COTS GPU Processor Development for On-board Demonstration

Akira Chiba, Shusuke Yoshida, Mayu Miyamoto, Shinya Hirakuri, Minoru Yoshida,
Jin Miyazawa, Yosuke Sato, Kakeru Fujishiro, Shohei Nakamura

Mitsubishi Electric Corporation (MELCO)

European Data Handling and Data Processing Conference 2023 (EDHPC2023)

©Mitsubishi Electric Corporation

Table of contents

- Introduction
- Selection and Opportunity
- GEMINI
  - Purpose
  - Specification
  - SAR processing
  - Target Detection with AI
  - Status
- Summary

©Mitsubishi Electric Corporation

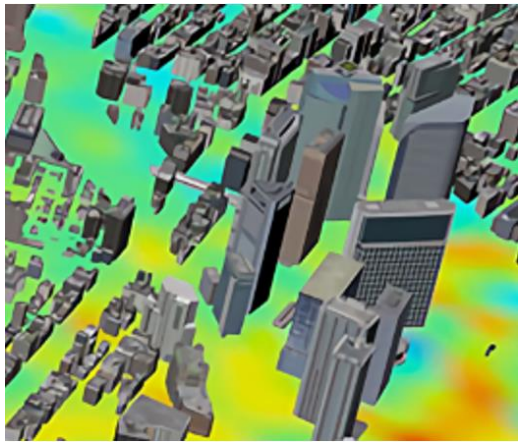
Introduction

Many mission so far:

GEO Satellite

LEO Satellite

Lander



Ground

Data Handling

- CCSDS TC/AOS
- SpaceWire
- 1553B…

Data Processing

- SAR imaging
- Optical imaging
- Target detecting
- Template matching …

©Mitsubishi Electric Corporation

Introduction

Recent Requirements

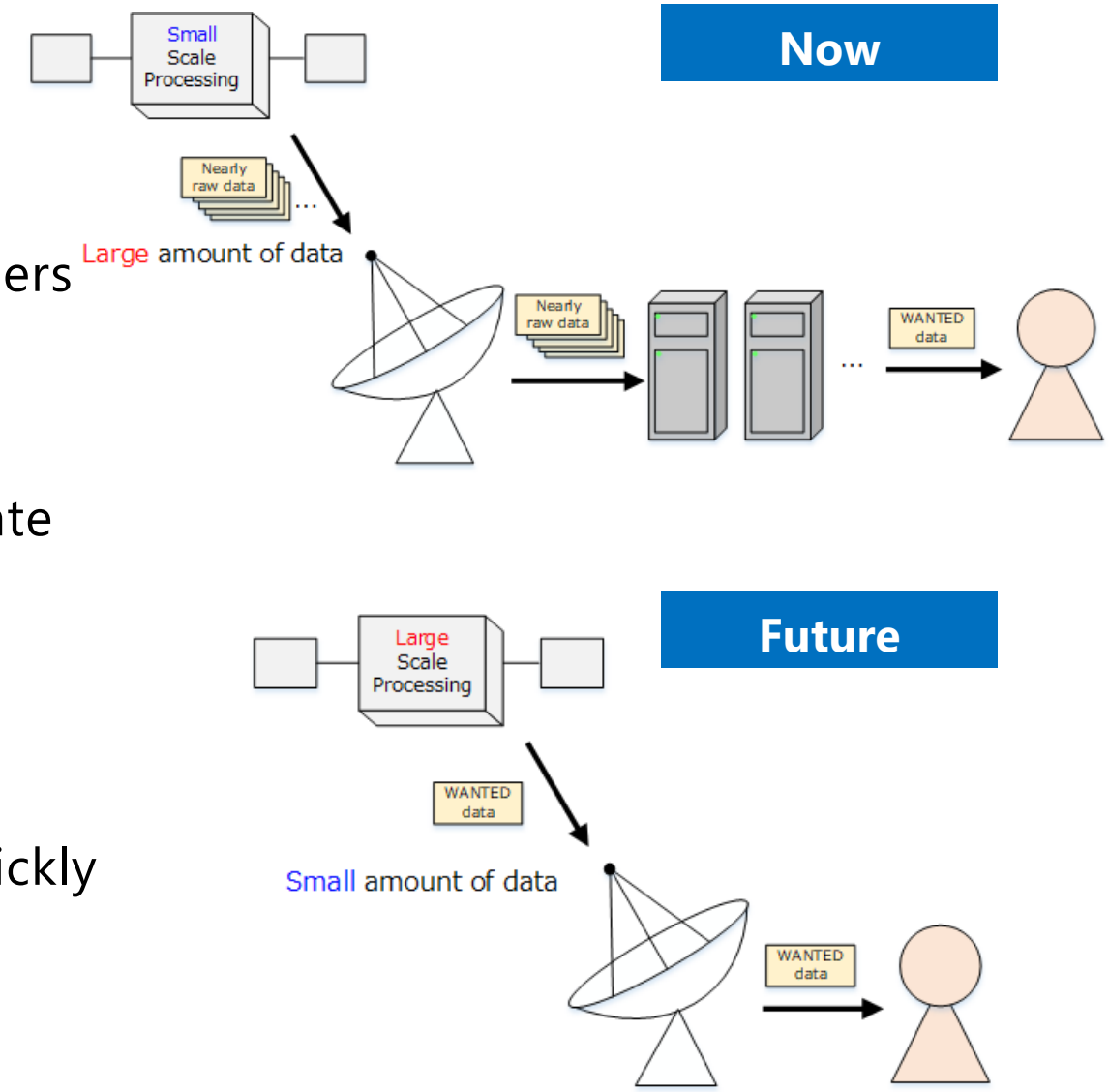
- The amount of payload data is increasing
- Shorter time to deriver the WANTED DATA to users

