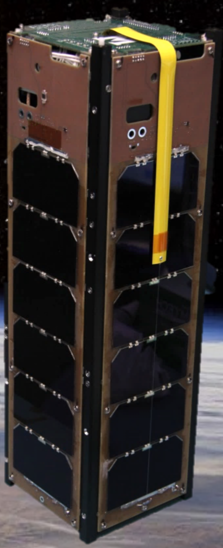
GRIFEX

GEO-CAPE ROIC In-Flight Experiment



Jet Propulsion Laboratory

D. Rider

23 June 2015

Advanced imaging technology enabling atmospheric chemistry and pollution transport science from GEO

Jet Propulsion Laboratory
California Institute of Technology

NASA

MICHIGAN

ESTO
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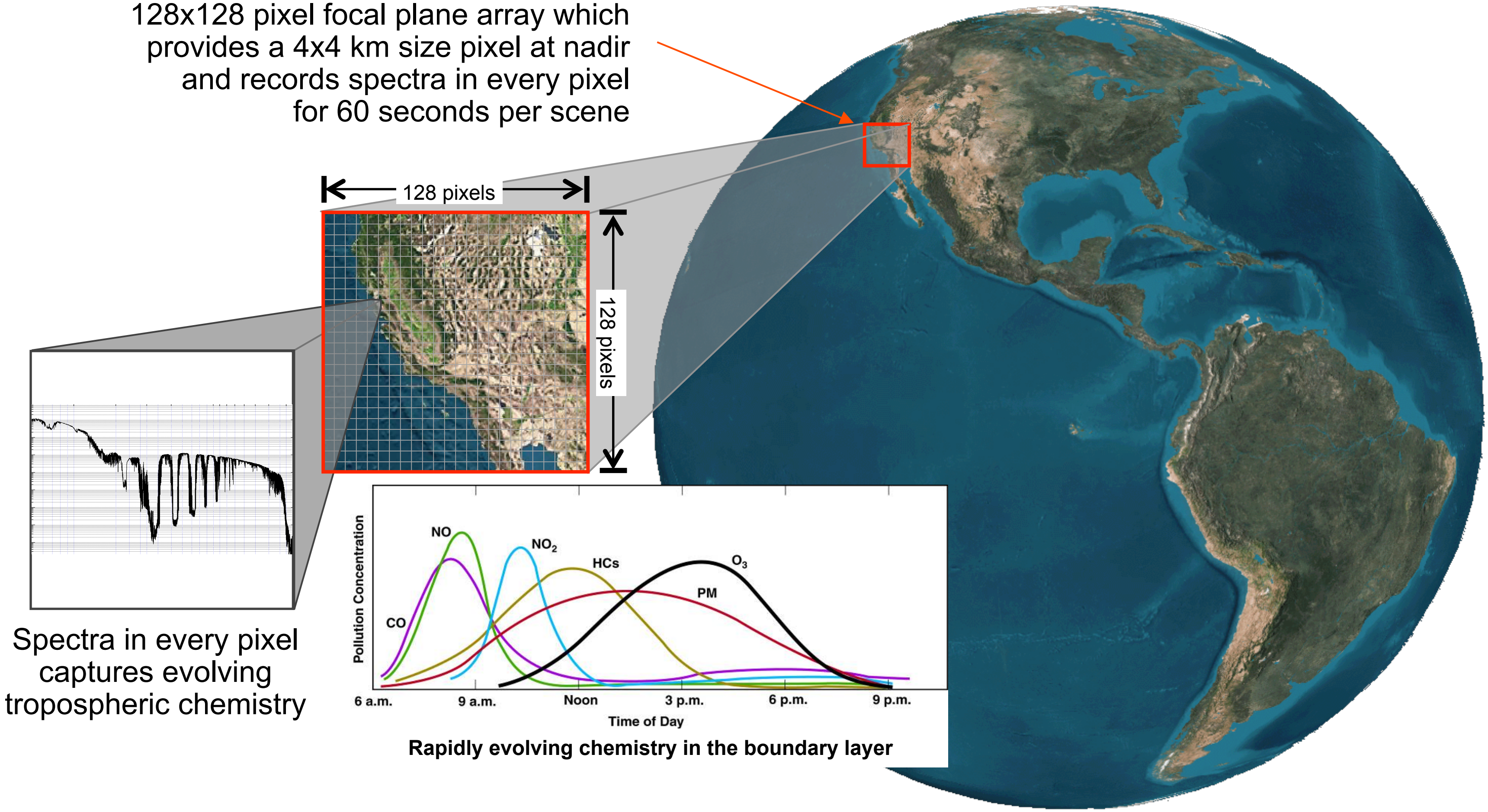
Geostationary Orbit Observing Scenario

