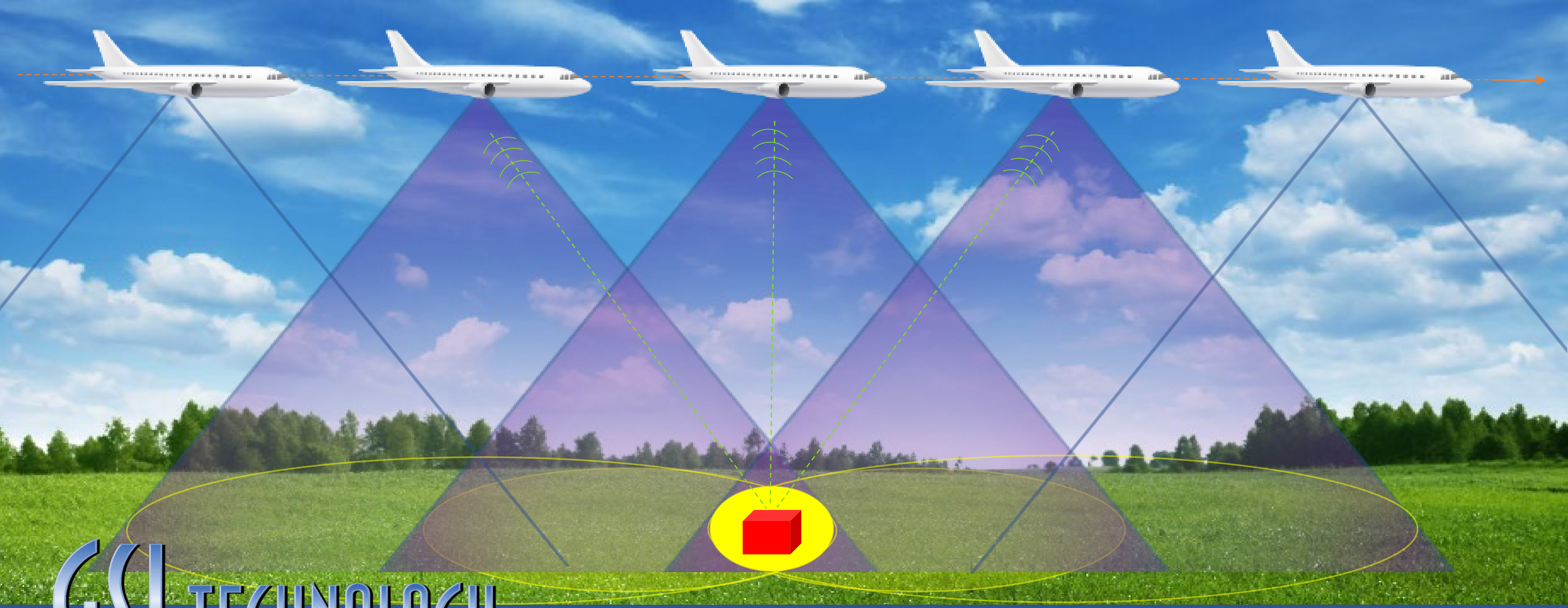


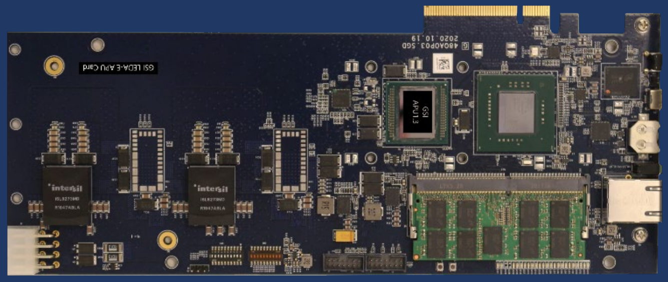
Accelerated SAR Spotlight Images Formation Using GSI APU Technology & Fast Back Projection Algorithm

Near Real Time, High Resolution

May 2023

GSI APU+FBP ACCELERATION SAR IMAGE FORMATION SYSTEM

- Based on GSI APU (Associative Processor Unit)
- Based on GSI Fast Back Projection Algorithm
- Based on Leda-S/Leda-E PCIe Boards
- 2U server can store 8 Leda-E Boards
- 1U server can store 16 Leda-S Boards
- ~ 3 1U Leda-S servers (~3U) can compute SAR Image of 100M pixels in 1 sec (Portable)



