LetSat-1: A GPU Tech Demo and Image-Based Navigation System

LeTourneau University

Clifford White cliff@letsat.org
Chandler Griscom chandler@letsat.org

Outline

- Mission
- Description of Technology
  - Payload Hardware
  - Payload Software
- Concept of Operations
- Future Applications
- Timeline

LetSat-1 Mission

- Demonstrate commercial GPU hardware on a LEO platform
- Develop a software suite utilizing the GPU to determine position and attitude of the satellite without ground station or GPS contact

Description of Technology

- Payload Hardware:
  - Two NVIDIA Tegra K1 GPUs, with associated peripherals
  - Crystalspace CAM1U, fitted with a fisheye lens
- Payload Software:
  - Images processed by GPU to recognize surface features
  - Surface features compared to reference map to determine position

Description of Tech – Payload Hardware

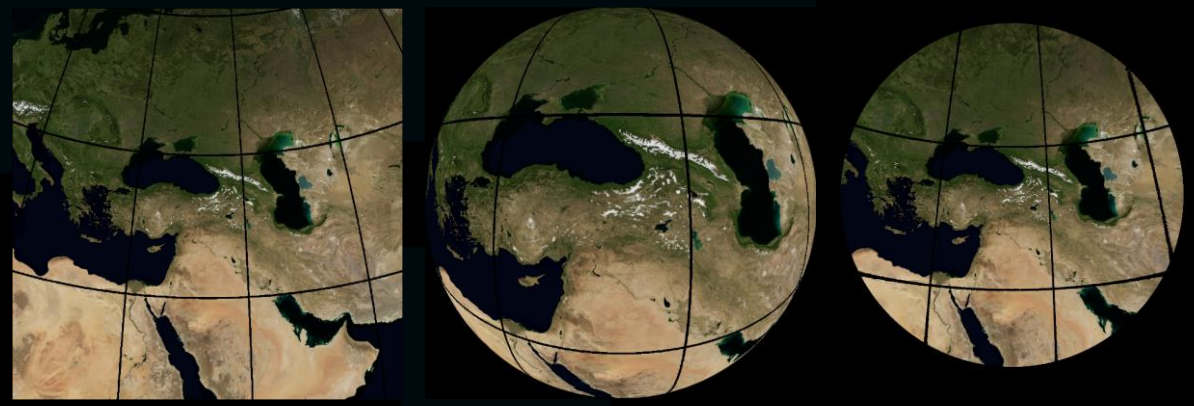
- NVIDIA Tegra-K1 GPU
  - Integrated onto ruggedized COM Express module by Abaco Systems
  - Two identical modules, second for redundancy
- Crystalspace CAM1U, with fisheye lens
  - Can image Earth's entire sphere
- Custom carrier boards
  - Mounts GPU module and SSD
  - Interfaces with satellite bus

Description of Tech – NVIDIA Tegra K1

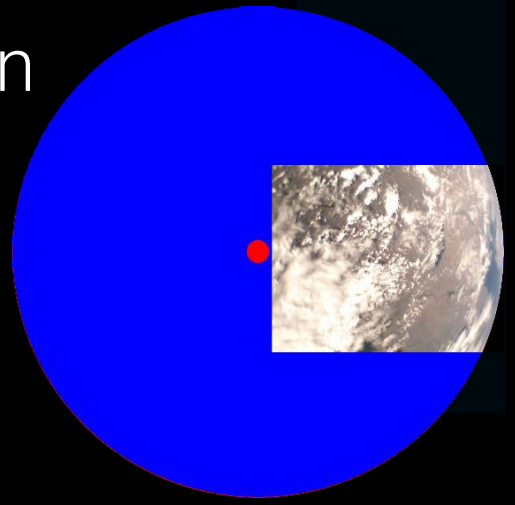
- 192 GPU CUDA Cores
- Quad-core ARM Cortex A15 CPU
- Linux OS – Ubuntu modified for GPU use
- Power consumption: 6 watts at idle, 13 watts maximum
- Ruggedized, yet small form factor – mCOM10
- 84mm x 55mm x 13mm
- Mil-spec thermal and vibration ratings

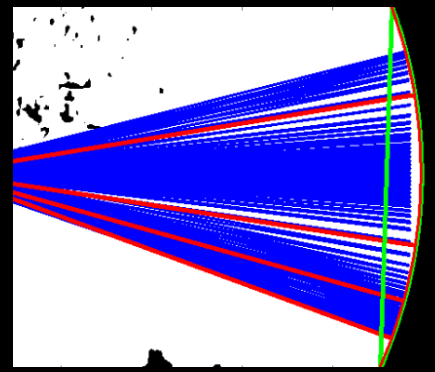
Description of Tech – Payload Software

- Distortion removal
  - Trigonometric computation on parallel CPU
  - Remapping on GPU



- Attitude and Altitude Determination
  - Algorithmic approach on CPU

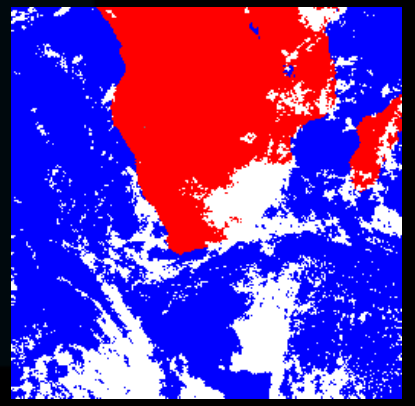




Description of Tech – Payload Software

- Neural Network Components
  - Pixel-by-pixel classification of image data
  - Cloud filtering and masking

- Lat/Long Determination
  - Database of panoramic images
  - Keypoints, probability-based comparisons



Concept of Operations

- ADCS Requirements:
  - Solar panels facing Sun
  - Camera pointing nadir during imaging passes
- ADCS Hardware:
  - Course sun sensors
  - MEMS gyroscopes, accelerometers
  - Camera as earth-tracker
    - Several low-resolution images of the earth are taken in succession
    - Center-detection done live for nadir-pointing modes
  - Mag-torquers

Concept of Operations

- Imaging Passes at “Local Noon”:
  - GPU boots slightly before local noon
  - Attitude control rotates satellite to point camera to nadir
  - Image captured for processing
  - Satellite rotates back to solar panels facing Sun
  - Image processed, if it’s useful
  - GPU shutdown
  - Results downlinked during next ground station pass

Applications – GPU Hardware

- Space-side processing of science data
  - Reduces required downlink bandwidth
- Neural networks / artificial intelligence / machine learning
- Computer vision
- Image processing
- Pattern recognition
- Others

Applications – Image-Based Navigation

- Interplanetary probes
  - Works around any orbital object with permanent terrain
  - Combine with pulsar-based Galactic Positioning System
  - Can react faster than Earth-In-The-Loop systems
- Missions where ground station and GPS contact is limited
- Extra layers of redundancy

Timeline

- Beginning: March 2017
- CDR: September 2018
- Launch: Early 2020
- Operations: Launch through re-entry

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