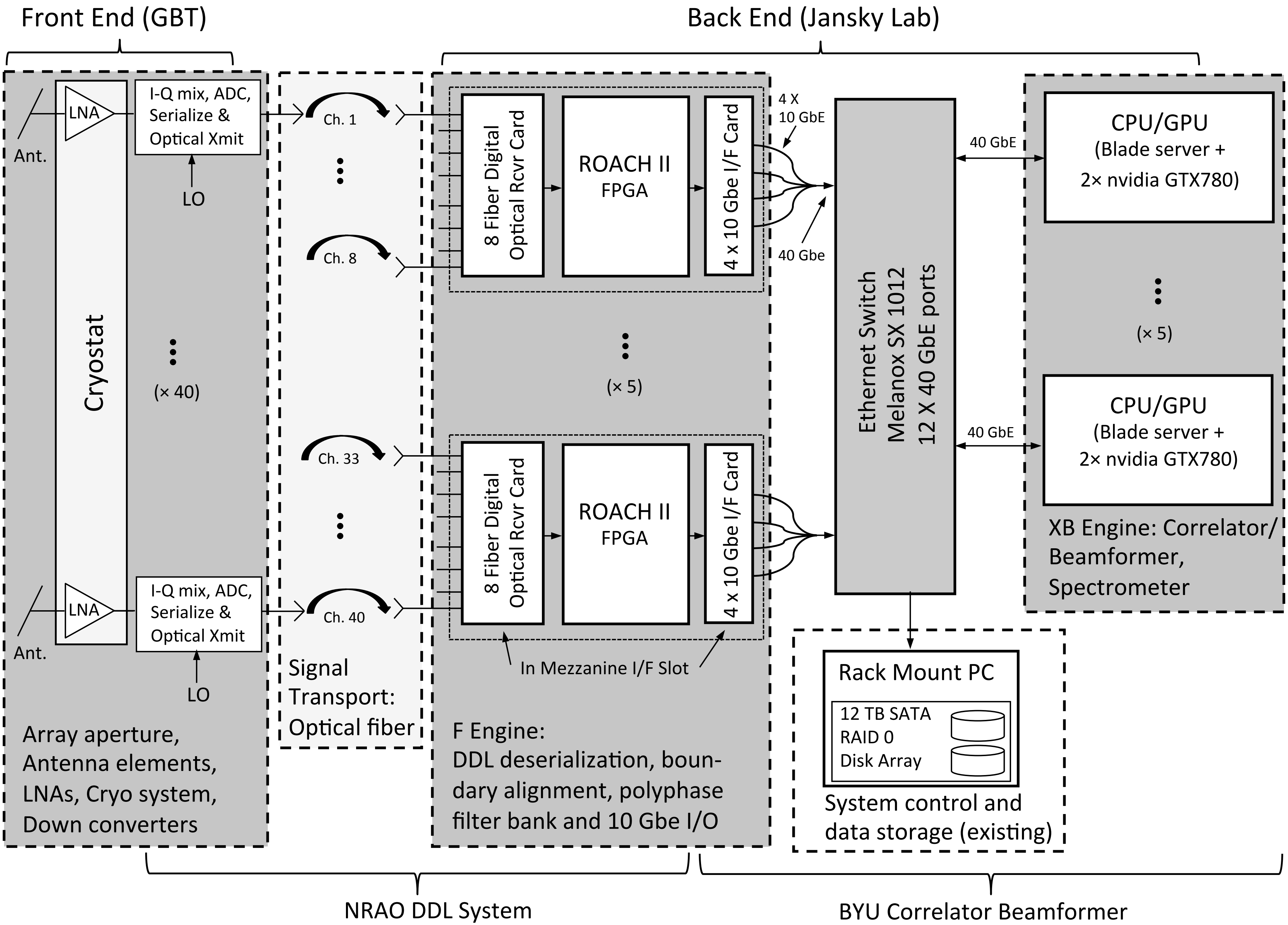
FLAG BEAMFORMER
Back End Processing Functional Block Diagrams