GSI TECHNOLOGY

SAR UNIQUE ATTRIBUTES

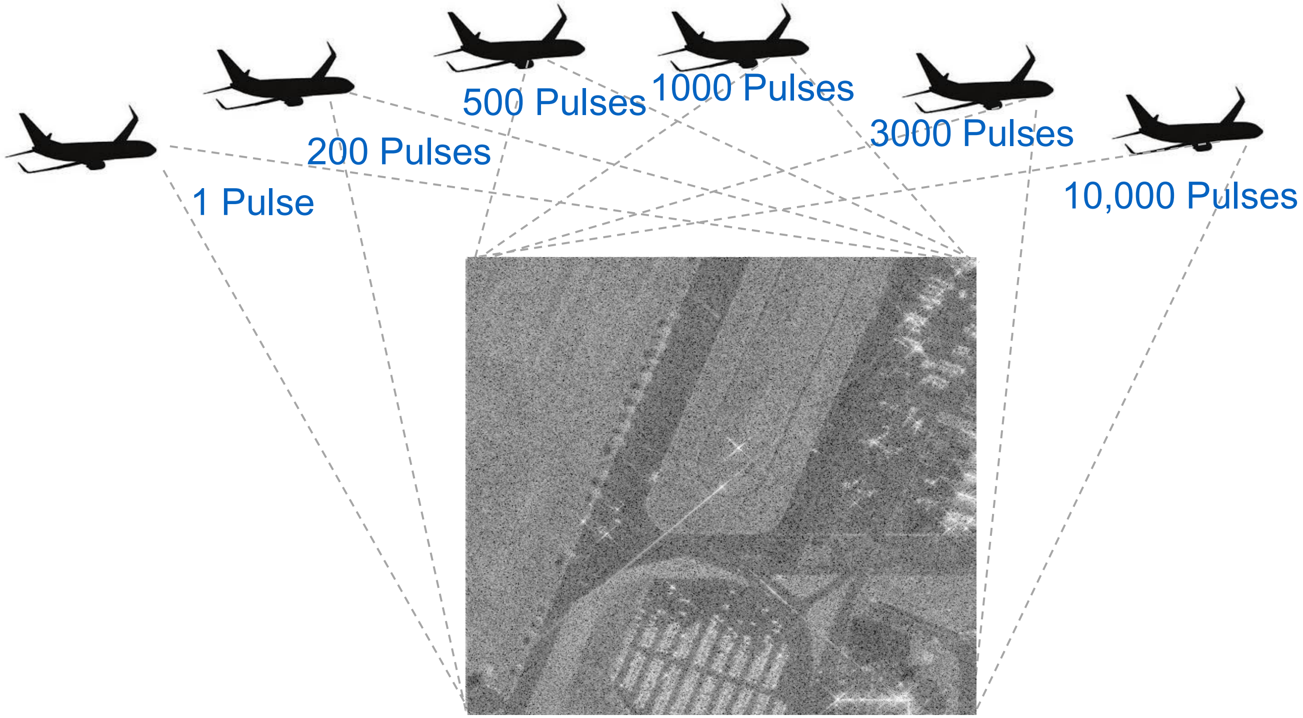
- Active sensor
- All weather
- Moving airborne platform only
- 2 main imaging operation modes
  - Spotlight—Limited area with high resolution
  - Strip—Coverge of wide areas in low resolution
- Resolution: From 100 meter to sub meter 0.5
- Platforms: Satellite to Quadcopter
- Imaging Range: 1000 km (Satellite) to 100 meters (Quadcopter)

THE IDEAL SAR IMAGE FORMATION PROCESSING ALGORITHM—BACK PROJECTION

Advantages	Disadvantages
Perfect focus for arbitrarily wide bandwidths and integration angles	High computational expense
Support low frequencies L/S/UHF with low artifact levels	Requires precise knowledge of imaging geometry
Unlimited scene size	
Support non-ideal motion/sampling	
Perfect motion compensation for any flight path and imaging geometries	
It is not affected by any kind of “Aliasing effects”	
Matches space/time filter yields—antenna gain compensation	
Compensates platform motion with high maneuver (Quadcopter,UAV)	
Support low range (Critical for: Quadcopter, UAV)	