Idea

- MORE on-board processing to extract or generate
- Increasing downlink speed to the ground

Problem

- Space CPU cannot perform complex process quickly
- Implementing on FPGA is not flexible than CPU
- Increasing downlink capacity is difficult



©Mitsubishi Electric Corporation

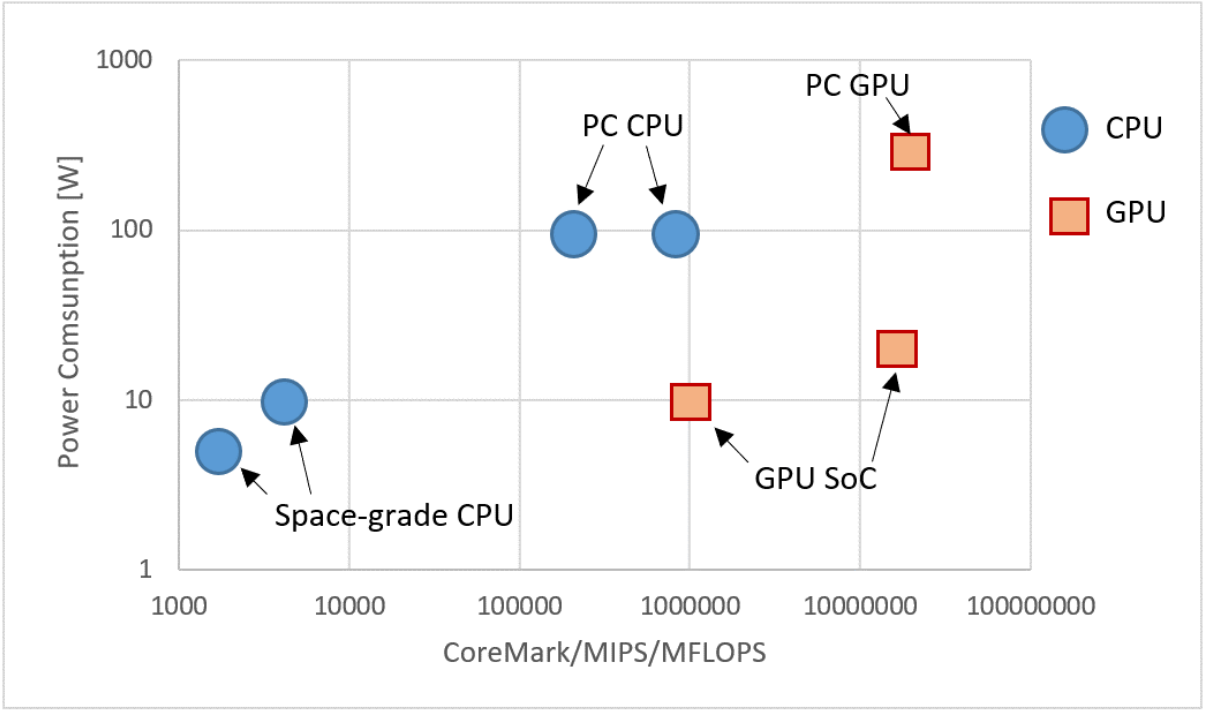
Selection and Opportunity

COTS CPU

- High-performance
- Large power consumption

COTS GPU (SoC)

- Useful for edge device
- High-performance
- Low power consumption is in market



We selected COTS GPU, however:

- Integrated peripheral (DRAM, non-volatile memory, power supply, OS etc.) product as module.
  → Impossible to replace all of them with designs for the space environment (radiation etc.)

