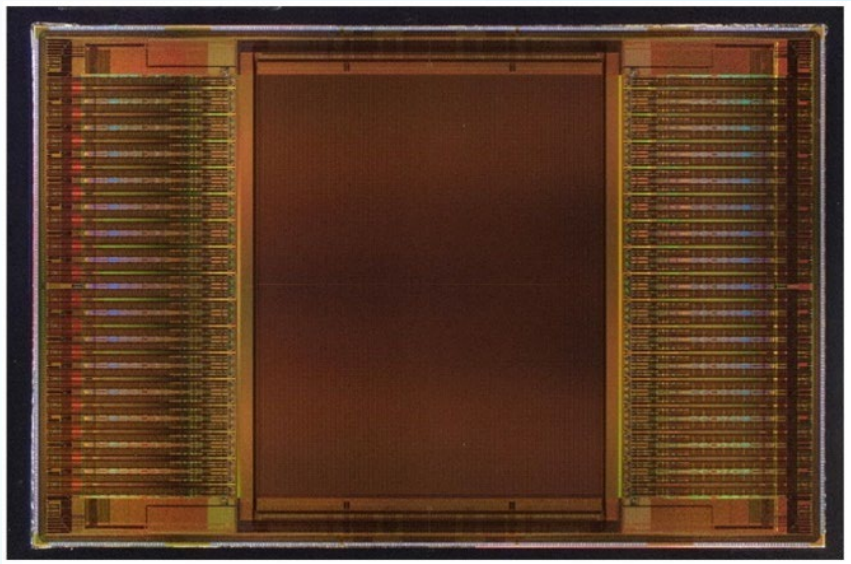
Falcon-RH Image Sensor (Test Chip)



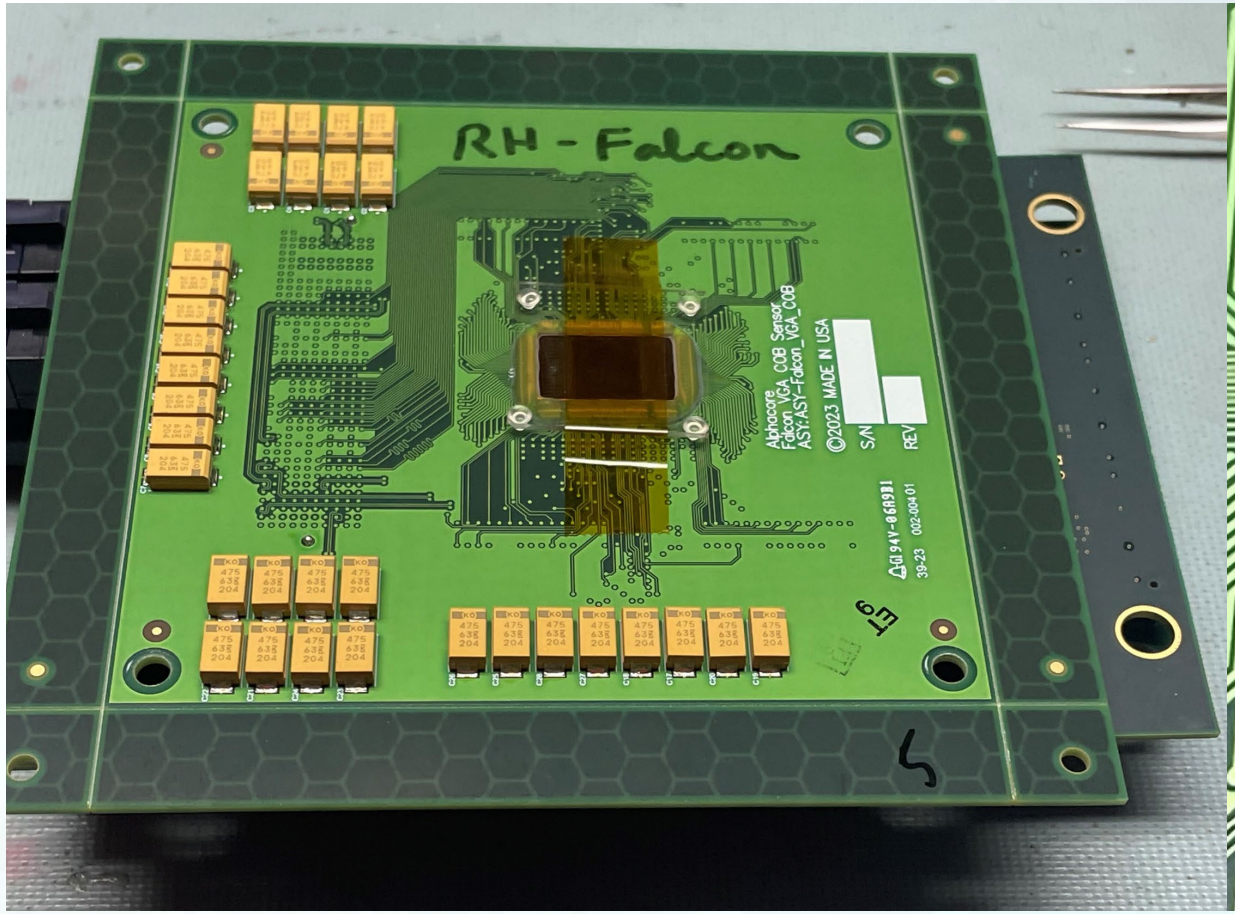
- Mechanical Design
  - Two enclosures
- Board Design
  - Sensor Board – Completed
  - Power Board – Completed
  - Digital Electronics Board – Completed
- Firmware/Software Development
  - On-going