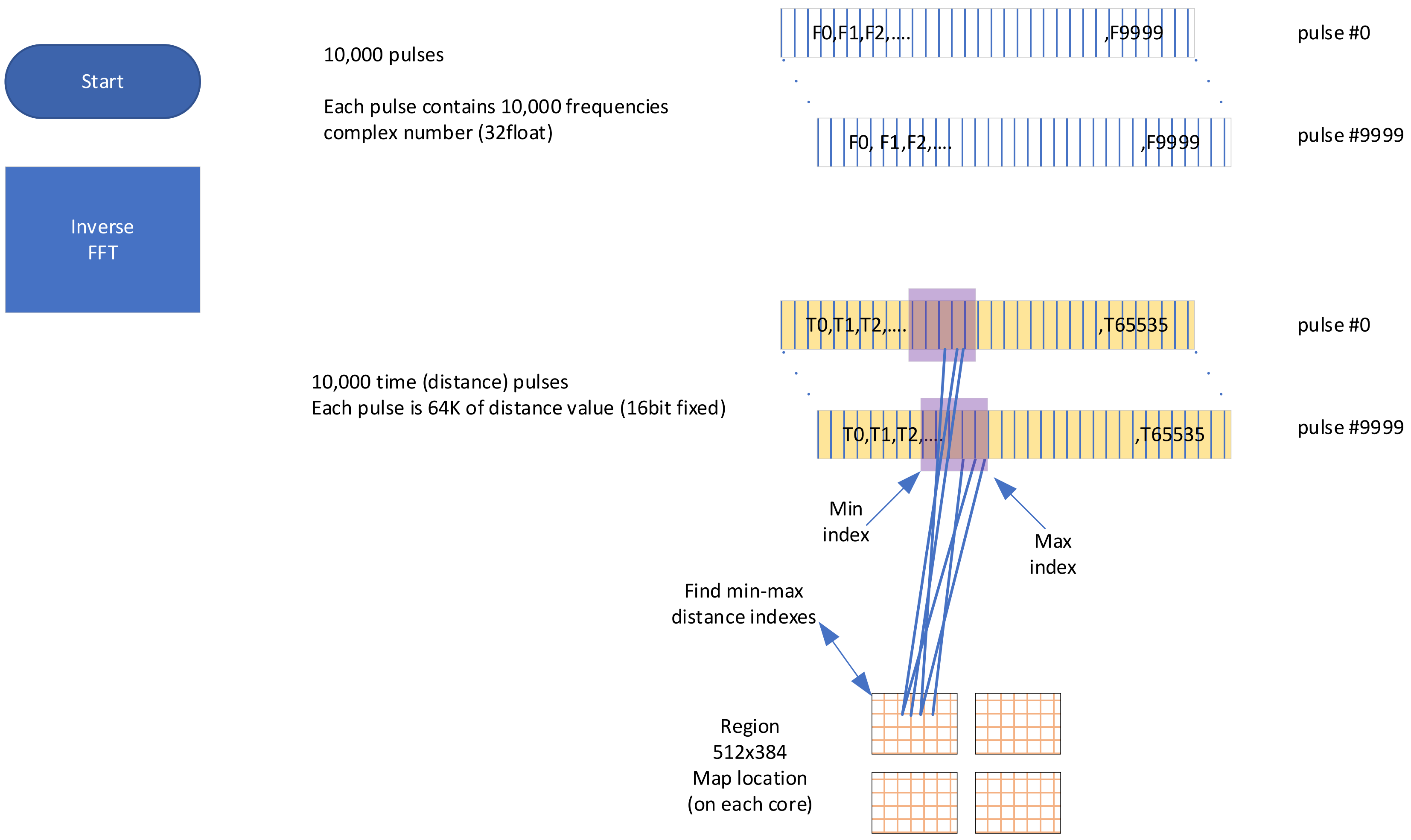
Back Projection is the Ideal Algorithm for Synthetic-Aperture Radar.