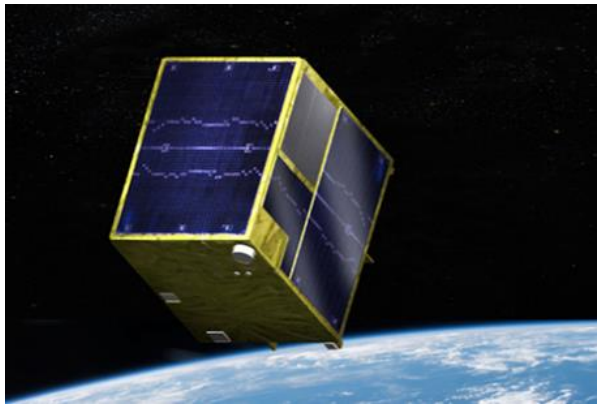
Acquiring basic operation data in space environment using as a module is strongly required.

©Mitsubishi Electric Corporation

Selection and Opportunity

Innovative Satellite Technology Demonstration Program

- JAXA's technology demonstration series program.
- Demonstration opportunities for equipment, parts, microsatellites, Cube-Sats developed by private companies, universities, research institutions, etc.
- 3D printed antenna had been demonstrated through this program(RAISE-2)
- RAISE-4 will be launched JFY2024.



RAISE-2 (launched: JFY2021)

GEMINI

- Instruments for on-board COTS GPU demonstration
- Selected for the Innovative Satellite Technology Demonstration Program-4
- Development started in JFY2020 and will be mounted on RAISE-4

3D printed antenna

RAISE-* (**RA**pid **I**nnovative payload demonstration **S**atellit**E**-*):
a satellite for on-orbit demonstration themes selected in the "Innovative Satellite Technology Demonstration Program".

GEMINI: cots **G**PU based **E**dge computing for **MI**ssion systems utilizing model based systems engi**N**eer**I**ng)

©Mitsubishi Electric Corporation

GEMINI – Purpose –

Purpose

- Acquiring the basic on-board operation data
- Measurement the error rate in space environment

Applying the data for:

- Future instrument design
- Future system architecture etc.

Success criteria

- Setting the Min. / Full / Extra success.

	Criteria
Minimum Success	(1) Measurement of MTBF for SEU and SEFI. (2) Observation of whether the GPU SoC will fail permanently due to the presumed cause of total dose.
Full Success	(1) MTBF should be no less than 2200 seconds. (Double error rate of 0.1% after 40 seconds of processing in triple majority configuration.) (2) The GPU SoC should not be failed permanently due to the presumed cause of total dose. (3) The results of the on-orbit software processing generated by the model-based development should match the expected results.
Extra Success	(1) No permanent failure of the GPU SoC by any reason.

©Mitsubishi Electric Corporation

GEMINI – Specification –

Specification

- Small size and low power consumption
- Data interface is RS-422 only
- Hardware redundancy (Switching between Nom. and Red. is realized by pulse command)

