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Development of new high-speed readout system for SOI pixel detectors

○Ryutaro NISHIMURA (SOKENDAI / KEK),
Y. Arai, T. Miyoshi, K. Hirano, S. Kishimoto,
R. Hashimoto, L. Song, Y. Lu, Q. Ouyang
and SOIPIX Group

Outline

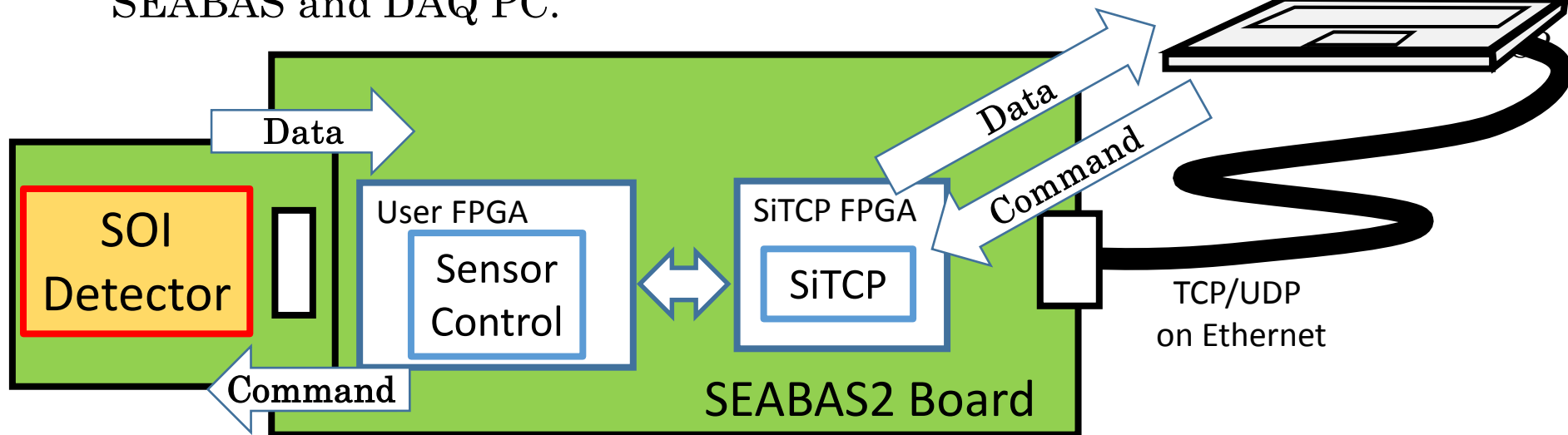
- Recent status of SEABAS DAQ
 - Increase readout speed by software re-development
 - Verification of readout speed
- Main Board replacement
 - Limit of SEABAS
 - Kintex-7 FPGA (KC705)
 - KC705 DAQ system prototype
- Conclusion

Recent status of SEABAS DAQ

SEABAS DAQ system



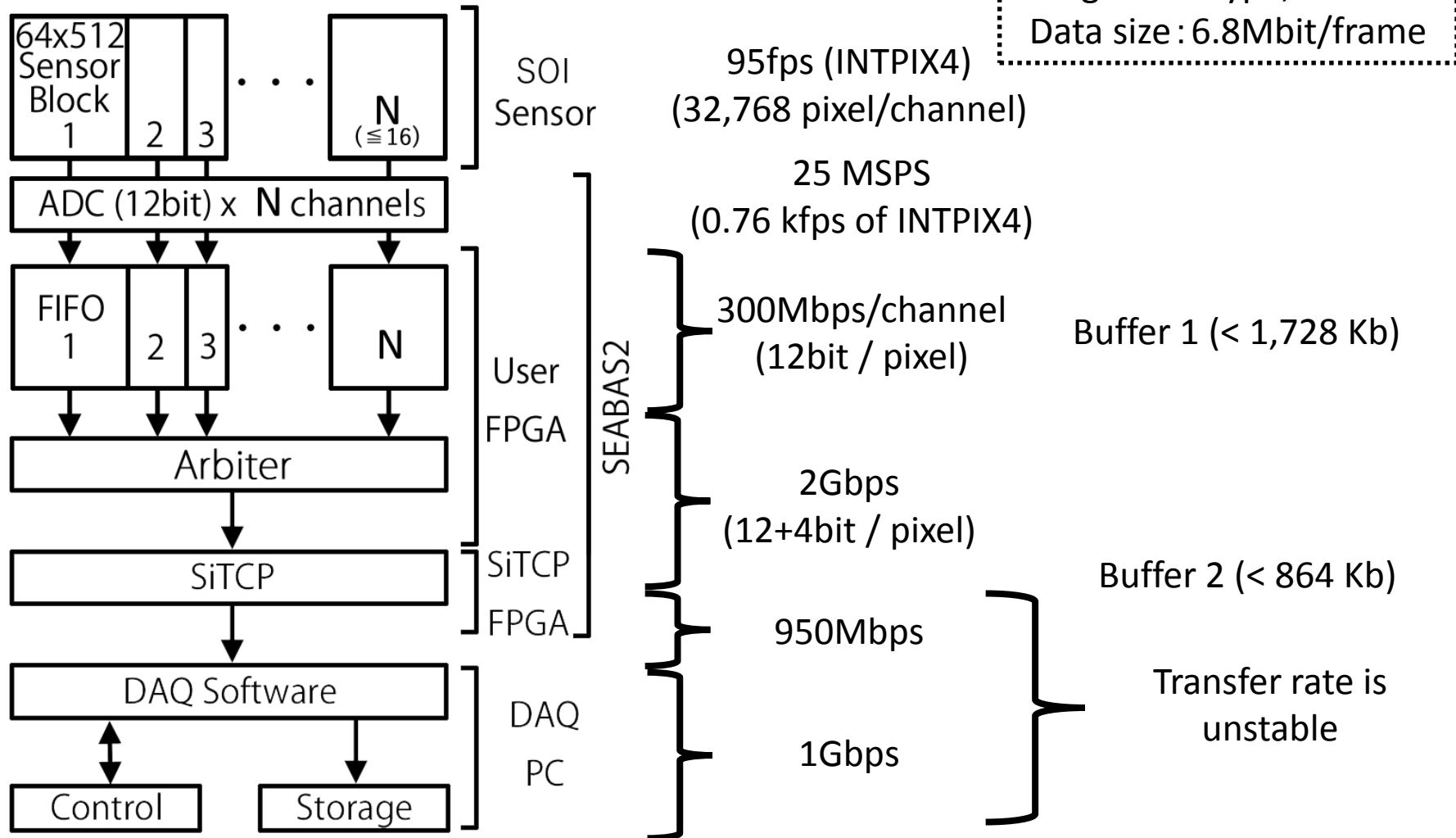
SEABAS DAQ is consist of DAQ Main board SEABAS and DAQ PC.



DAQ Software and SEABAS are connected by Ethernet and communicate by TCP/UDP protocol.

→We can construct DAQ with normal PC (Linux Windows Mac ...).

Bottleneck of Current SEABAS DAQ



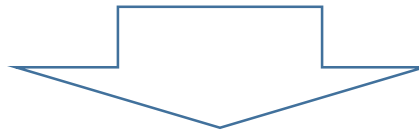
Solution for Bottleneck

Problem

1. All buffer has not enough capacity.
 2. Flow has unstable period (SiTCP — DAQ PC).
- } → Sensitive to fluctuation of transfer.