500 km x 500 km scene is imaged onto a 128x128 pixel focal plane array which provides a 4x4 km size pixel at nadir and records spectra in every pixel for 60 seconds per scene



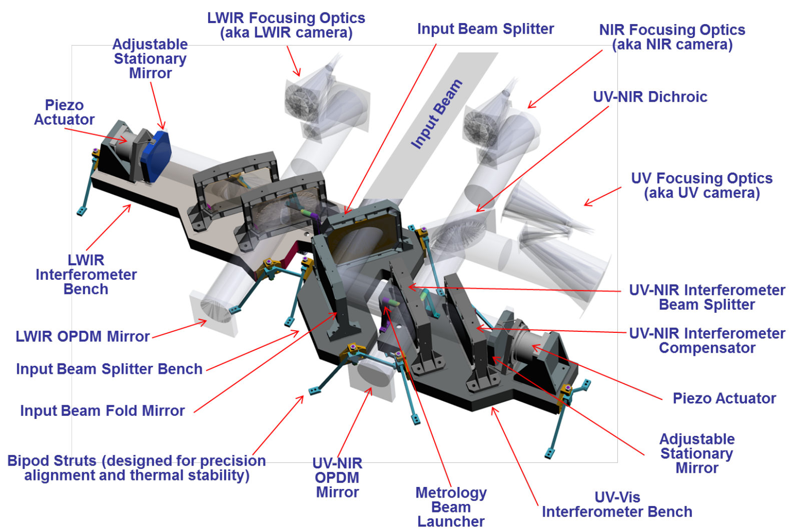
Spectra in every pixel captures evolving tropospheric chemistry

Rapidly evolving chemistry in the boundary layer

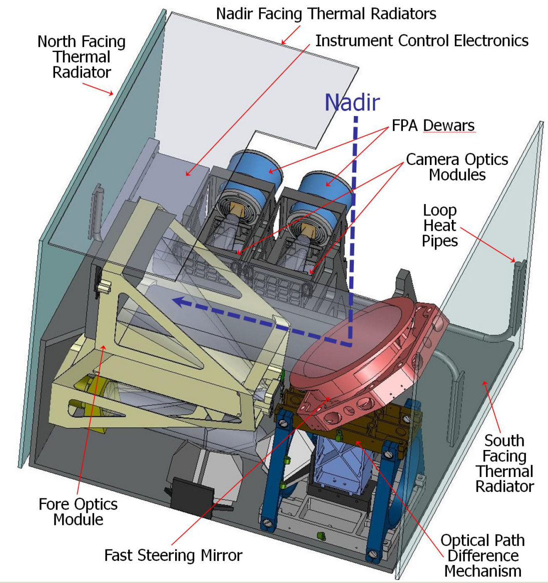
From geostationary orbit PanFTS can map all of North and South America hourly with high resolution measurements (temporal, spatial, and spectral) that capture rapidly evolving tropospheric chemistry with planetary boundary layer sensitivity