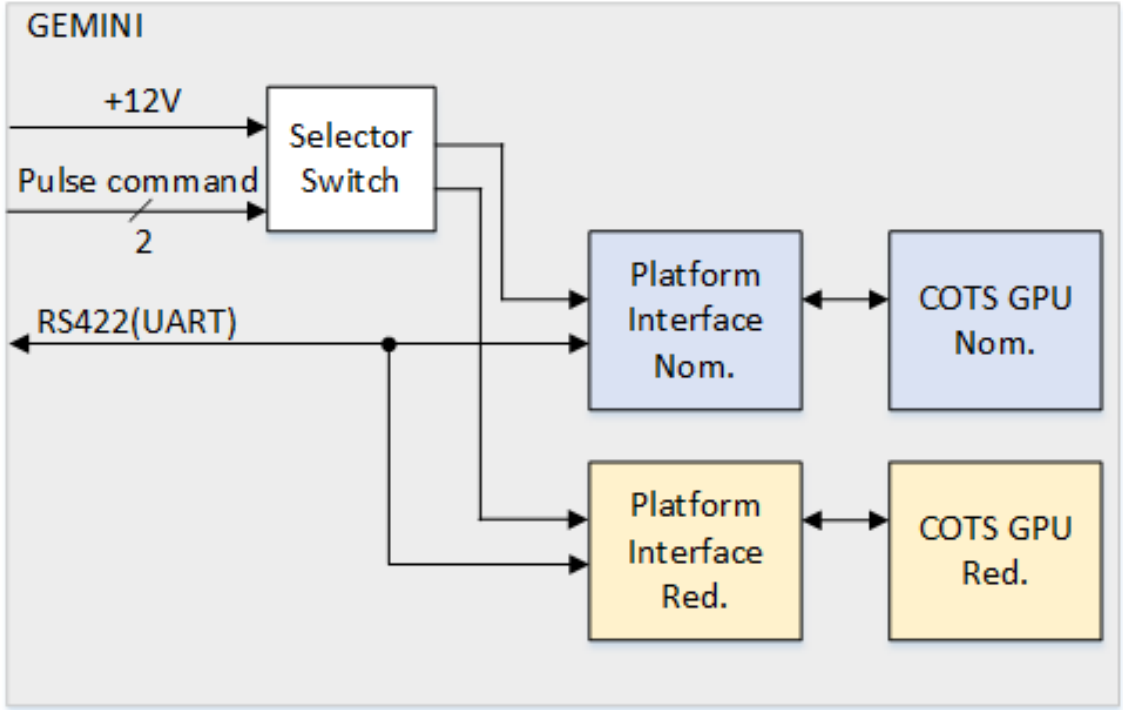
Parameter	Specification Value
Size (typ.)	X: 142.8 mm Y: 143.0 mm Z: 45.0 mm
Mass (typ.)	700 g
Power Consumption	< 20W
Power Interface	+12V ± 2V
I/O Data Interface	RS422-UART (Baudrate:115,200bps)

©Mitsubishi Electric Corporation

GEMINI – Specification –

Specification

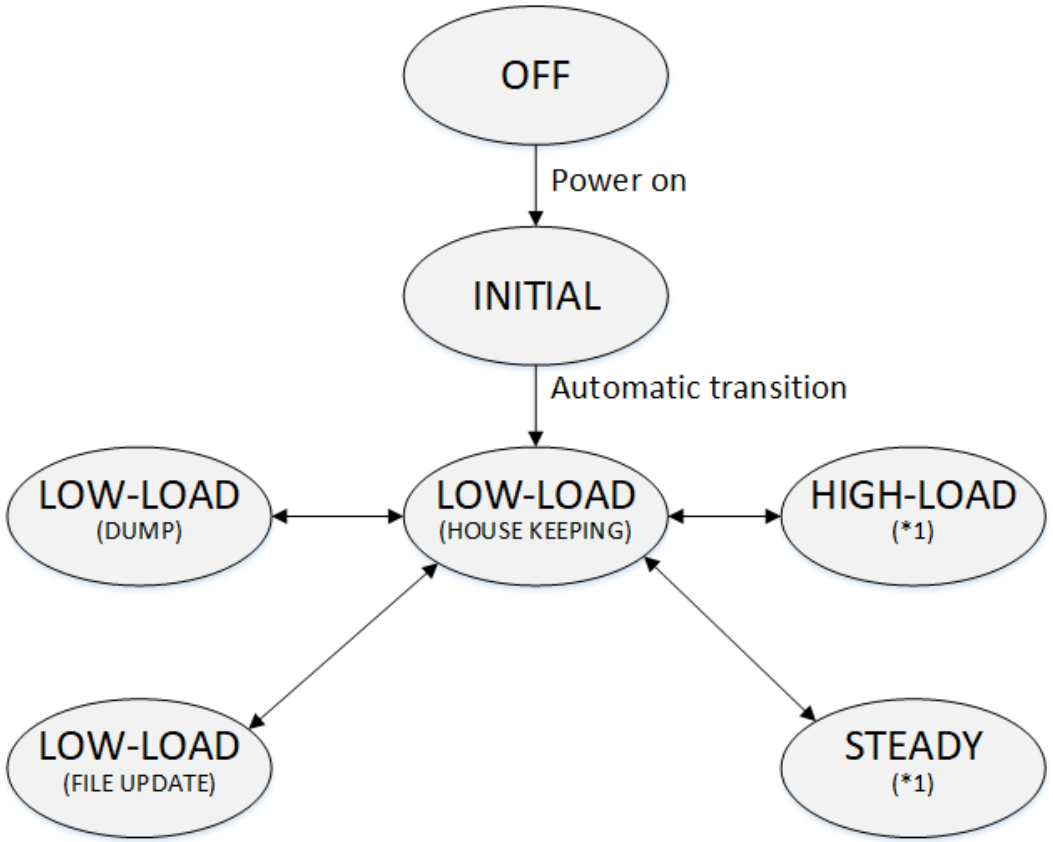
- Small size and low power consumption
- Data interface is RS-422 only
- Hardware redundancy (Switching between Nom. and Red. is realized by pulse command)