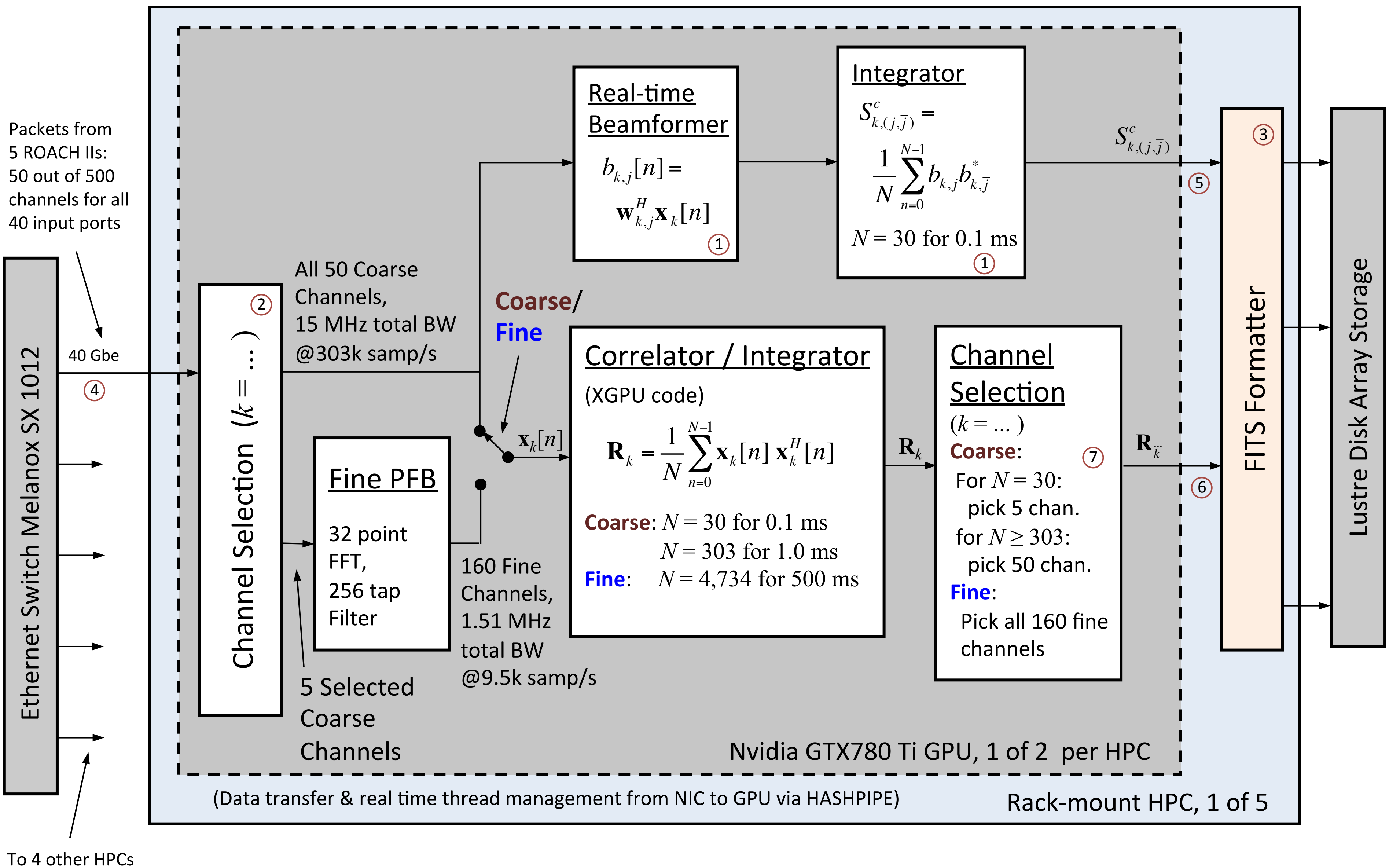
Brian D. Jeffs

Revision 2.0
February 19, 2015

Document Number: A02977D001

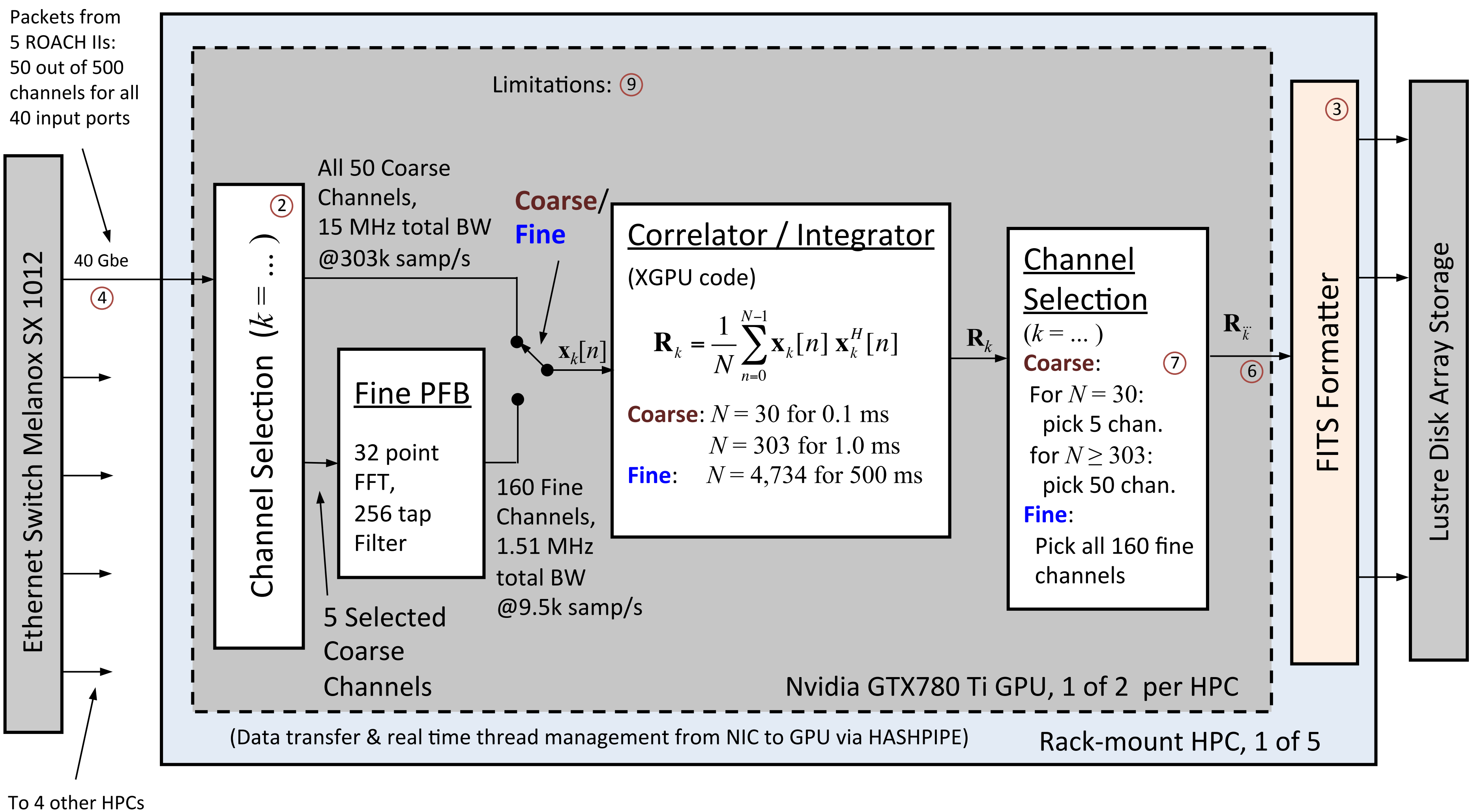

Front End (GBT)
Back End (Jansky Lab)
Ant.
LNA
Cryostat
I-Q mix, ADC, Serialize & Optical Xmit
LO
(× 40)
Ant.
LNA
I-Q mix, ADC, Serialize & Optical Xmit
LO
Array aperture, Antenna elements, LNAs, Cryo system, Down converters
Ch. 1
Ch. 8
Ch. 33
Ch. 40
Signal Transport: Optical fiber
8 Fiber Digital Optical Rcvr Card
ROACH II FPGA
4 x 10 Gbe I/F Card
(× 5)
In Mezzanine I/F Slot
F Engine: DDL deserialization, boundary alignment, polyphase filter bank and 10 Gbe I/O
4 X 10 GbE
40 Gbe
Ethernet Switch Melanox SX 1012 12 X 40 GbE ports
40 GbE
40 GbE
CPU/GPU (Blade server + 2× nvidia GTX780)
(× 5)
CPU/GPU (Blade server + 2× nvidia GTX780)
XB Engine: Correlator/ Beamformer, Spectrometer
Rack Mount PC
12 TB SATA RAID 0 Disk Array
System control and data storage (existing)
NRAO DDL System
BYU Correlator Beamformer

Target Design: XB-engine Processing Functional Block Diagram (1 of 10 GPUs shown)



Legend: ① ... ⑦: See notes on following pages.

Simplified Version 1: XB-engine Processing Functional Block Diagram (1 of 10 GPUs shown)



Legend: ① ... ⑦: See notes on following pages.

Notes