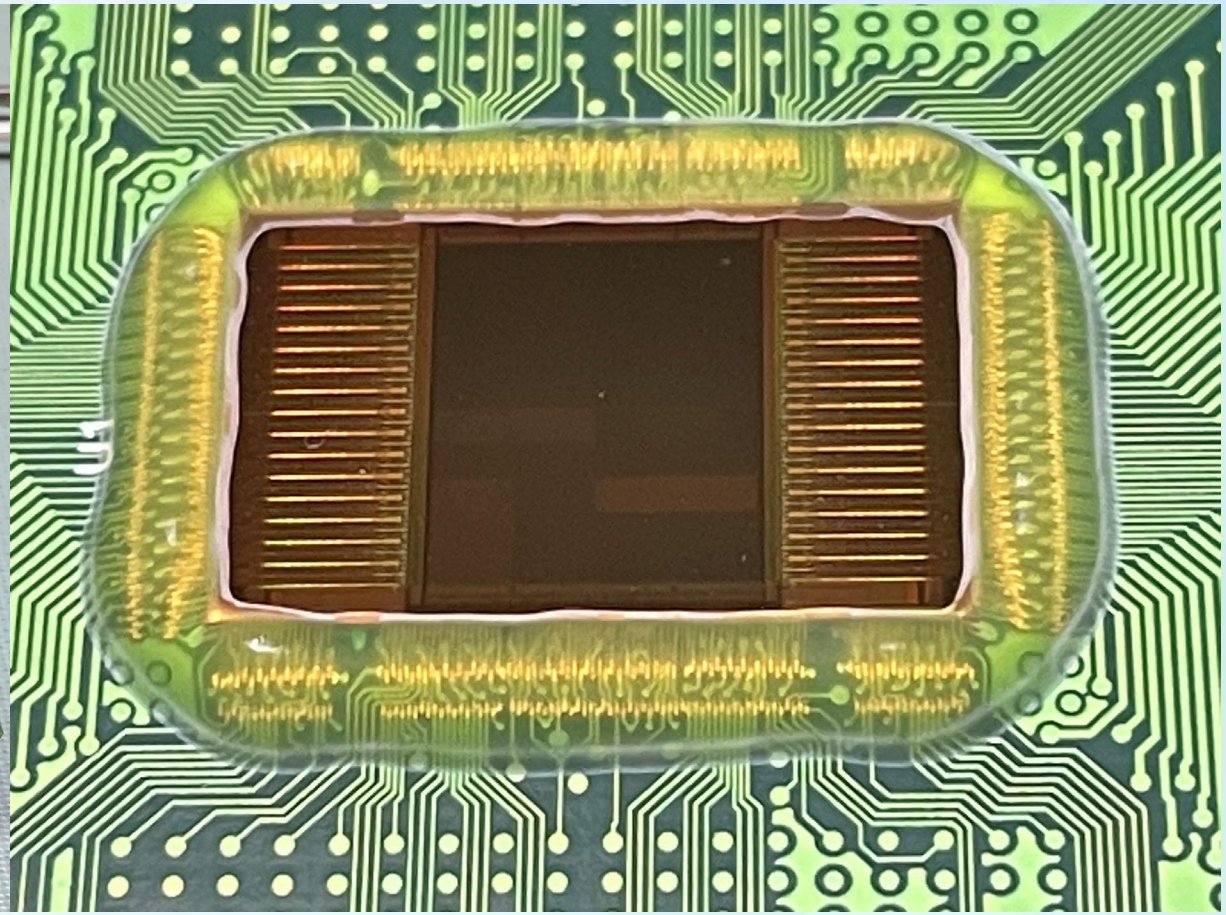
Results and Accomplishments: Image Sensor