PanFTS Instrument Concept

PanFTS EM



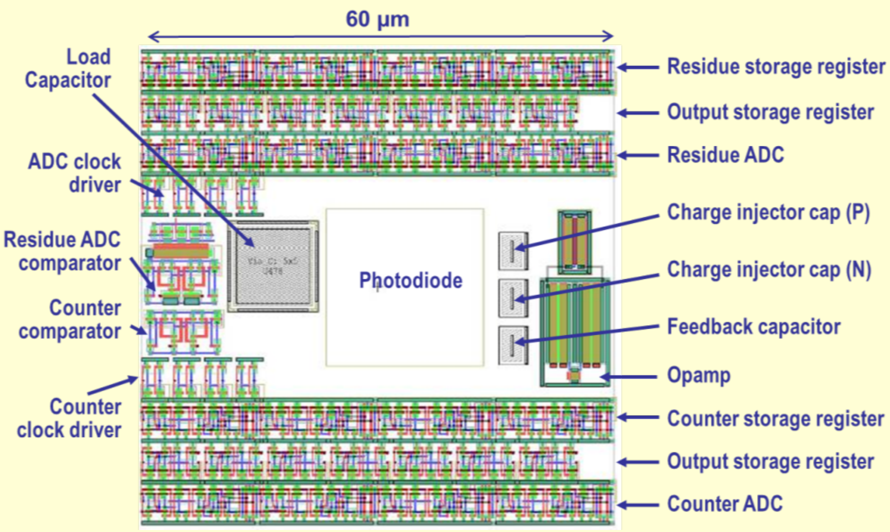
GCPI Concept



- High spectral resolution (0.06 cm^{-1}) and wide spectral sensitivity (15 to 0.26 μm) allows simultaneous measurement of reflected sunlight and thermal emission (day and night) enabling retrieval of several important atmospheric composition species such as Pollutants (O_3, NO_2, NH_3, SO_2, HCHO, CH_3OH, CO), Greenhouse Gases (CO_2, CH_4, N_2O, O_3, H_2O), and Transport Tracers (HDO, N_2O, O_2, O_4)
- The PanFTS design has two separate channels optimized for the infrared and Vis spectral domains, and multiple high speed focal plane arrays (FPAs) which simultaneously capture high-precision interferograms in each pixel for all of the wavelengths in the spectral range
- The UV-Vis side of the interferometer is based on the Fourier Transform UV Spectrometer (FTUVS) which has been operating for over 12 years at the Table Mountain Facility
- The overall design is compact because the two channels share a common fore optics, and a single common interferometer optical path difference mechanism (OPDM)

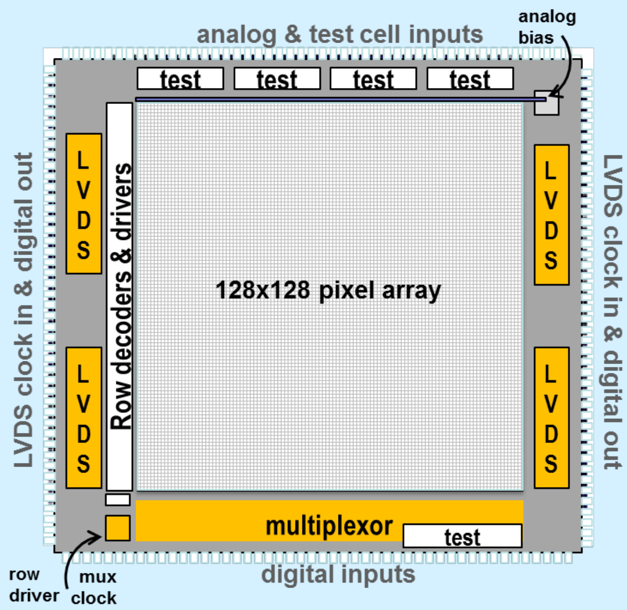
ROIC Design

Single Pixel Design



- High readout rate (12 kHz)
- High resolution readout (14 bits)
- Mixed analog/digital signal circuit elements
- Pixel footprint size limited to 60 µm
- Low power draw at full speed
- Design for testability