1. Beam indexing: The specification is for $J = 7$ dual pol beams. Beam index j, $1 \leq j \leq J$ denotes X polarization beams and $J+1 \leq j \leq 2J$ denotes the corresponding Y pol beams. Effective beam polarization is determined by the beamformer weight vectors $\mathbf{w}_{k,j}$ which for example could have all zero entries in the PAF element positions corresponding to the non-desired polarization. Integrated spectra $S^{c}_{k,(j,\bar{j})}$ include both self (XX^*, YY^*) and cross pol (XY^*) terms, and all 3 are stored to disk. For Self pol spectra $\bar{j} = j$. For cross pol $\bar{j} = j \pm J$.
2. User selects which 5 coarse channels, k, are used for fine filter bank processing. Selected channels need not be contiguous. After development it will be determined if it is possible to "fine" processes more than 5 coarse channels.
3. It has not yet been determined if there is sufficient processing and I/O capacity to perform the data conversion to fits format in real time on the 5 HPCs. Data may need to be saved in a compact raw GPU format and later converted in post processing to FITs file format. This operation will also increase file size.
4. 16 bit complex data (8 bit I & 8 bit Q) for 50 channels and 40 ports, 9.7 Gb/s per GPU.
5. Four 32 bit floats per dual pol beam per channel, 448 Mb/s per GPU.
6. Maximum 820 complex floats per channel per matrix, max rate 2.625 Gb/s per GPU. In fine PFB mode, max rate 89.6 kb/s per GPU (trivial rate).
7. As N is adjusted between 30 and 303, the number of channels which may be selected for output increases approximately linearly from 5, to the full 50. This keeps the output data rate capped at 2.625 Gb/s per GPU. For $N \geq 303$ all channels will be output to disk storage.

