Integration of a Network Synchronized Motion Tracking Camera into a Real-Time Positron Emission Tomography Data Acquisition System

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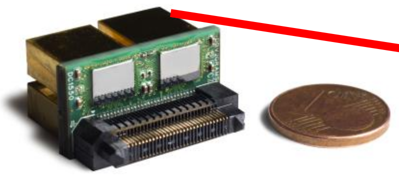
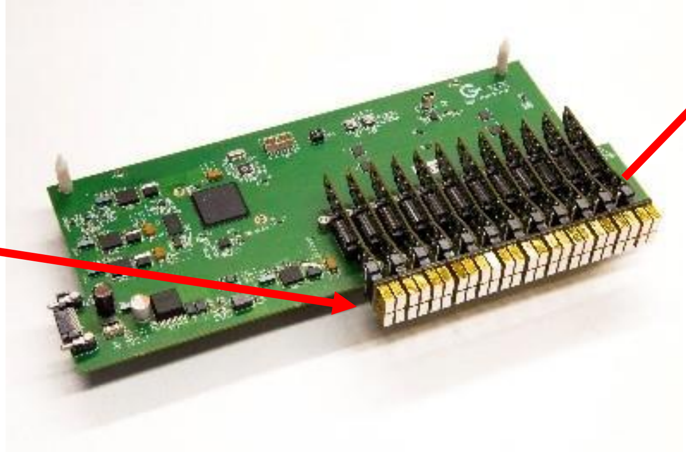
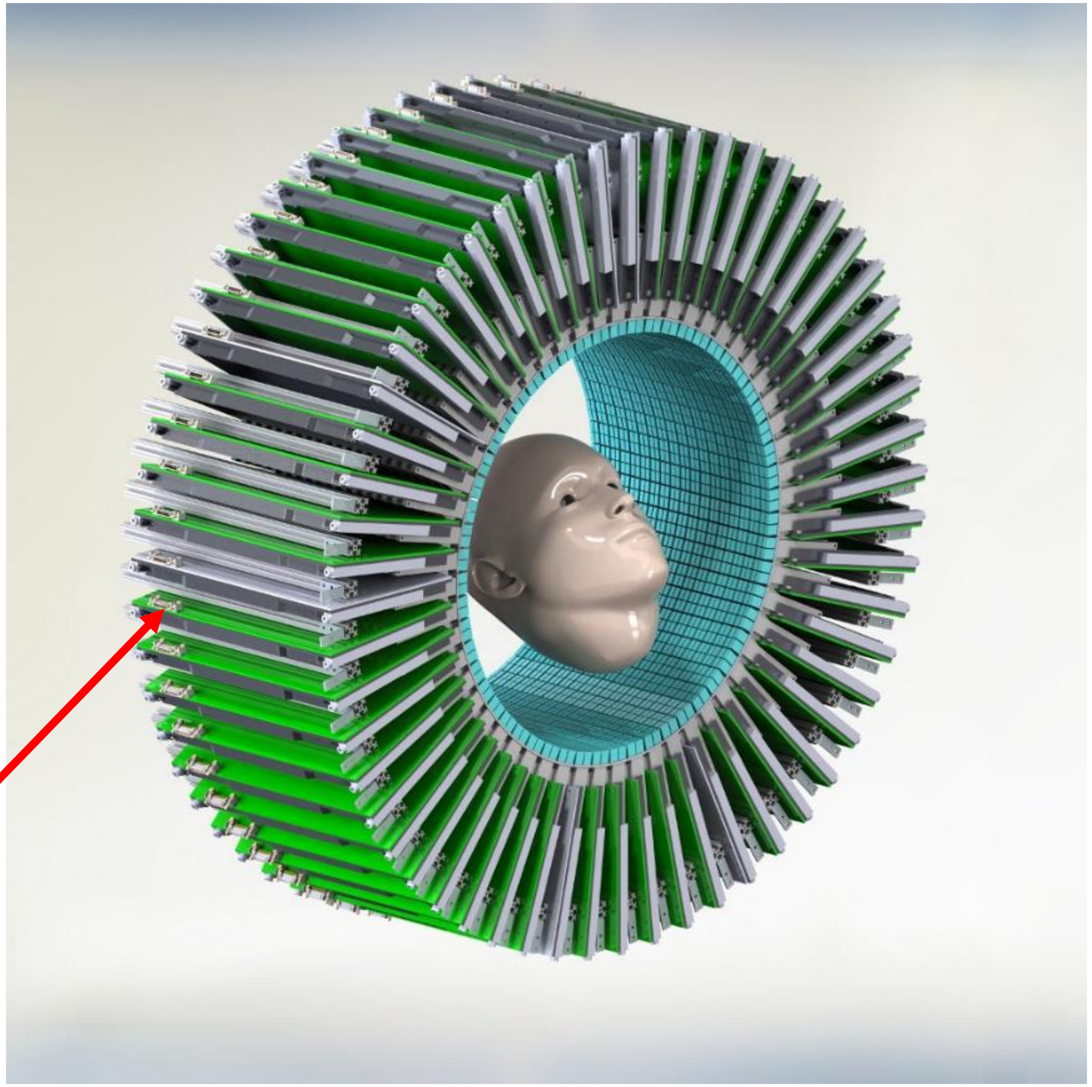
Context