128x128 Pixel Array Design

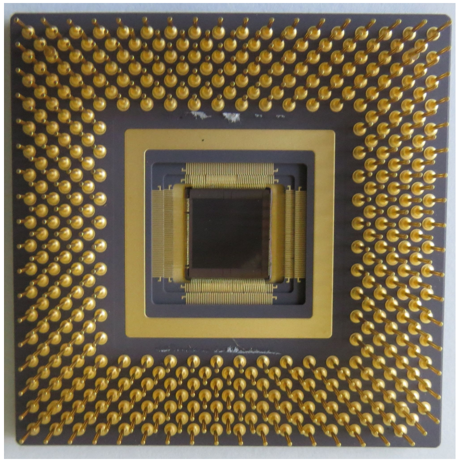


- High speed full frame (snapshot) readout
- Robust power distribution and signal flow
- Layout that minimizes pixel-to-pixel crosstalk
- Minimal sensitivity to manufacturing limitations
- Low power draw (slow clock rates)
- Design for testability and hybridization

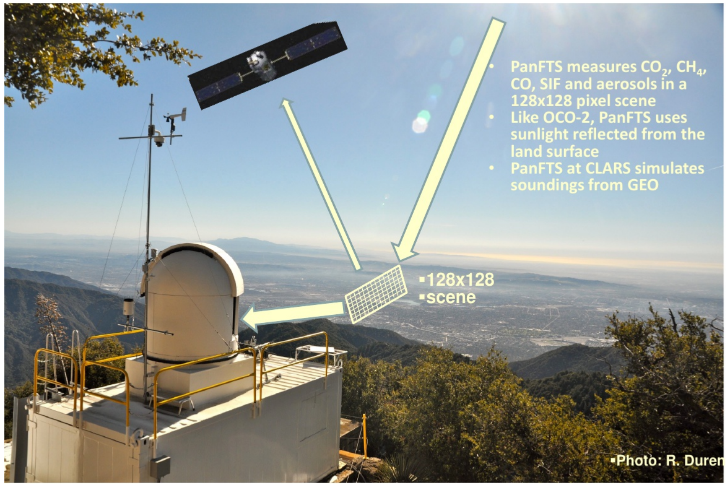
In-Pixel digitization ROIC encompasses two tightly coupled design challenges: (1) pixel design, and (2) array design

High Speed Imaging Demonstration

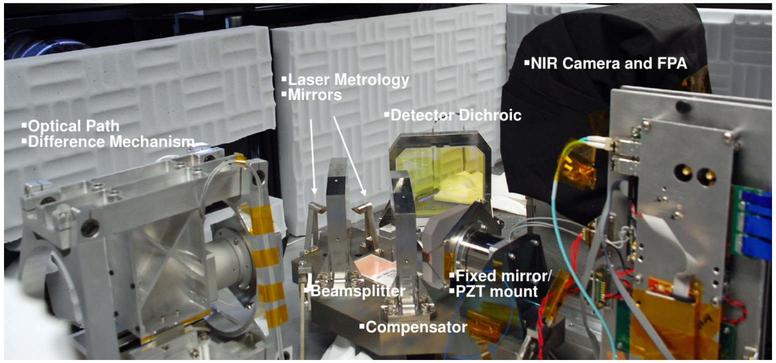
- Designed and fabricated the 128 X 128 ROIC in 180 nm CMOS
- Innovative in-pixel digitization ROIC has been developed that enables all digital FPAs (photons in produces bits out proportional to the intensity of the incident light)
- First run success developing brand new, unique ROIC design and fabrication
- Stop action experiment demonstrated ROIC capability for the high speed imaging needed to make rapid measurements
- Overall ROIC performance is outstanding and can be improved with array design refinements