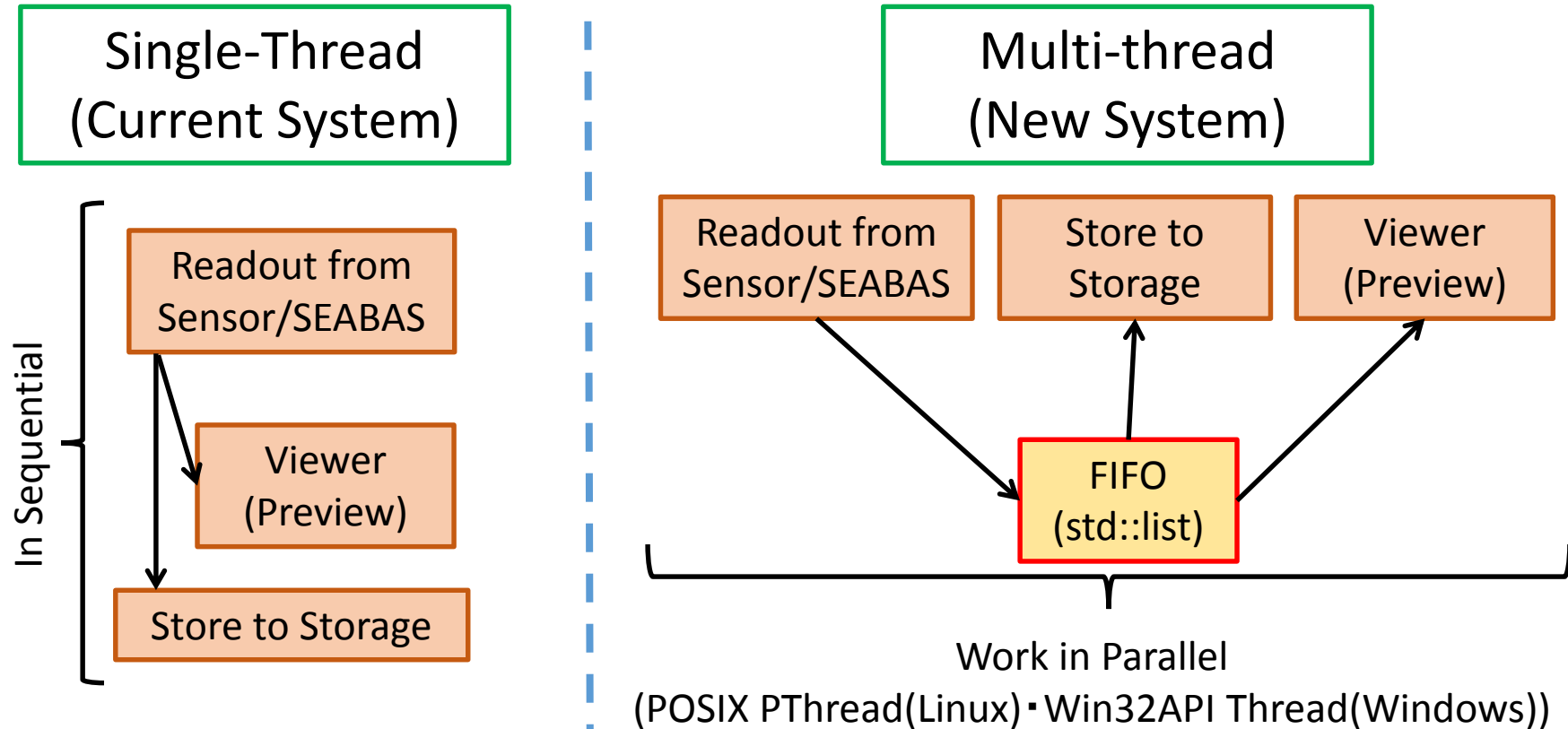
Solution

1. Add large capacity buffer. => Must redesign SEABAS 2.
2. Maximize transfer rate of unstable period by Software re-development. => Must redesign DAQ Software. <= Easier

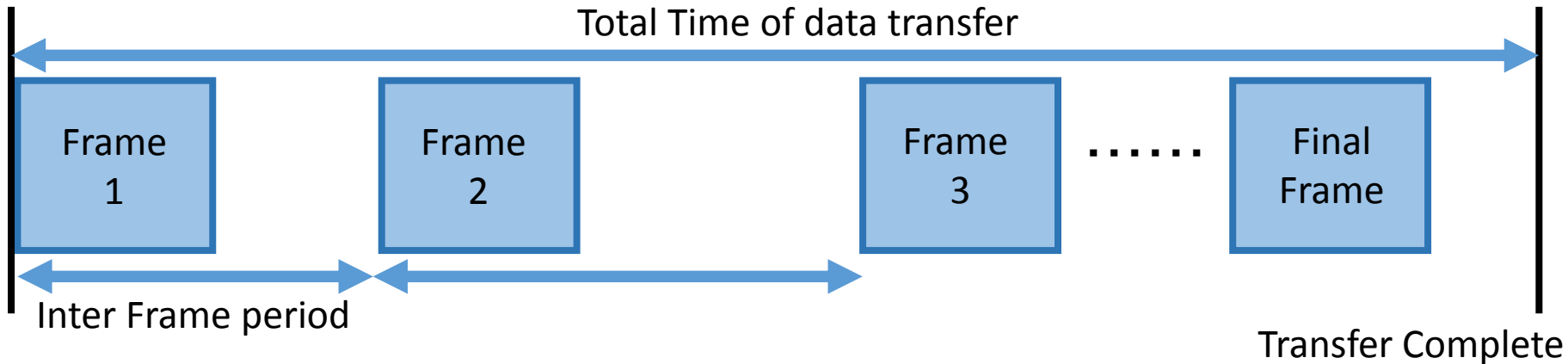


Try Software re-development at first.

Maximize transfer rate : Multi-thread processing



Verification of Average Transfer Rate ▪ Stability of Inter Frame period



- ▶ Average Transfer Rate :
$$\text{Total Data size} / \text{Total Time of data transfer}$$
- ▶ Inter Frame period:
Period between start point of current frame's transfer and same point of next frame's.
- ▶ In this DAQ, downstream buffer's remaining capacity is checked before every transfer procedure.
=> This period will be extended / unstable when buffer has not enough capacity.

Average Transfer Rate

Settings

Detector : INTPIX4

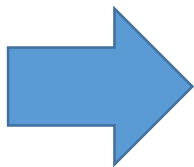
Exposure Time : 1us / frame、

ScanTime : 320ns/pix、

ResetTime : 5us / frame

Total Frame Number : 2500

	OLD(Current) DAQ	New DAQ
Total Time of data transfer	96.990 sec	26.777 sec
Average Frame Rate	25.78 fps	92.74 fps
Average Transfer Rate	<u>175.7 Mbps</u>	<u>632.1 Mbps</u>
Transfer efficiency (VS. Estimate transfer rate (649.6 Mbps))	27.0 %	97.3 %