GEMINI – Mode –

Mode

– After initialization, three main mode and each sub-mode, switching by telecommand.



Mode Name	Sub-Mode Name (*1)	Power Consumption
OFF	NON	< 0.1W
INITIAL	NON	< 10W
LOW-LOAD	HOUSE KEEPING DUMP FILE UPTATE	< 3W
STEADY	AUTOMATIC IMAGING(SAR) EXTRACTION(SAR) ENCRYPTION(SAR) AI	< 5W
HIGH-LOAD	AUTOMATIC IMAGING(SAR) EXTRACTION(SAR) ENCRYPTION(SAR) AI	< 16.8W

©Mitsubishi Electric Corporation

GEMINI – SAR Processing –

SAR Processing

1st SAR imaging

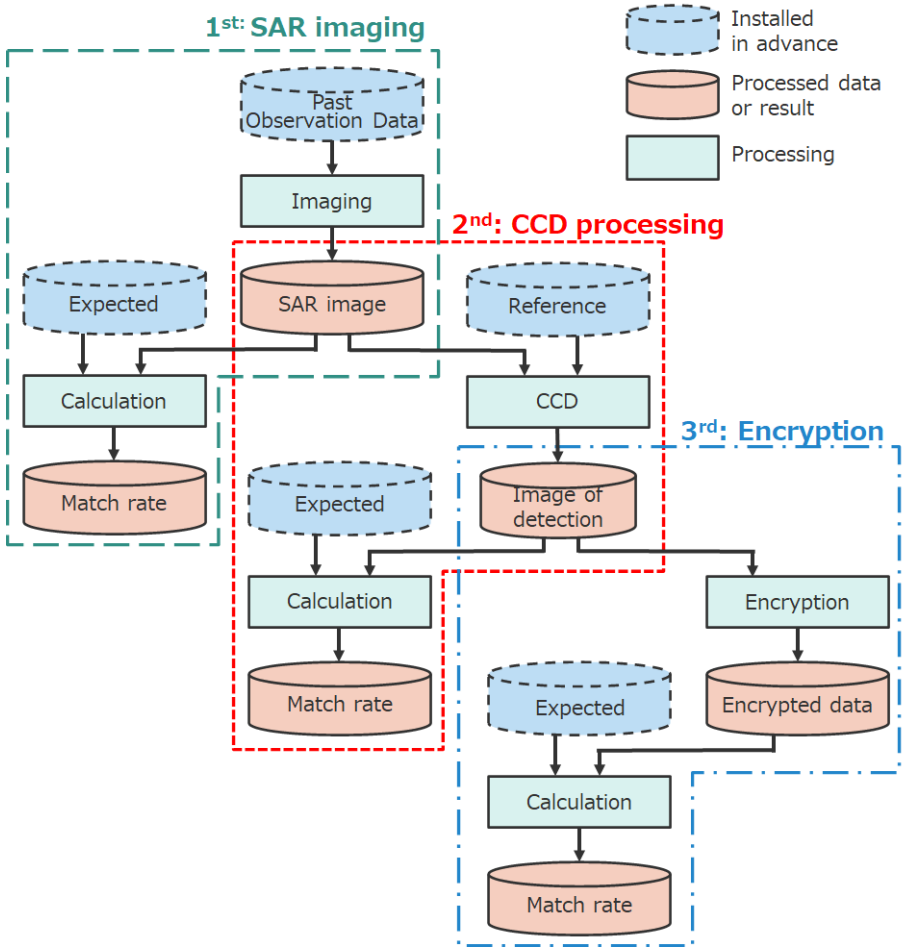
- Imaging for past observation data
- Comparing match with expected image