- Designed and taped out (photo shown)



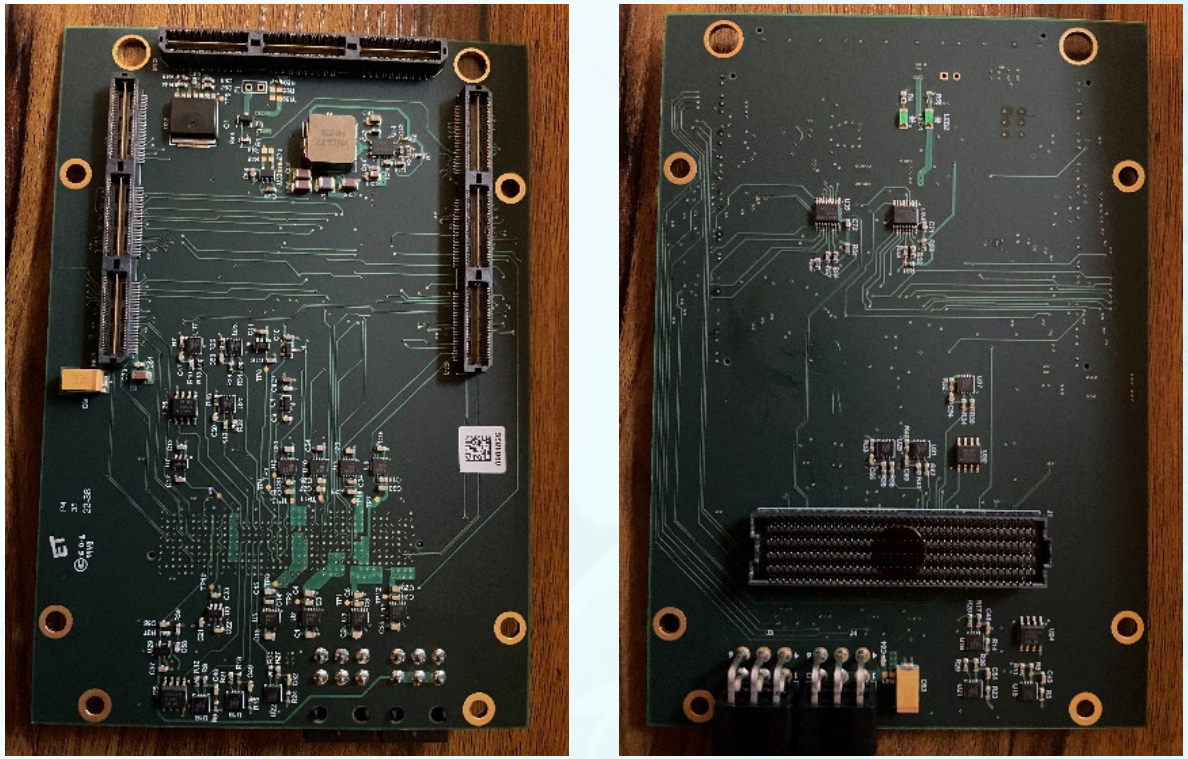
Results and Accomplishments: Falcon-RH Sensor Board