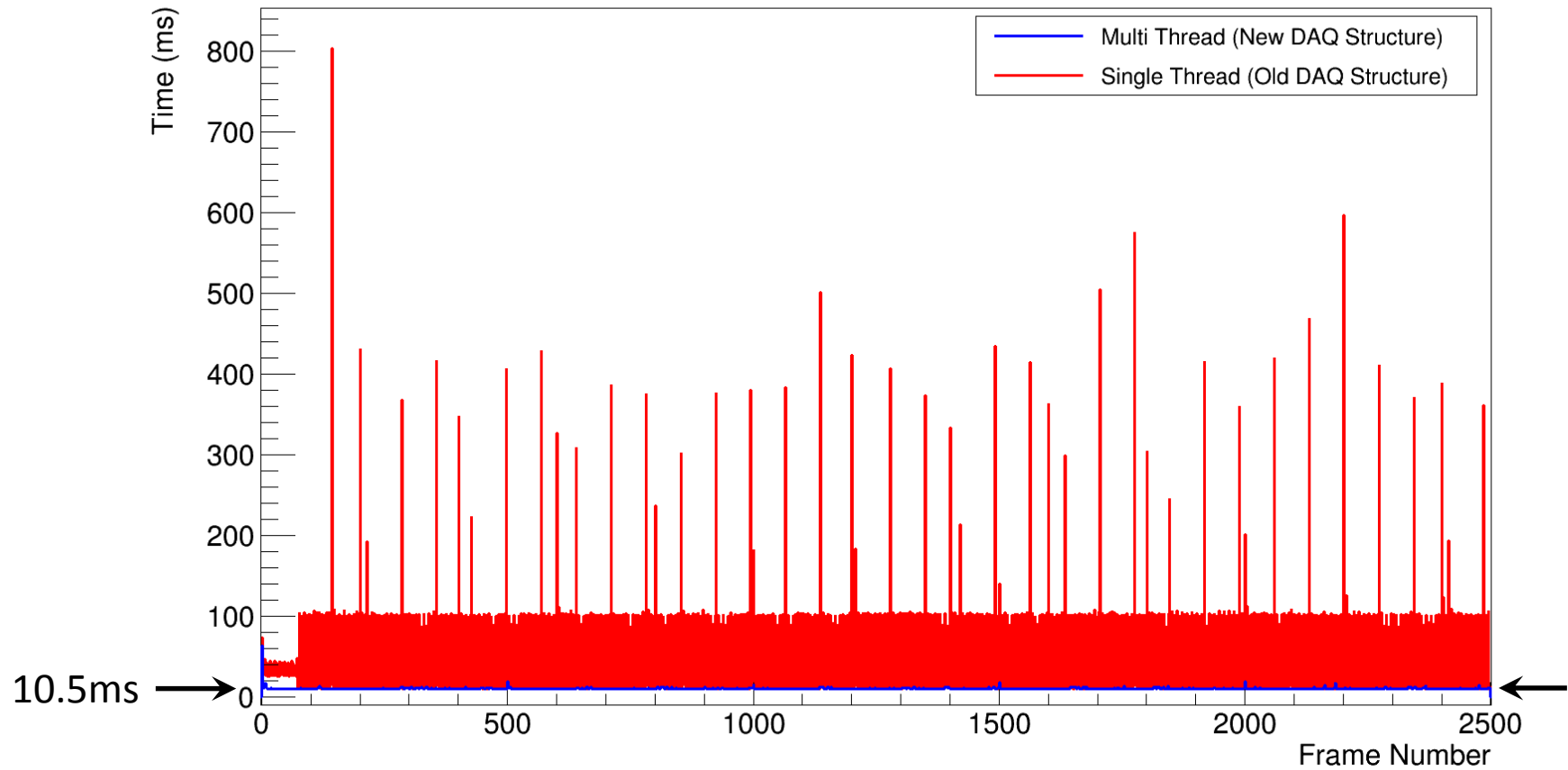


New system's transfer rate is drastically faster than old system's.

Stability of Inter Frame period

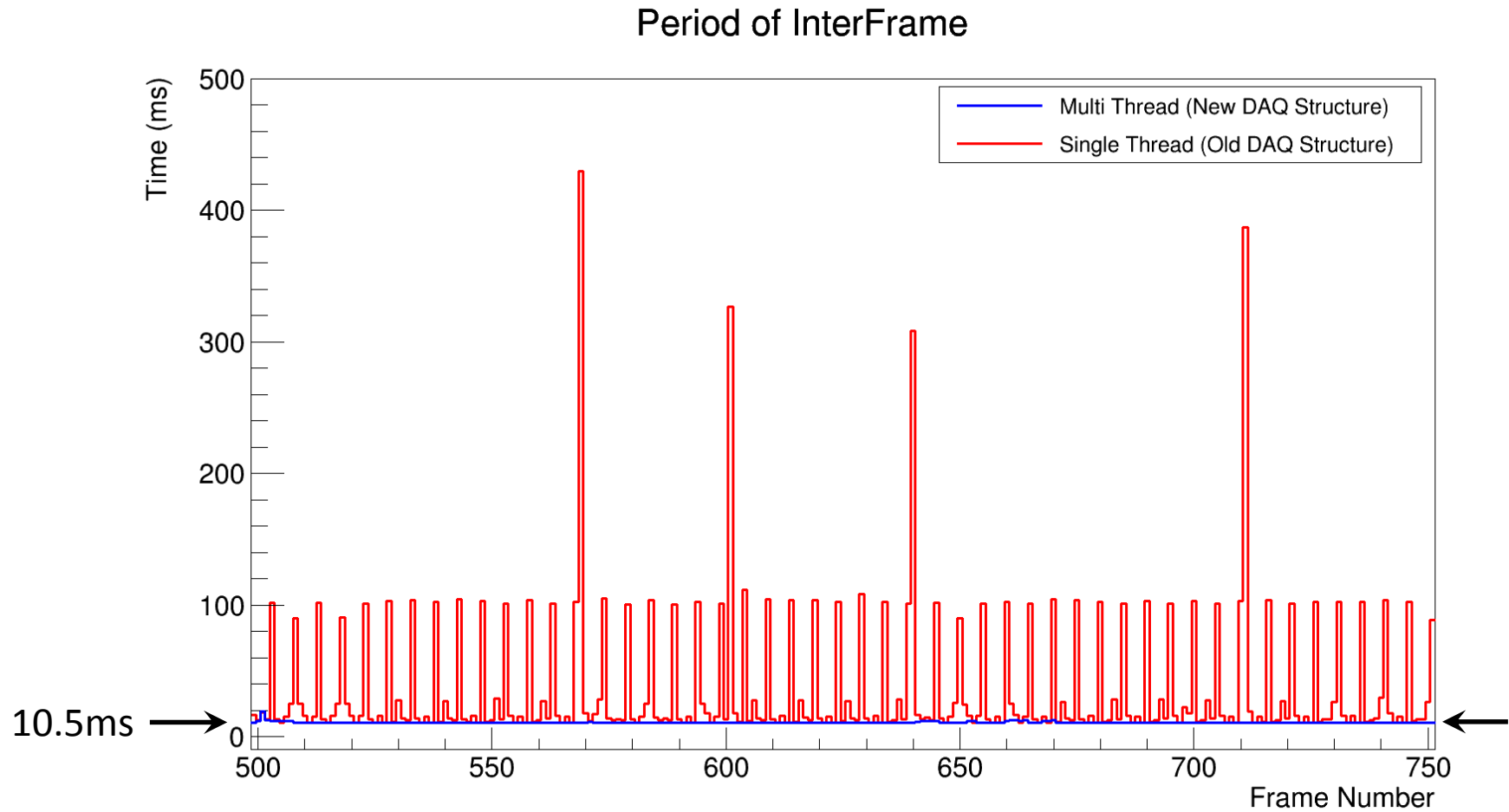
Minimum inter frame period :
10.5ms/frame