2nd CCD processing

- Generated using 1st process output with reference.
- Comparing match with expected image

3rd Encryption

- Encrypting for 2nd process output.
- Comparing match with expected data



SAR processing flow

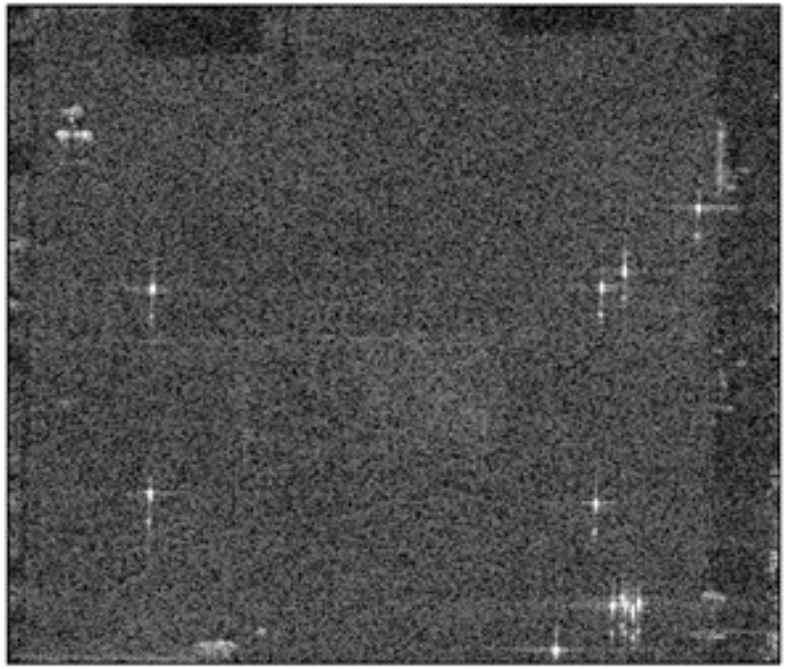
CCD: **C**oherent **C**hange **D**etection

©Mitsubishi Electric Corporation

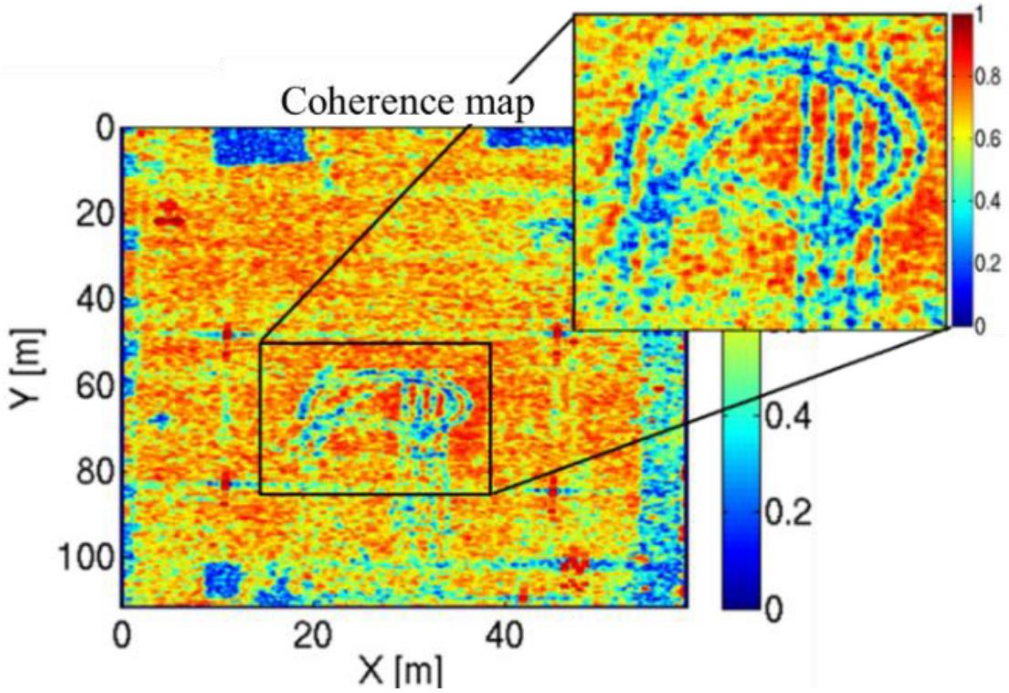
GEMINI – SAR Processing –

SAR Processing

- All three functions output is compared with expected data
  → Math rate is downlinked to ground with telemetry