Results and Accomplishments: Falcon-RH Sensor Power Board

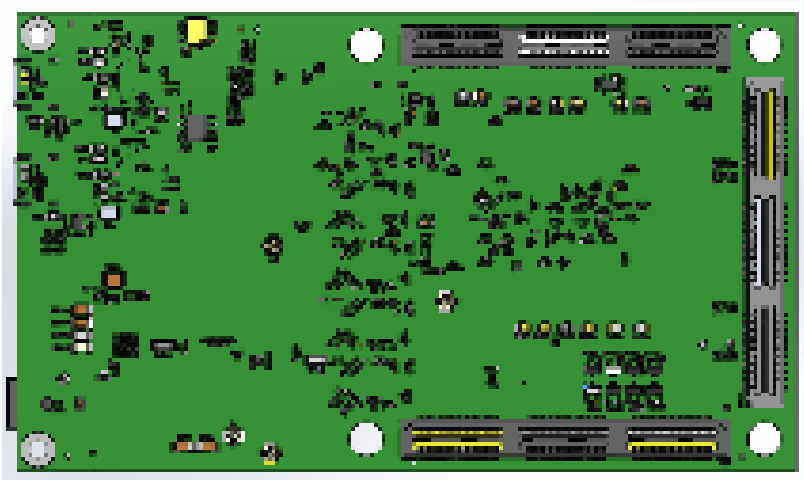
- Falcon Power Board shown below

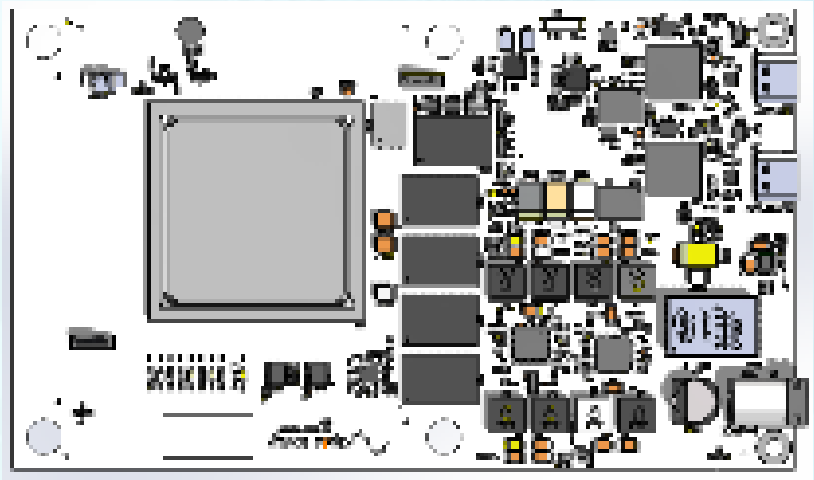


Falcon-RH Power Boards

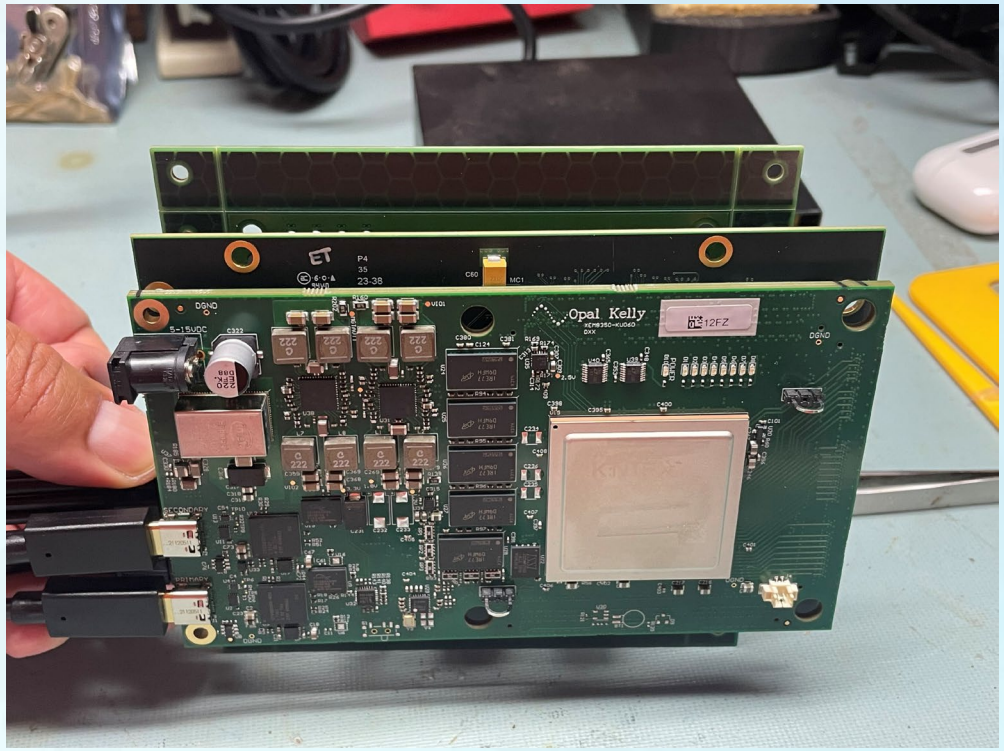
Results and Accomplishments: Falcon-RH Digital Electronics Board