Period of InterFrame



Stability of Inter Frame period

Minimum inter frame period :
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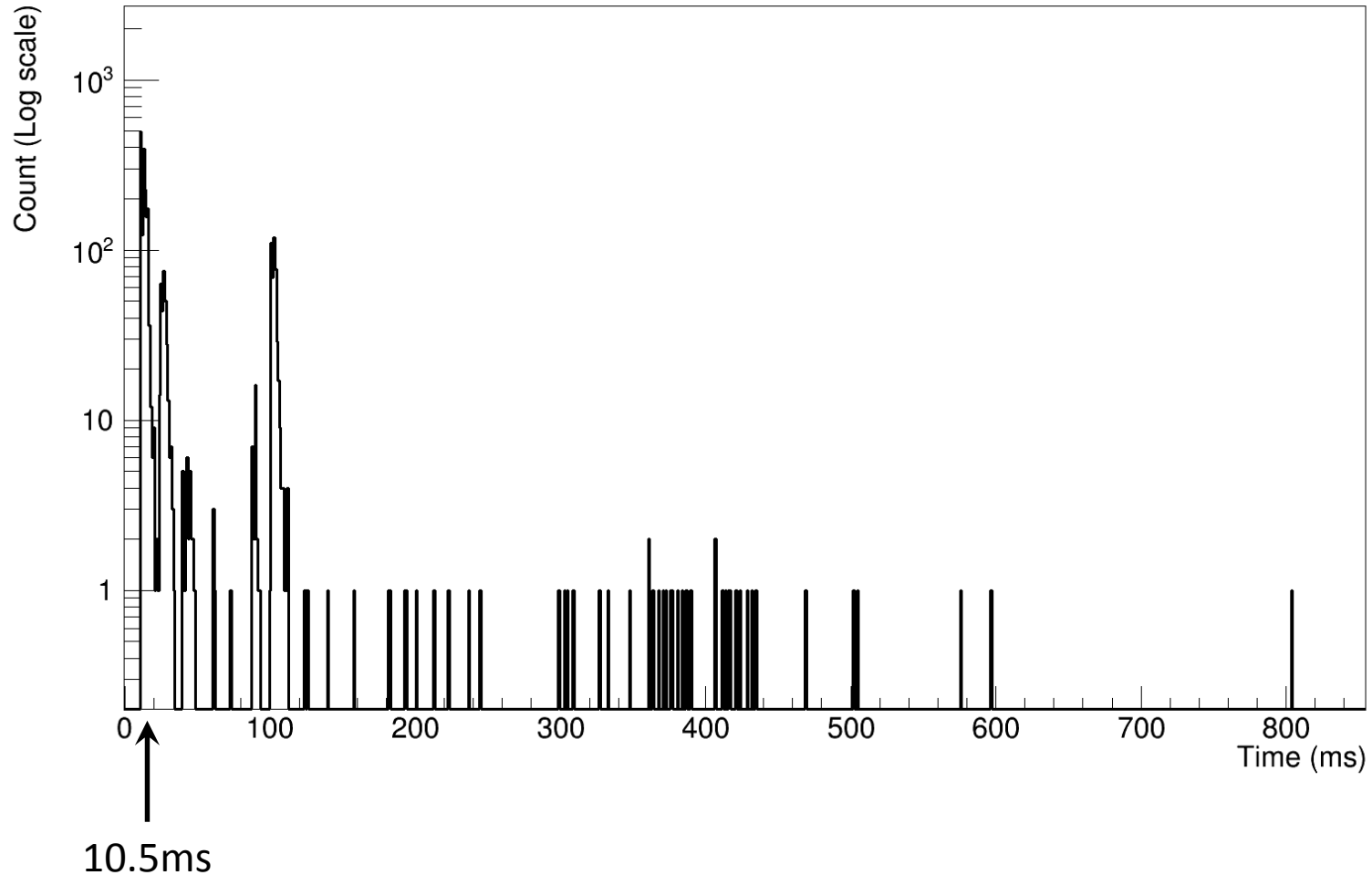


Stability of Inter Frame period

Minimum inter frame period :
10.5ms/frame

OLD DAQ SW

Dispersion of InterFrame Period

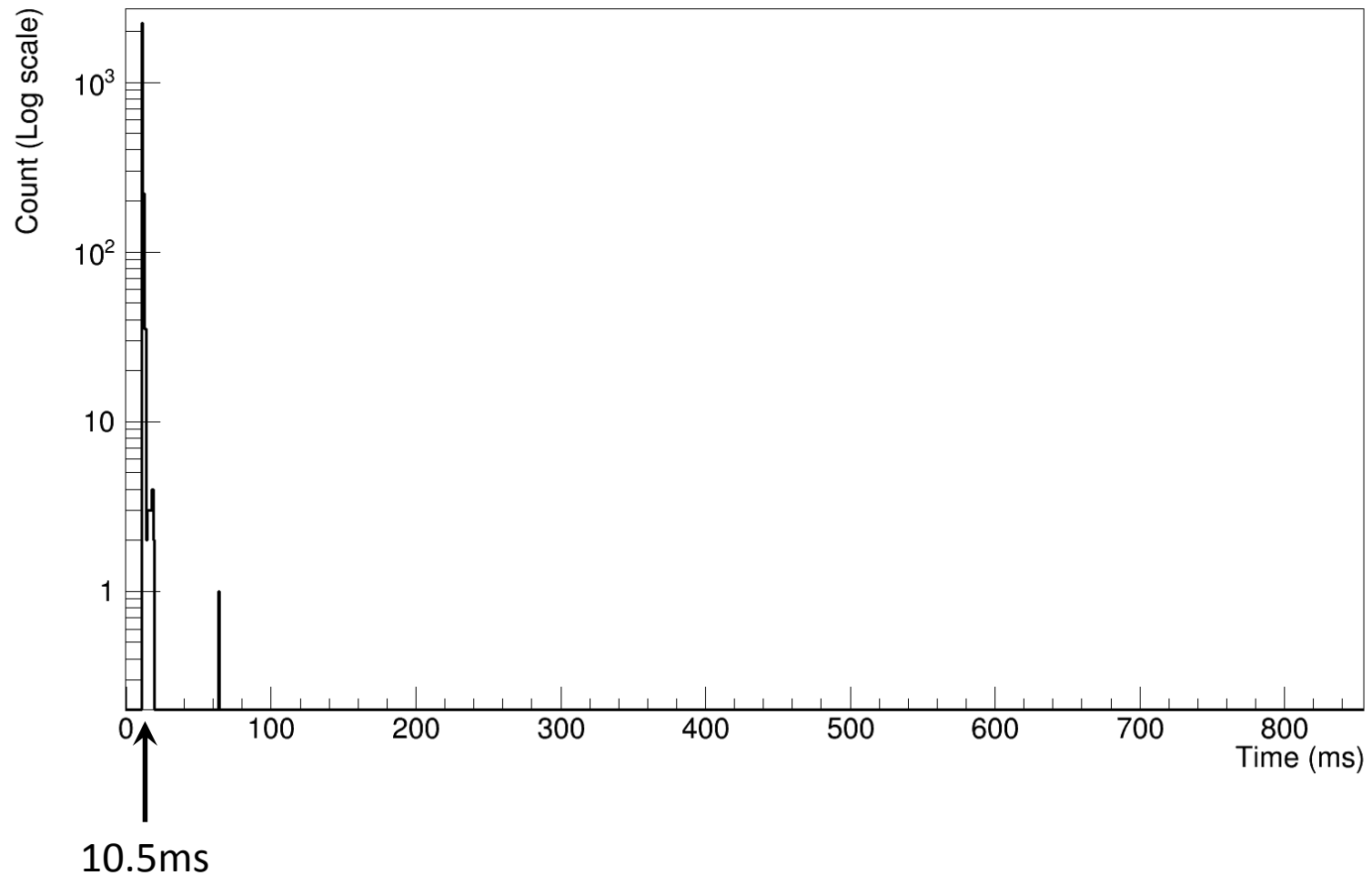


Stability of Inter Frame period

Minimum inter frame period :
10.5ms/frame

New DAQ SW

Dispersion of InterFrame Period



These results mean

New SEABAS DAQ system is :

- drastically faster
 - more stable
- than old DAQ system.

If we need more speed-up,

Main Board replacement

Main Board replacement :

Limit of SEABAS

Speed-up

- To increase speed by software is reaching limit.
- If we need more, large buffer on SEABAS is required.
- Block RAM ($\sim 2,160\text{Kb}$) is not enough for such buffer.
- Expand RAM by external memory is difficult for present SEABAS.
- Poor slices ($\sim 7,200$) make it difficult to implement advanced function.