We are building a high-resolution brain PET scanner, the Scanner Approaching in Vivo Autoradiographic Neuro Tomography (SAVANT) [1]. Based on the LabPET-II's technology platform with 1:1:1 crystal to APD to electronic channel coupling, it is expected to reach 2 μL volumetric resolution. At this resolution level, slight, involuntary head movement and even normal physiologic processes such as respiratory and cardiac activities will blur the image and spoil the exquisite intrinsic performance of the device. An accurate head motion correction scheme is therefore paramount to maintain the target spatial resolution *in vivo*. Similarly, by including high accuracy motion information in the reconstruction engine, it becomes possible to attempt super-resolution image reconstruction, potentially magnifying the obtained spatial resolution. An external motion capture device therefore needs to be integrated in the overall PET system.



LabPET-II module

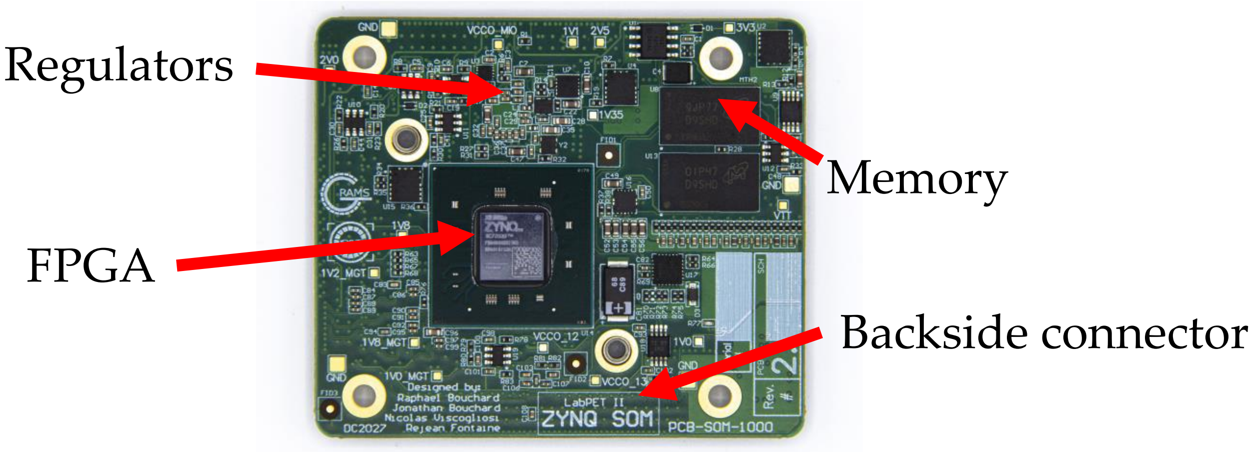




Materials

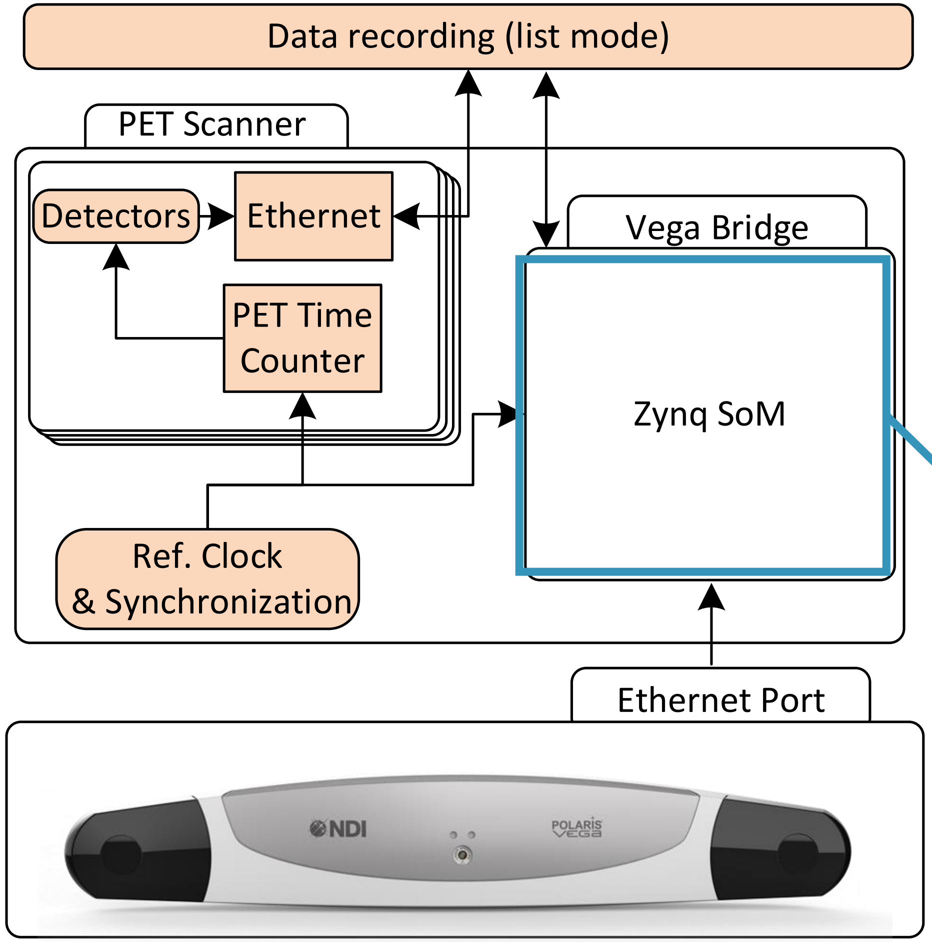
- Polaris Vega
  - 6D motion capture camera
  - Ethernet connection only
    - no trigger ports
  - 0.12 mm RMS spatial resolution
  - 20, 30 or 60 frames per second
  - 400 to 1200 us exposure time

- PET DAQ: Zynq-7000 module
  - Clock distribution, data collection, control, monitoring
  - Supports multi-ethernet ports
  - See poster #160
    - Bouchard et al, RT2020 [2]