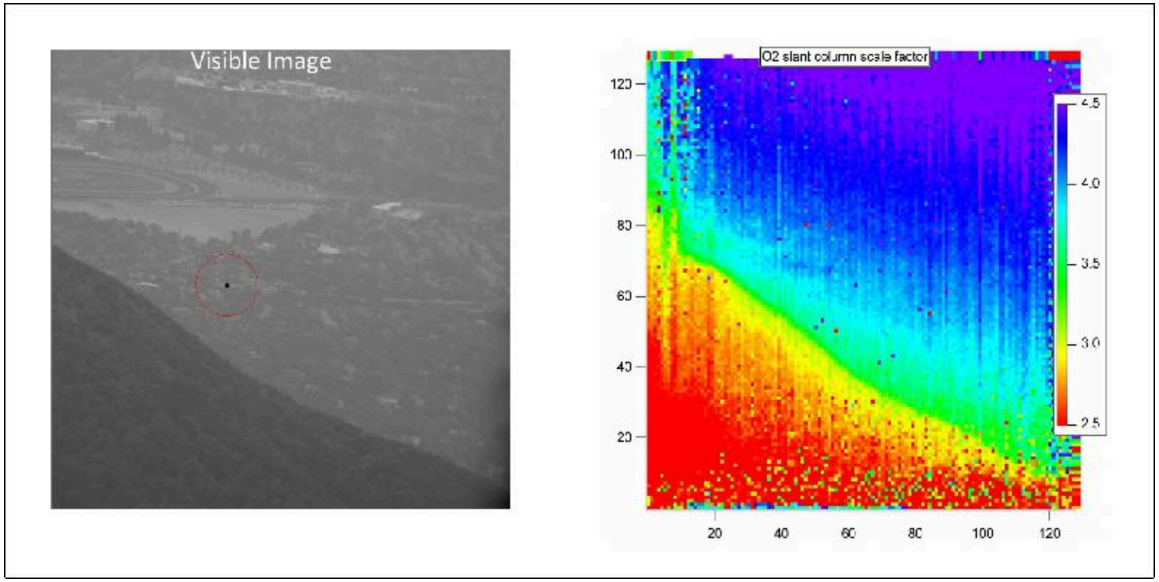
GRIFEX Detector In CLARS PanFTS



PanFTS Viewing Geometry at CLARS



PanFTS Interferometer at CLARS



Visible image (L) and retrieved O_2 image spectra acquired with GIFEX detector

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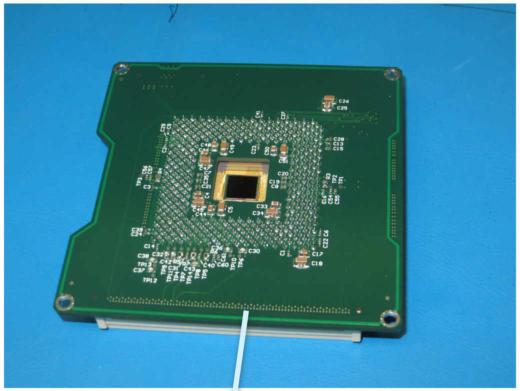
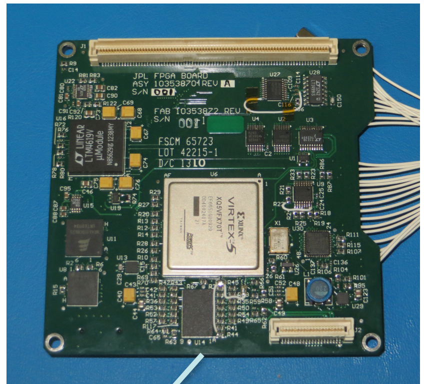
The GRIFEX CubeSat Camera

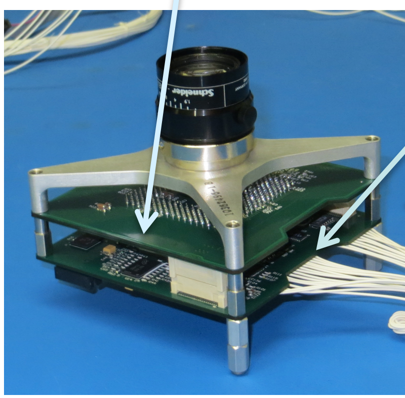
JPL
Jet Propulsion Laboratory
California Institute of Technology