FPGA's generation

- Virtex4(SEABAS1) / Virtex5(SEABAS2) are old FPGA.
- Production is terminated. (Now stocks are only in market)
- Development environment software (ISE14.7) is also no longer supported in latest OS.

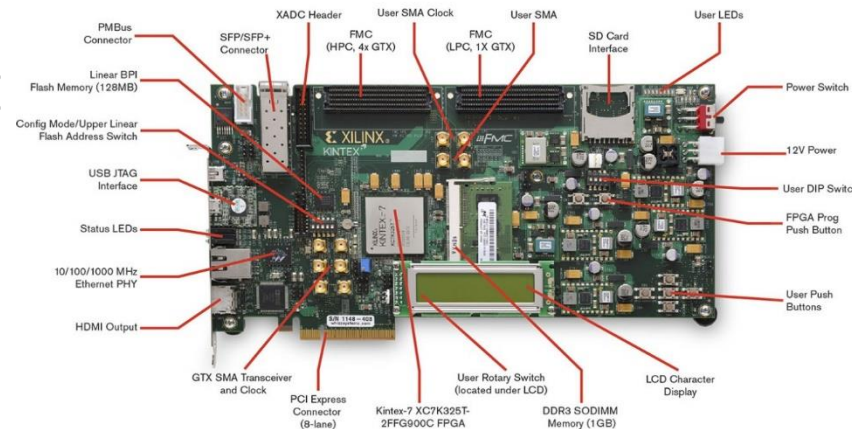


1. Develop SEABAS3. => Now it started, but need more time.
2. Use Commercial Evaluation board.
=> Now I'm trying with KC705 board.

Main Board replacement : Kintex-7 FPGA (KC705)

KC705 is Commercial Evaluation board developed by Xilinx.

This board has Kintex-7 FPGA (XC7K325T).



<https://www.xilinx.com/products/boards-and-kits/ek-k7-kc705-g.html>

Merits

- SiTCP can be worked. => We can inherit SEABAS's legacy.
- Rich Block RAM ($\sim 16,020$ Kb) capacity.
- DDR3 SO-DIMM memory slot is available. (1GB module is onboard.)
- Kintex-7 is later generation FPGA. => Now on Production.
- Use with new development environment software (Vivado).

Demerits

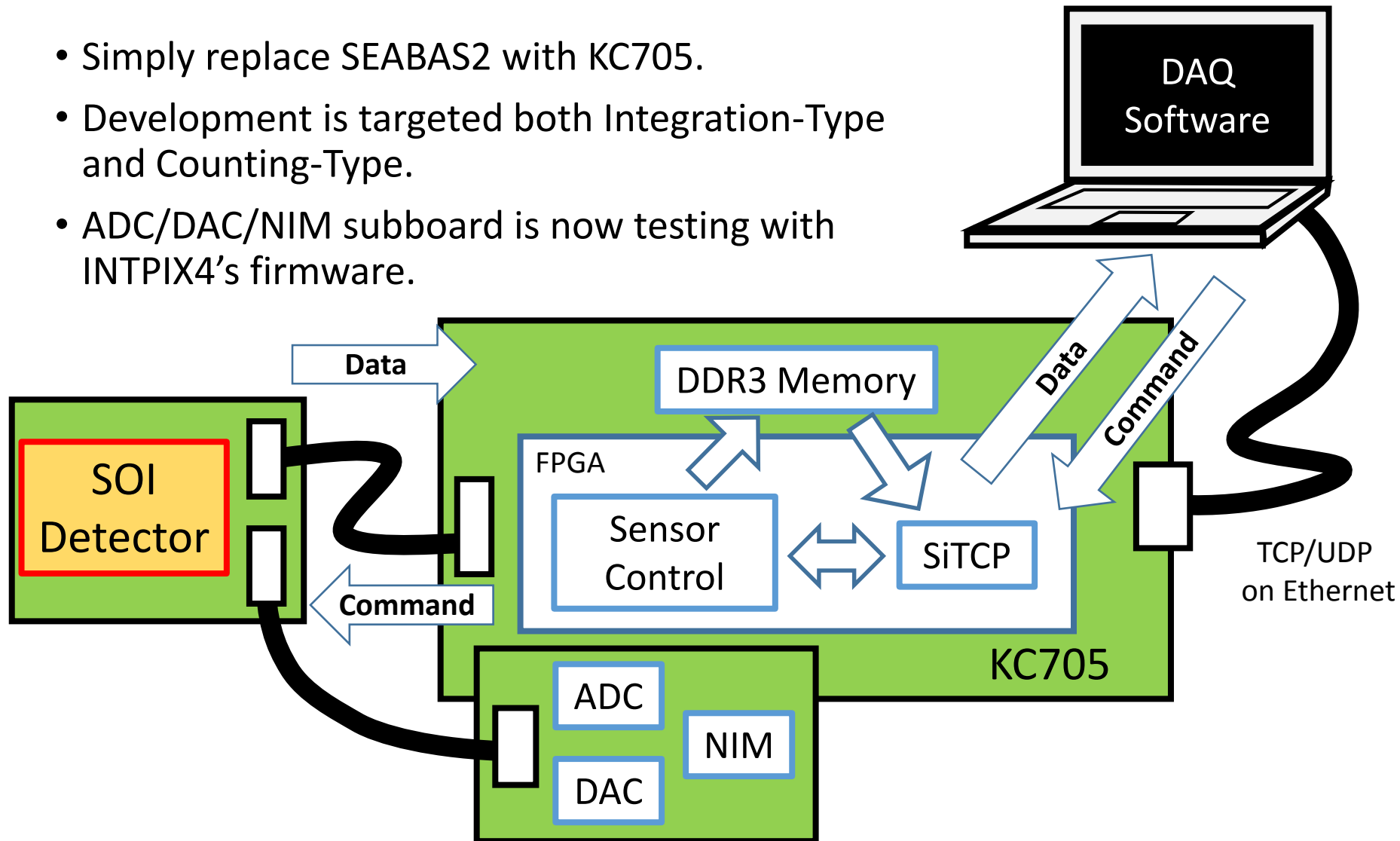
- This board has unnecessary modules. (HDMI IO etc.)
- Vivado Design Edition license is required. (One node locked was attached)
- No onboard ADCs. => Have to develop ADC subboard for Integration type detector.
- No NIM IO.