APU—PARALLEL IN-MEMORY CONCEPT OF FAST BP ALGORITHM COMPUTING



- APU: Works on all pixels in the grid for each pulse in **parallel**
- CPU: Works pixel by pixel, Pulse by Pulse

GSI PARALLEL BACK PROJECTION COMPUTATION (PARALLEL ACCUMULATE)



Back projection of parallel 512 x 384 x 4.

Data is distributed to all the needed pixels.

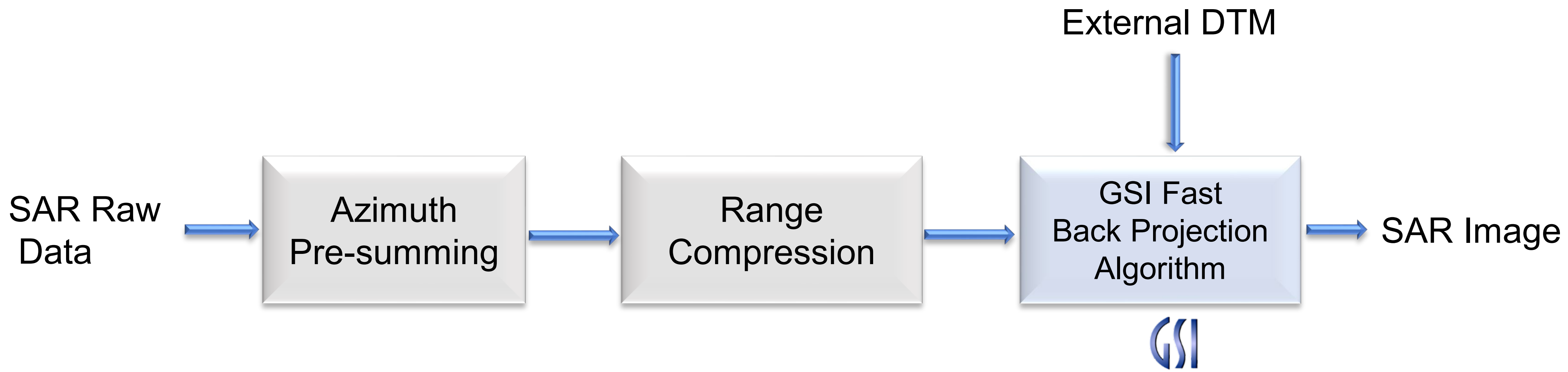
GSI APU TECHNOLOGY PARALLEL COMPUTATION

- APU generates in parallel, all pixels at once for every pulse inside the memory
- Utilizing huge parallelism capabilities for each APU:
  - Architecture is divided into 4 sections
  - 98,304 parallel SAR processing aggregators on each sections
- Calculate In-Memory 4 tiles of 384 x 256 pixels per chip
- Interpolation is mandatory as part of the BP algorithm

WHY APU IS BETTER THAN CPU/GPU FOR SAR BACK PROJECTION

- **In-Memory Compute—Improving BW, Reduce Power**
  - APU generates in parallel, all pixels at once for every pulse inside the memory
  - Compared to GPU core, which works pixel by pixel sequentially
- **Flexible Precision—For Real Time Optimization**
  - APU is a flexible bit processor that can be adapted to keep accuracy while working on flexible precision at any step of the flow. For example, FFT can be done on 16 bits, but non-linear function, such as square root, requires 40-50 bits. This technique keeps the highest accuracy, as well as the highest optimized solution.
  - GPU is adapted for 32/64-bit float that is not needed in most cases—this slows the processes and increases power.
- **Non-Linear Arithmetic Capabilities**
  - APU is a flexible bit processor with capabilities to implement efficient non-linear functions, such as COS, SIN, SQRT, and table look up—the key functions of back projection.
  - GPU is great in floating point MAC, but poor in non-linear operations.
- **Content-Based Computing**
  - When a new IFFT pulse signal (in time-distance domain) comes in, APU (as a non-Von Neuman processor) broadcasts every distance from the pulse to any location in memory in one shot based on its content (precomputed indices in memory), which improves speed significantly.
  - GPU works as standard von Neumann approach and can't distribute data in Parallel—causing power increase and reduce IO speed.