GRIFEX Detector Board

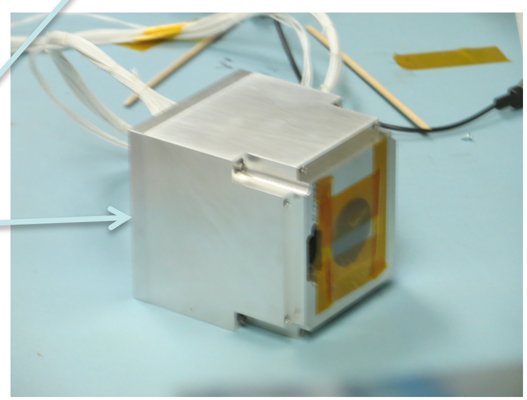


Camera Controller Board





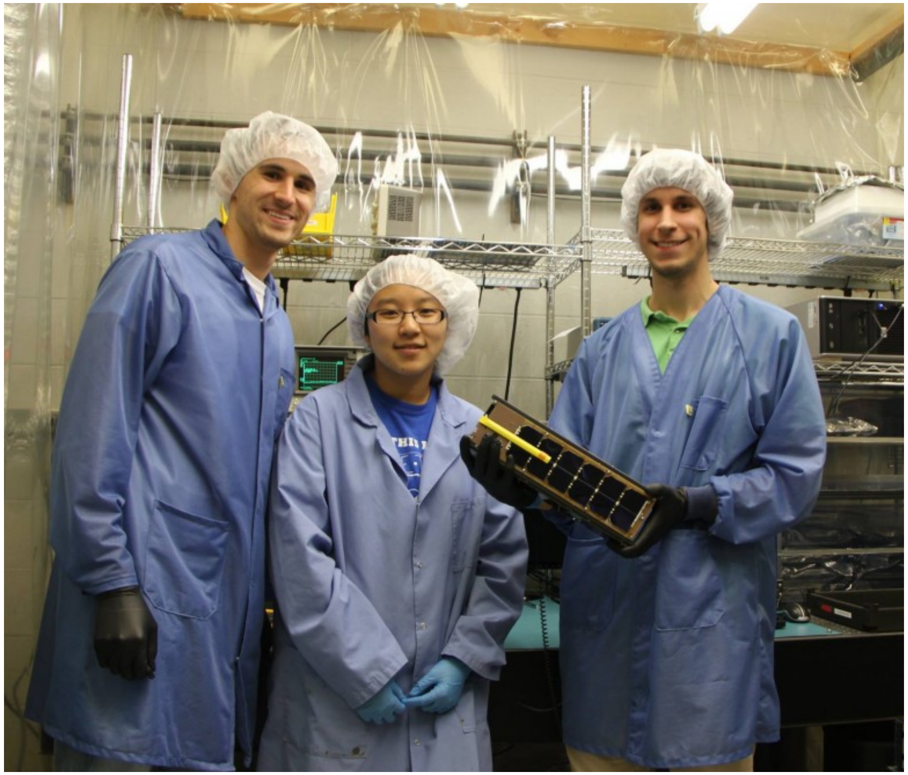
Built-up Camera



1-U GRIFEX Camera Al Housing

- ROIC hybridized to Raytheon Vision Systems Si PIN photo diode array
- All electronic parts are commercial off the shelf (i.e. Digilab)
- Optic is a ruggedized commercial lens
- The camera runs at 8 kHz frame rate
- Controller was derived from the M^3 CubeSat design and buffers 150 frames of camera data.

GRIFEX Spacecraft



A few of the very many University of Michigan MXL students who worked on GRIFEX

The 3-U GRIFEX CubeSat was designed, built, tested and integrated by the students of the Michigan Exploration Laboratory (MXL):

- 10 cm x 10 cm x 30 cm, 3 kg and ~6 W
- Magnetic field attitude stabilized

MXL is also doing all operations too.

Launched on as an auxiliary payload aboard the SMAP launch vehicle on January 31, 2015

Lunch vehicle integration was managed by the Educational Launch of Nanosatellites program (Kennedy and CalPoly SLO)

In an approximately 650 km circular orbit with 6 am/6 pm equator crossing time and 95 minute orbit period