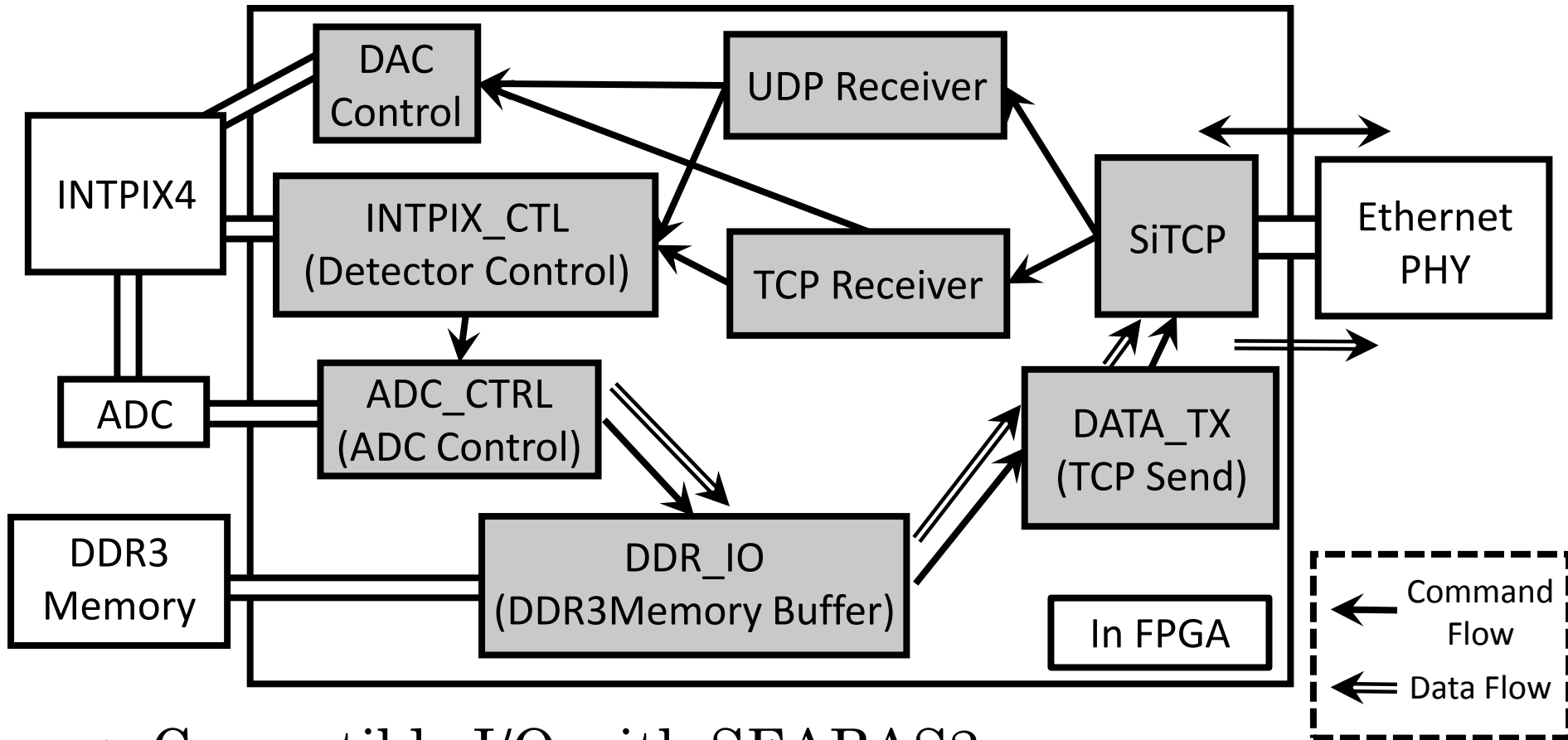
We can use this for the successor of SEABAS2.

KC705 DAQ system (Proposed)

- Simply replace SEABAS2 with KC705.
- Development is targeted both Integration-Type and Counting-Type.
- ADC/DAC/NIM subboard is now testing with INTPIX4's firmware.



Firmware structure of KC705 DAQ system (for INTPIX4 prototype)



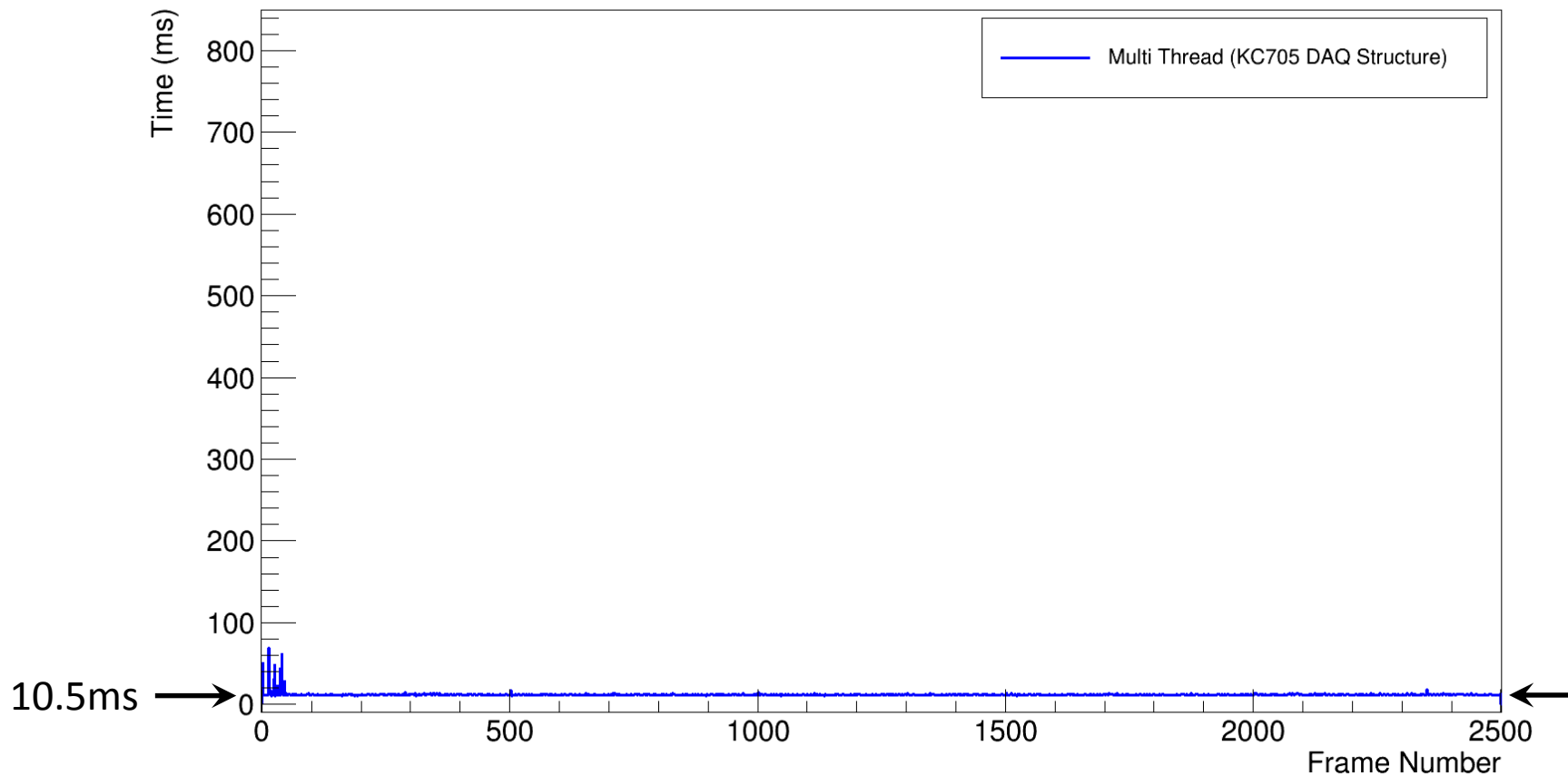
- ▶ Compatible I/O with SEABAS2.
- ▶ Add DDR3 Memory buffer(~256MB)
=> Check the stability of frame period.