8. In this revision the back end operates exclusively in one mode at a time, either coarse or fine (HI or pulsar) mode. It will not be possible to have background or parallel FRB survey operations while observing HI. This limitation may be required due to constraints in GPU processing capacity, I/O write to disk capacity, and/or inadequate development funding and time.
9. User provided control parameter inputs per GPU:
    8. Filter bank mode: coarse or fine. (15 MHz or 1.51 MHz total BW, i.e. 303 kHz or 9.5 kHz channel BW per GPU respectively)
    9. Beamformer weight vectors $\mathbf{w}_{k,m}$ for each coarse channel k and beam m.
    10. List of 5 selected coarse channels for subsequent fine PFB processing.
    11. List of 5 selected coarse channels for covariance matrix output in coarse PFB mode.
    12. Integration length in samples, N, if larger than the minimum specified for the current coarse or fine PFB operational mode.
10. Unsupported operations (so far, possible future expansion):
    8. 50 MHz fine PFB coverage, Extragalactic HI, freq. switched mode. Fine processing 16 selected coarse channels per GPU yeields 48.5 MHz total fine PFB coverage.
    9. 1.5 kHz fine PFB resolution, Galactic HI/OH, freq. switched mode. Requires a 256 point FFT in the fine PFB.
    10. Real-time post-correlation beamformer.