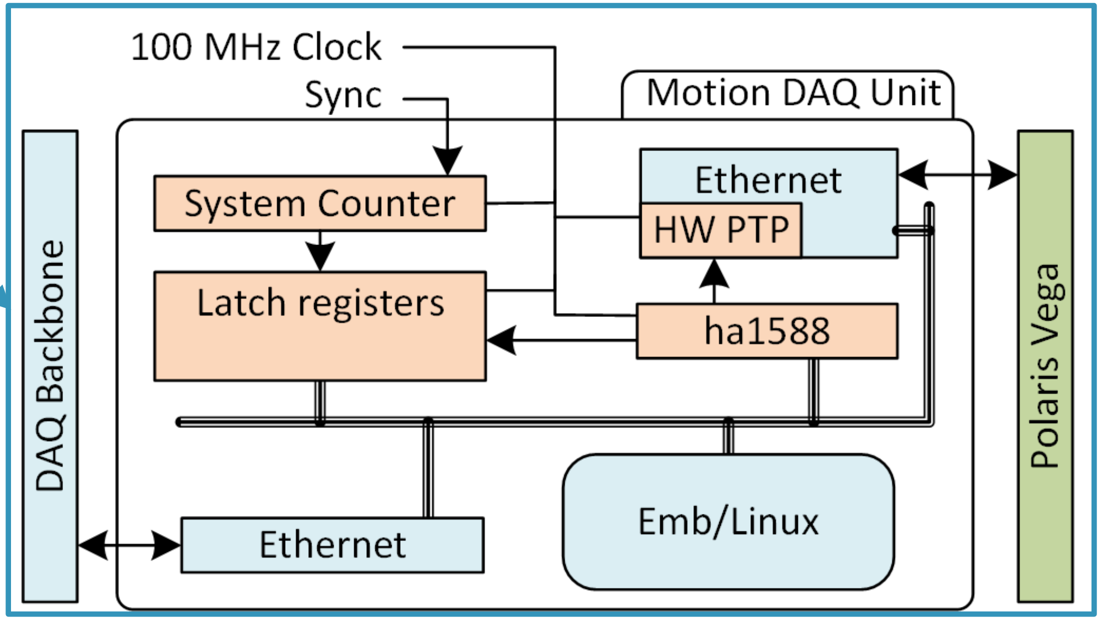


Methods

- Main DAQ system
  - Samson et al, RT2020, #66 [3]



- Vega PTP bridge design
  - Hardware/FPGA modules
    - Opensource VHDL + Linux driver
    - PTP counter in lockstep with PET counter
  - Software modules (Linux)
    - PTP Master service
    - Vega manager with motion data repackaging
      - Replaces PTP timestamp with PET timestamp



Methods

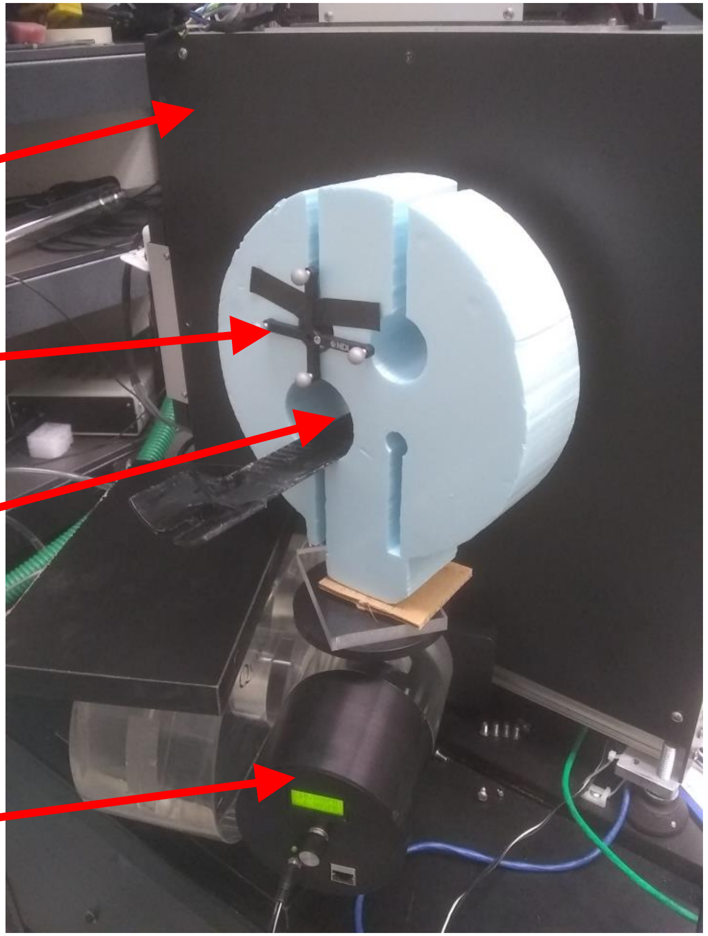
- System tests

Preclinical scanner

Tracking tool

Phantom (in bore)
  Ultra micro Derenzo

Up/down motion motor
  Sin-wave



Polaris Vega (not seen)
  Facing towards tracking tool

- Image Reconstruction
  - SAVANT engine under preperation
    - Basic Siddon projector
    - No corrections yet (randoms, attenuations, etc.)
  - Static phantom
    - MLEM
  - Motion phantom
    - Non-corrected MLEM
    - Motion corrected MLEM
      - Regular, linear motion
      - Split data into 20 positions
      - ~0.450 mm displacement between positions