Expected SAR image



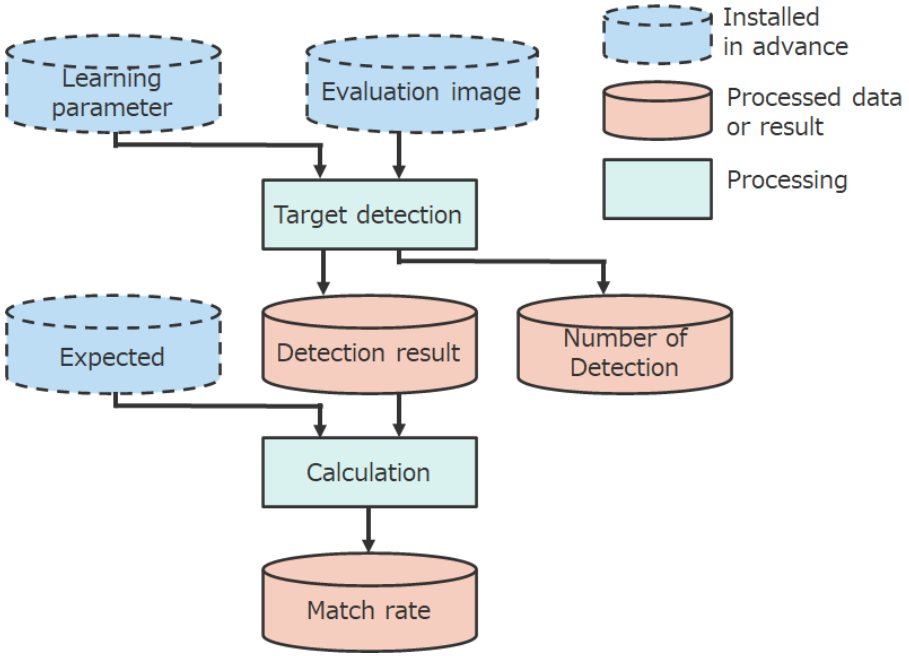
Expected CCD image

©Mitsubishi Electric Corporation

GEMINI – Target Detection with AI –

Target Detection (before update)

- Target detection is performed with AI.
- Learning parameter and optical evaluation image is installed in advance.
- Before update, **9 ships are detected**



Target detection flow

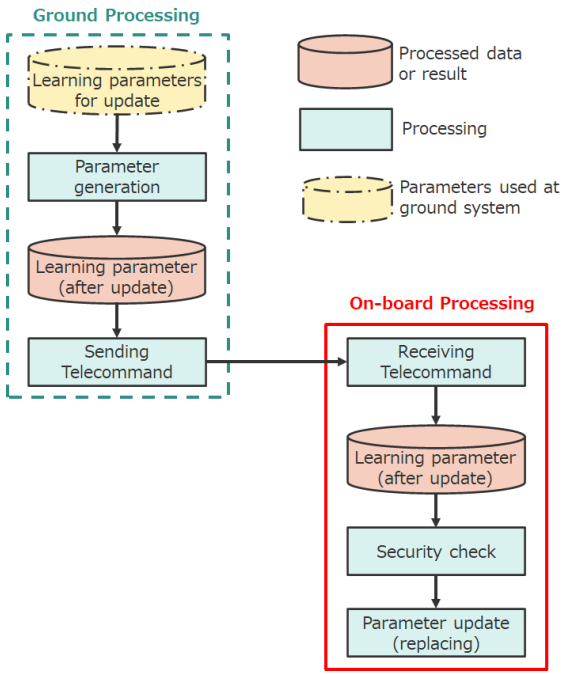
Expected detection result (before update)

©Mitsubishi Electric Corporation

GEMINI – Target Detection with AI –

Target Detection (after update)

- Target detection is performed with AI.
- Learning parameter can be updated through ground process and telecommand.
- After update, the function can be improved (**13 ships are detected**).