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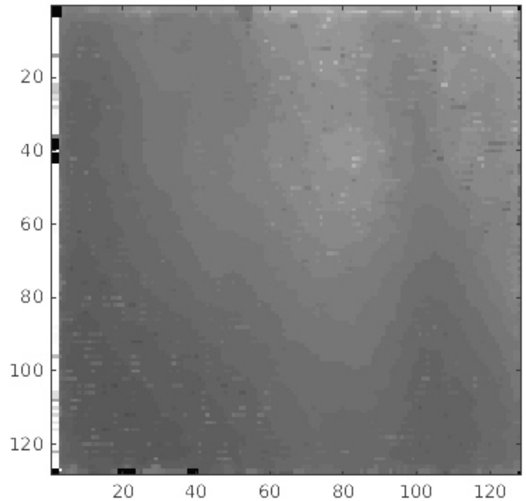
A Few GRIFEX Images

JPL Jet Propulsion Laboratory California Institute of Technology



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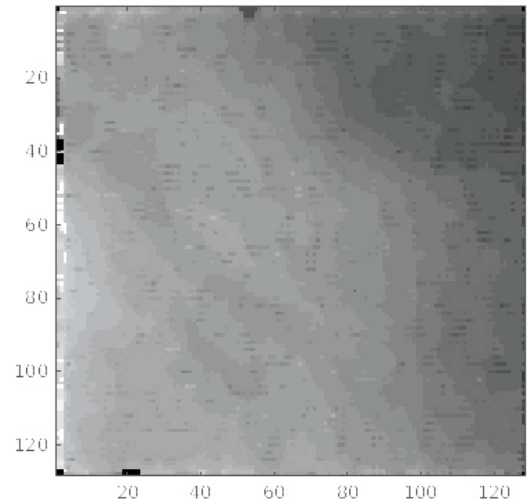

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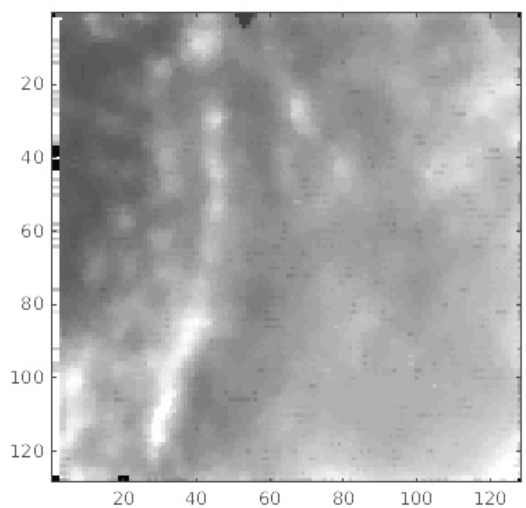

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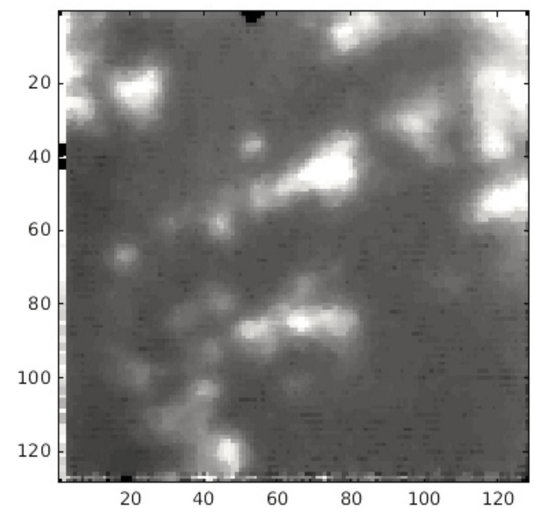

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Summary

- Innovative in-pixel digitization ROIC/Detector has been developed that enables all digital FPAs
  (photons in produces bits out proportional to the intensity of the incident light)

- Took 3 ½ years to build and launch – longer than originally planned

- Many more people contributed to the effort than originally thought.
  - Over 120 individuals made notable contributions. JPL, University of Michigan, Raytheon Vision Systems, Cal Poly San Luis Obispo, Kennedy Launch Services and Ham Radio Operators

- Collecting data is a bit slower than anticipated
  - S/C magnetic attitude stabilization is more is not quite as deterministic as inticipated

- The Spacecraft and the GRIFEX detector continue to operate normally and we anticipate many more months active operation and data collection.

- Demonstrated that the GRIFEX ROIC/Detector performs very well in the space environment.