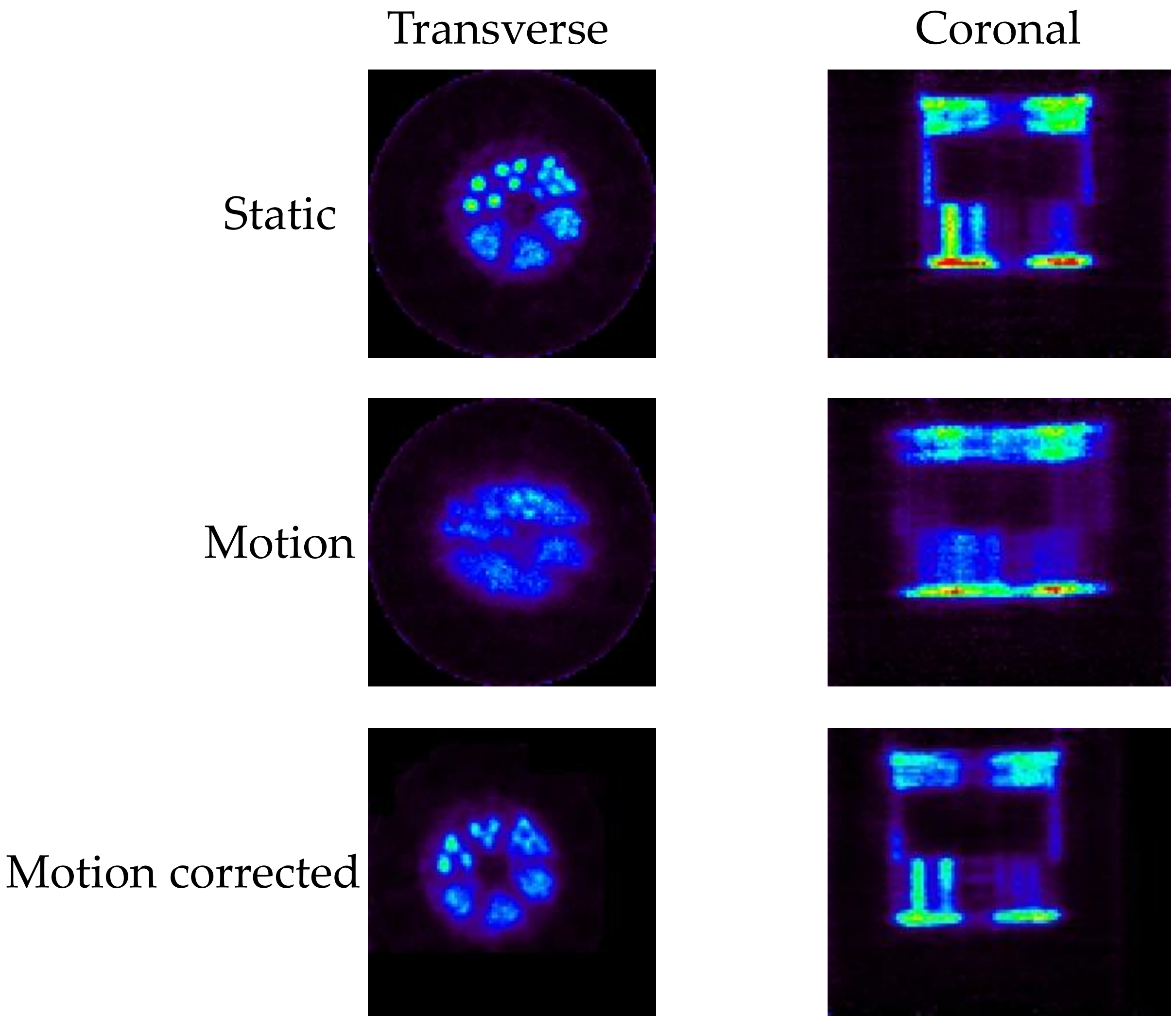
Results

- PTP synchronization results
  - Reported by Vega internal registers
  - Goal : 10x less than exposure time
    - Should be less than 40,000 ns

	Min (ns)	Max (ns)	SD (ns)
HW/PTP	-23	19	7.6
SW/Zynq	-1,098	2,428	495.6

  - Zynq-7000 can only use SW mode without SMP module
    - Still well within requirements
  - HW PTP reaches ±25 ns
    - Consistent with HW PTP results published in other applications [4]

- Motion correction



Conclusion

- Timing alignment successful
- Inserts motion data with PET system timestamps
- Successful reconstruction
- SW portion adaptable to other embedded platforms (i.e. RPi) [4]

- References

  - [1] Gaudin et al, IEEE TRPMS, 2019
  - [2] Bouchard et al, RT2020, Poster #160
  - [3] Samson et al, RT2020, #66
  - [4] Moreira et al, IEEE Tr. On Smart Grids, 2017