Update flow

Expected detection result (after update)

©Mitsubishi Electric Corporation

GEMINI – Status –

Engineering Model

Completely developed. Good results were obtained from tests below.

- Initial Electrical Test
- Vibration Test (Sine and Random)
- Shock Test
- Thermal Vacuum Test
- Final Electrical Test

Additional: EMC Test and Radiation Test (SEE and TID)

Flight Model

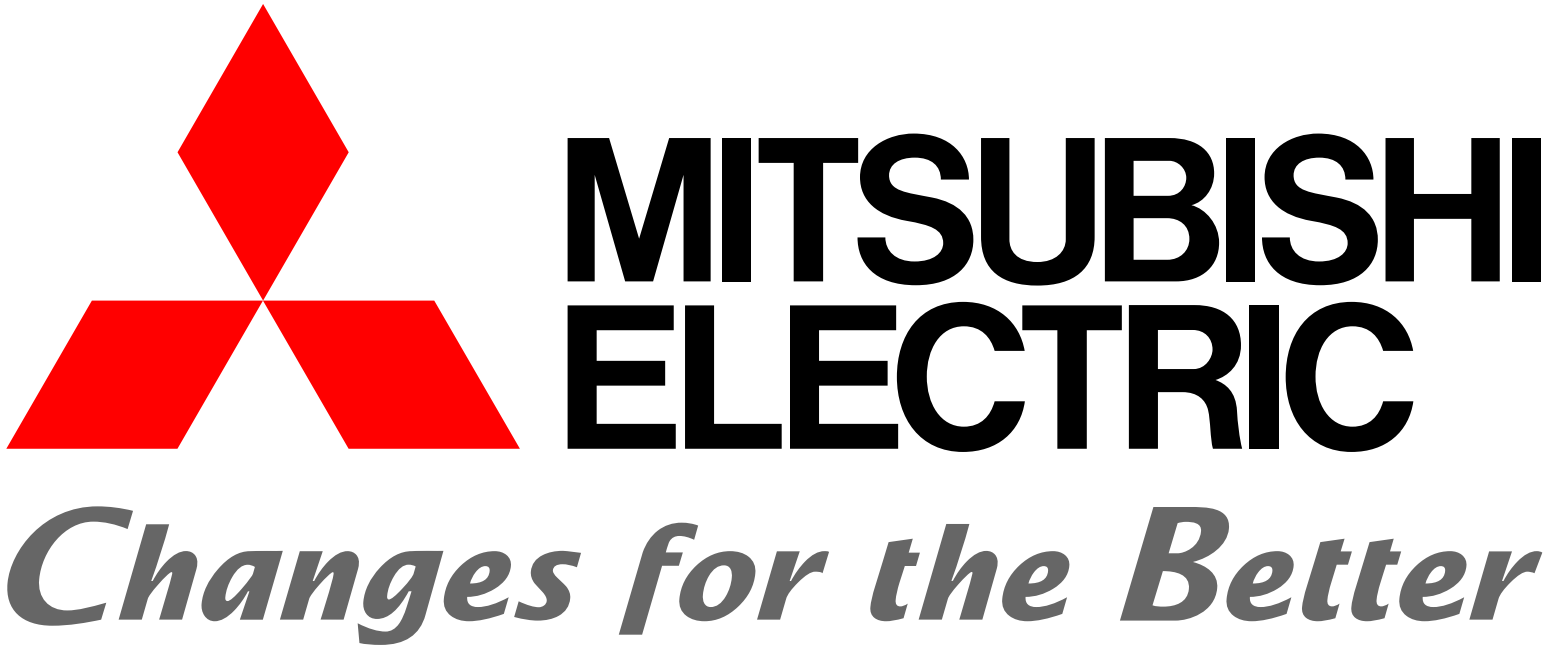
- Now manufacturing
- Proto Flight Test will be completed in JFY2023

©Mitsubishi Electric Corporation

Summary

- We have developed COTS GPU processor (GEMINI) for on-board demonstration program.
- Acquiring basic data and acknowledge of GEMINI, we will consider how to establish hardware and software architecture for COTS GPU.
- GEMINI's main function is SAR processing, target detection and update function which had already been verified at ground.
- Engineering model of GEMINI was completely developed, flight model will be manufactured and tested in this fiscal year.

©Mitsubishi Electric Corporation


MITSUBISHI
ELECTRIC
Changes for the Better