KC705 DAQ System (Prototype)

Stability of Inter Frame period

Exposure Time : 1 μ s / frame、
ScanTime : 320ns/pix、
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Total Frame Number : 2500
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Period of InterFrame

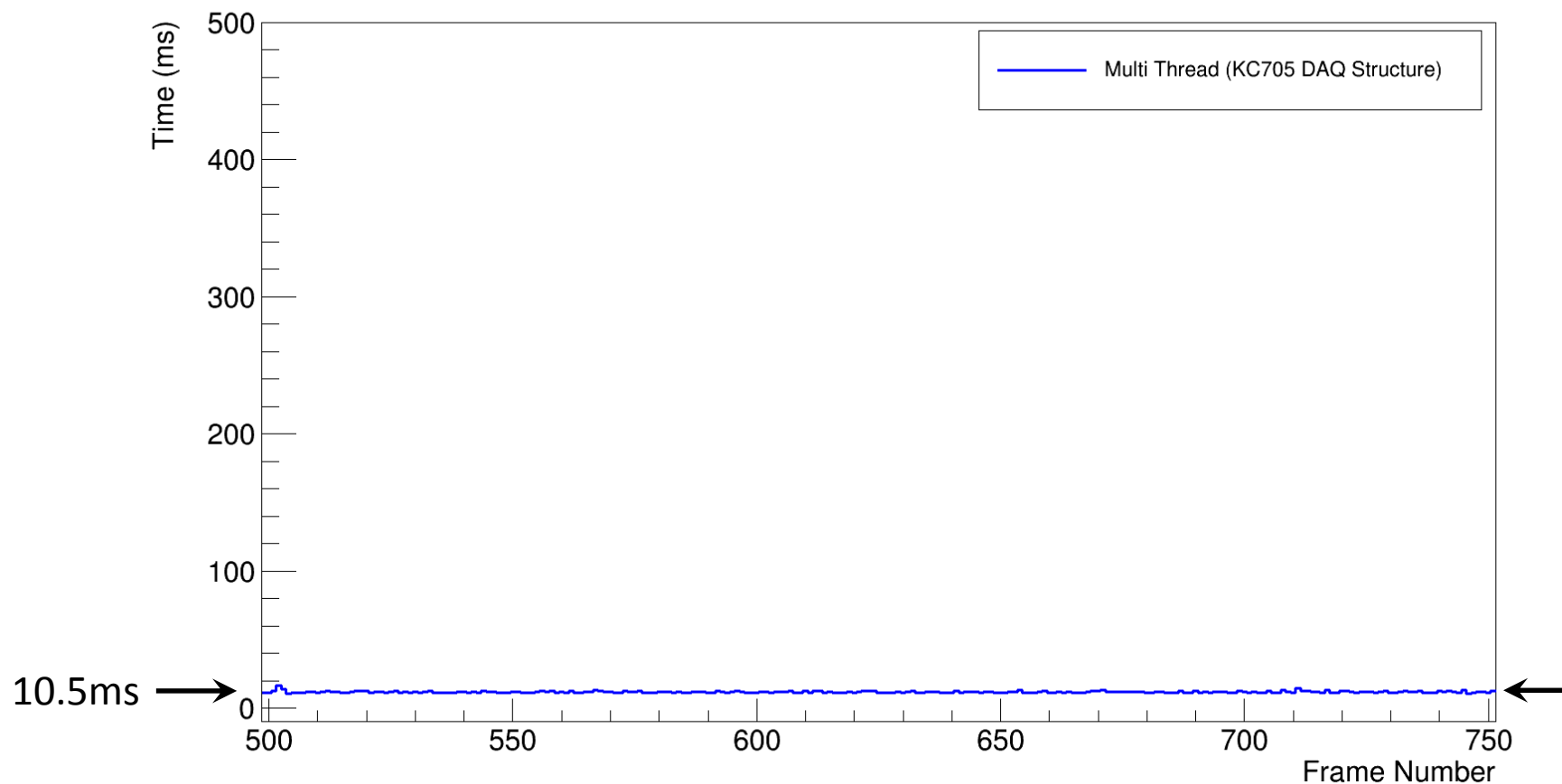


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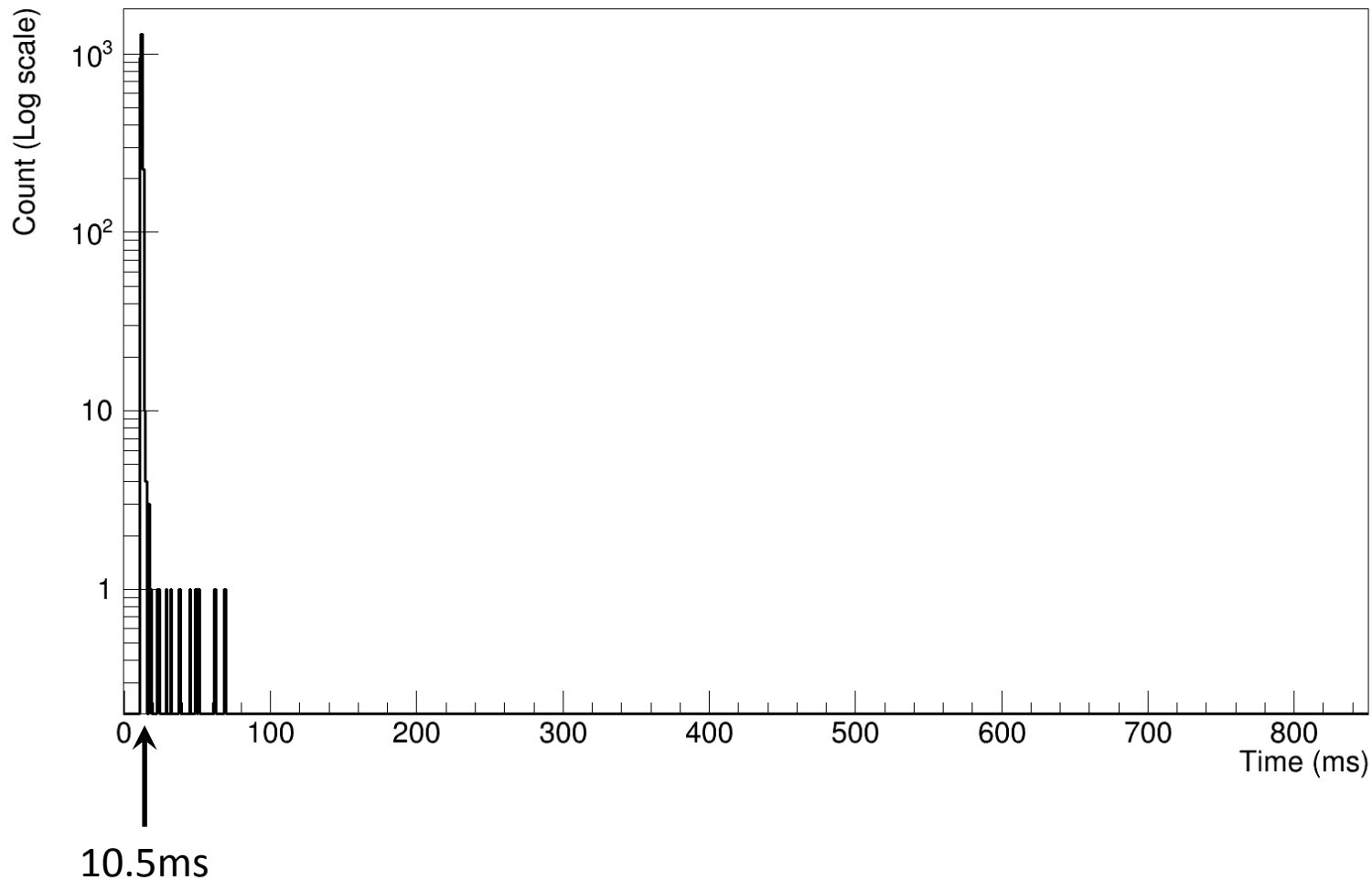


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Dispersion of InterFrame Period