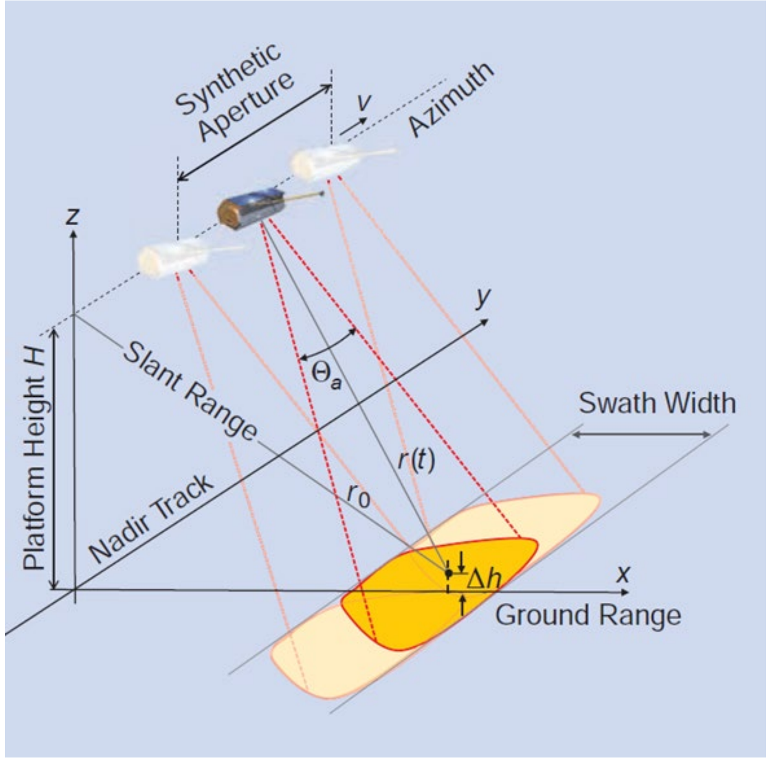
GSI FAST BP ALGORITHM—BLOCK DIAGRAM



SAR IMAGE FORMATION WITH FAST BP—*EXAMPLE IMAGE*

Image Characteristics:

- 5km x 5km, 0.5 m Resolution
- Input Pulses : 10 K
- Output Image Size: 10K x 10K Pixels
- Antenna position for each pulse (10K positions)
- FFT size : 10K bins input, 65K bins output for each pulse



SAR FAST BP ALGORITHM—EXAMPLE IMAGE—PERFORMANCES

Image Characteristic				
Pulses	**N-samples**	**Size (Pixels)**	**DTM (m)**	**Resolution (m)**
10,000	10,000	10,000*10,000	5,000*5,000	0.5
Range	**Frequency**		**Delta Frequency**	
10.5 km	9,340 MHz		28 KHz	

Actual Hardware Configuration in Use		
Desktop	Intel CPU—1	GSI—2 APU Leda E Boards
GSI Actual Measured Performances—Throughput **~11 seconds** **Can be run and checked by customer via remote access on GSI server.**		

Developed Hardware Configuration (Leda E)—Software is still in development		
2 U Server—Sky 6200	Intel CPU—2	GSI—8 APU Leda E Boards
GSI Estimated Performances—Throughput **~4.4–5.5 seconds**		

Developed Hardware Configuration (Leda S)—Software is still in development		
1 U Server—Super micro	Intel CPU—2	GSI—16 APU Leda S Boards
GSI Estimated Performances—Throughput **~2.64–3.3 seconds**		

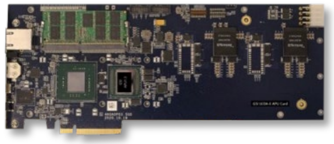
NRT SCENARIO—*EXAMPLE IMAGE—PERFORMANCES*

45 MIN

- **Example Image takes ~ 45 minutes to generate** on a Strong CPU with a regular BP Algorithm. GPUs run faster but consume a tremendous amount of power and have a much larger form factor, making them impractical for real-time applications.

11 SEC

- GSI demonstrates **11 sec per image generation** with 2 **Leda E APU Boards (Desktop configuration) with "*Fast BP Algorithm*".**



01 SEC

- **With ~ 3 GSI Leda S servers** (1/14 Cabinet), GSI can achieve **1 sec for single SAR image processing with Fast BP.**

GSI TECHNOLOGY

THANK YOU!