- Based on Xilinx UltraScale FPGA
- Supports Required I/O
  - Ample processing capabilities
  - USB 3.0 Output for ease of integration with computers





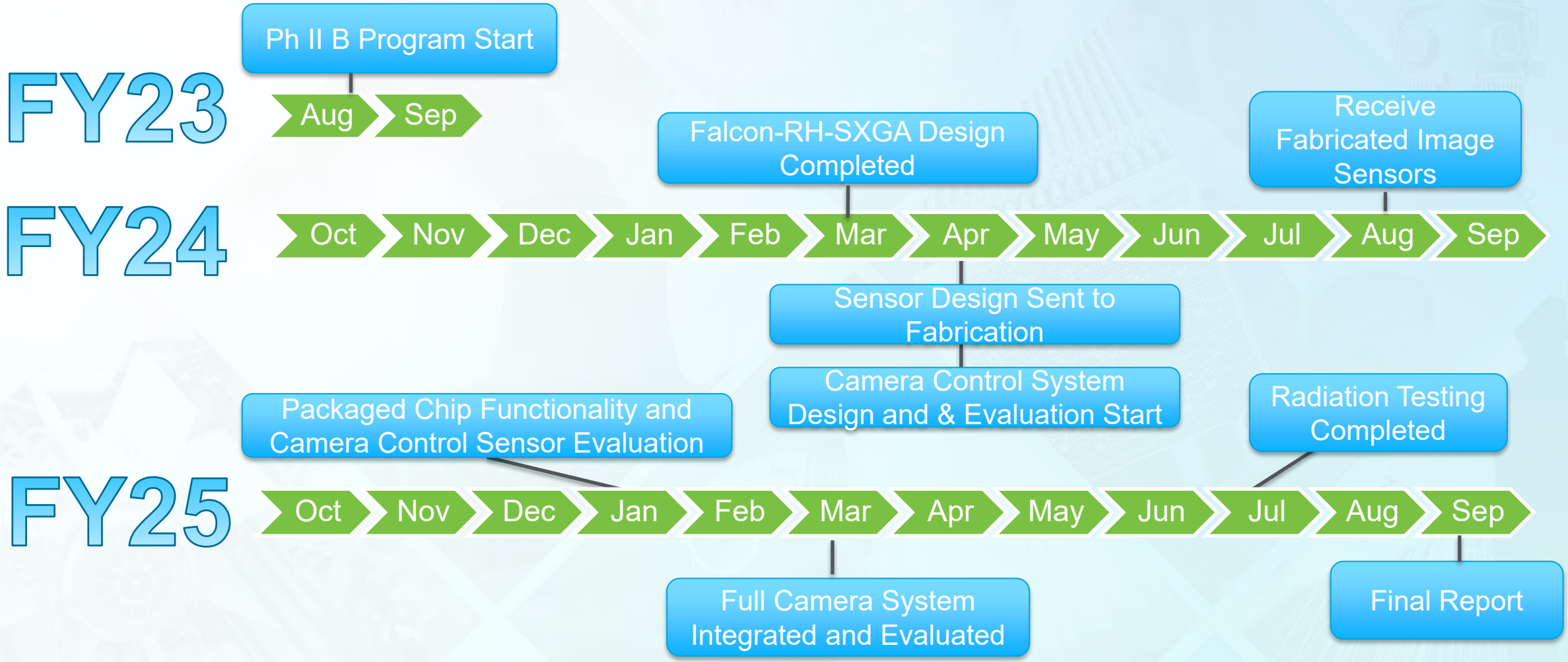
Results and Accomplishments: Falcon-RH Electronics Unit



Fully integrated Camera Electronics Unit with all three boards stacked (Side view and front view)

Phase IIB Project Schedule

Timeline of activities in FY-23 and FY-24



Concluding Remarks & Next steps

Novel CMOS Image Sensor will be offered to the Nuclear Facility Inspection/Monitoring market sector. Higher performance, higher radiation hardness, better manufacturability and lower cost than existing solutions.

Image sensor with potentially the highest level of radiation hardness will be offered to the booming space market sector.

Alphacore has made good progress on all five technical areas of the program: Falcon-RH Image Sensor, Enclosure/Optics, Rad-hard Cable with rad-hard Interface Circuit, Camera Control Board and Firmware/Software.

The image sensor architecture will be optimized to enable scalabilty for the Falcon-RH-SXGA, and the Sensor Tapeout is Scheduled for April 2024.

Full camera will be integrated and evaluated by March 2025.

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Thank You

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