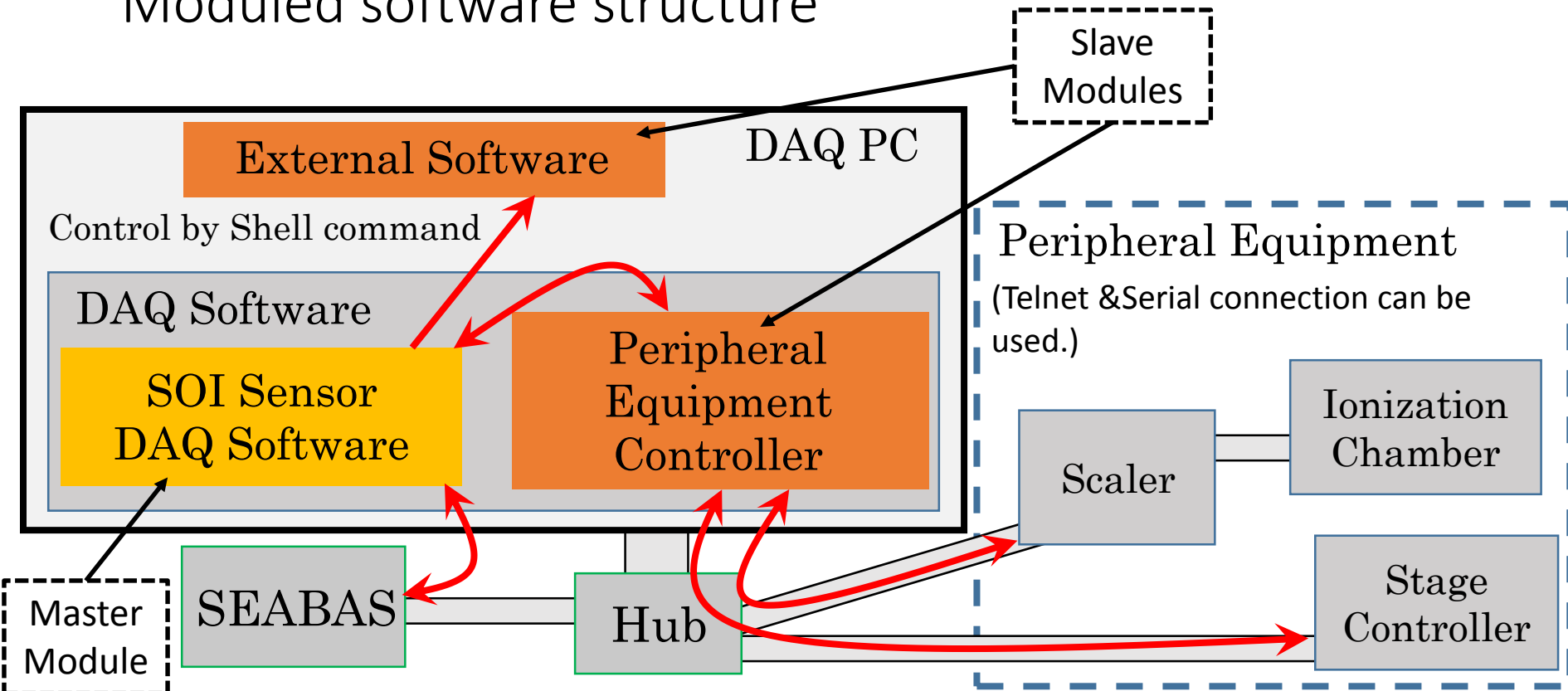
Conclusion

- SEABAS DAQ become faster and useful by recent works.
- For more speed-up, main board replacement is required.
- KC705 is one of better choice for the successor of SEABAS2.
- KC705 DAQ system is now under developing.
- KC705 prototype shows almost same performance as SEABAS2.

Thank you for your kind attention !

Backups

Framework for Automation & Laborsaving (1) : Moduled software structure



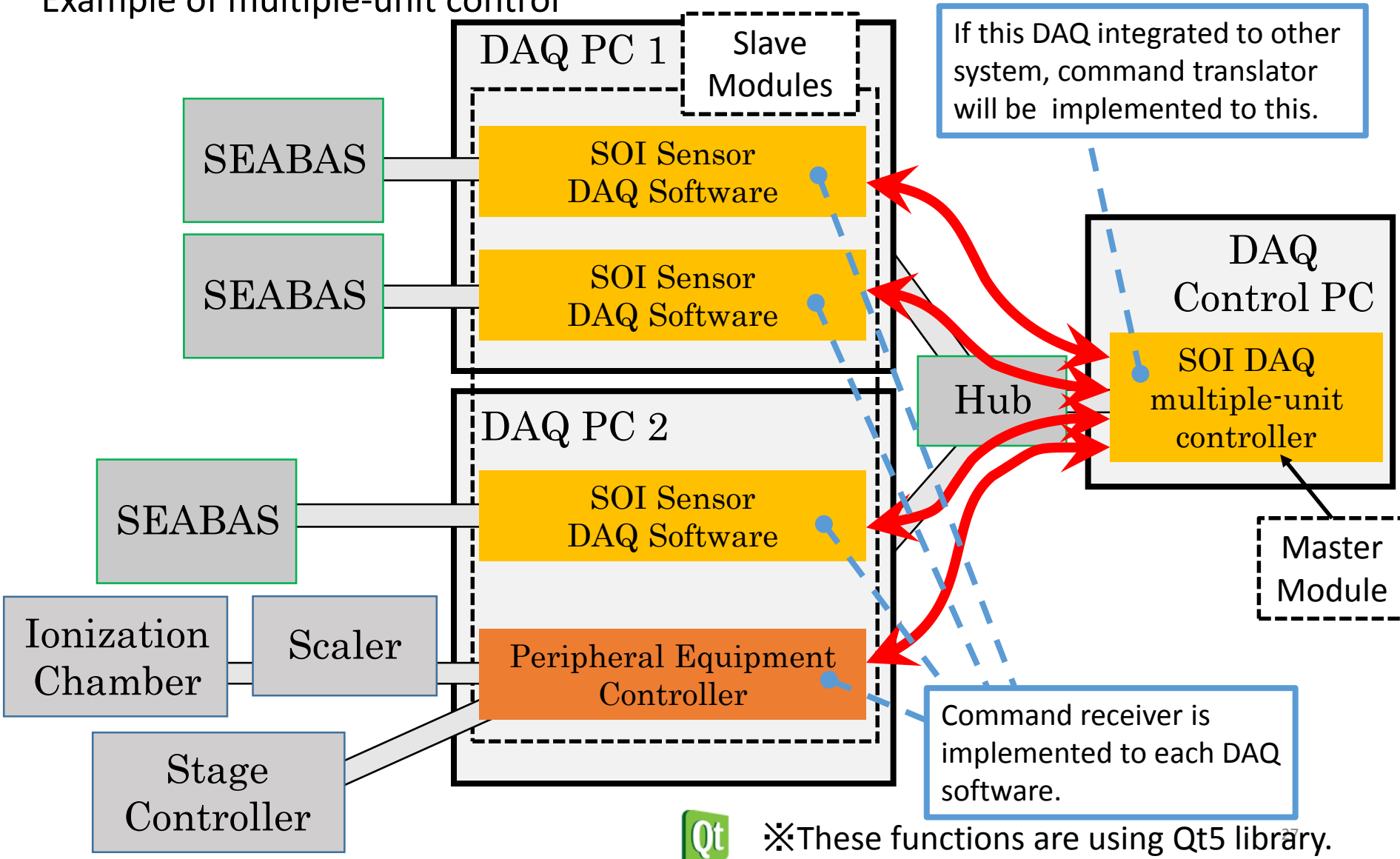
For Automation & Laborsaving :

- Implement Batch process function to Sensor's DAQ software. (Can take data repeatedly)
- Implement Peripheral Equipment Control module.
- Implement External Software controller to Sensor's DAQ software for Pre/Post processing.

Framework for Automation & Laborsaving (2) :

For Large system

Example of multiple-unit control



KC705 DAQ system : Whole view

