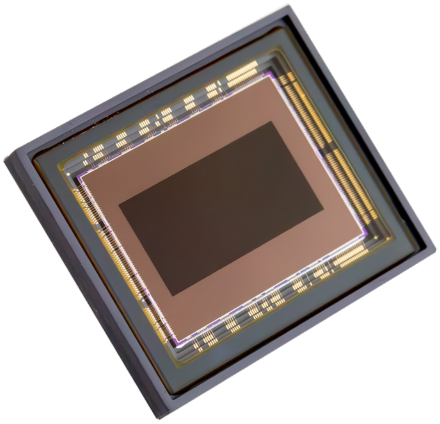
Future (In)Sight with Fairchild Imaging

Elevating COTS+ Imaging in Space

HWK4123

TRL 6 | 4/3” | 9.4MP | BSI | sCMOS 3.1 Technology



HWK4123 is a groundbreaking, ultra-low noise / ultra-low light imaging sensor. Incorporating sCMOS 3.1 technology, HWK4123 is a 4K image sensor capable of photon counting at 0.25e- RMS read noise.

Through this overview, we provide an introduction of expected mission environments and the effect of various sources of space radiation on electronics.

We focus on the primary effects of TID (Total Ionizing Dose) radiation and SEE (Single Event Effects) on electronics in space and how well Fairchild Imaging’s HWK4123 COTS+ (Component Off The Shelf) sensor can tolerate operating in these environments.

- **Lowest Noise Performance** – Full frame rate delivers superior data collection.
- **High Sensitivity** – Optimized for low-light and faint object detection, suitable for both Earth observation and deep space targets.
- **High Dynamic Range** – Enabling the capture of both bright and faint objects in a single exposure.
- **Stable Thermal Performance** – Reduced dark current variations across temperature swings.
- **Targeting SmallSat and CubeSat Imaging Markets** – High-performance yet compact sensors.
- **Enabling Hyperspectral and Multispectral Payloads** – Where high sensitivity and low noise are critical.
- **Ideal for Rapid Revisit and Persistent Monitoring** — Optimized for integration into constellations.
- **Designed for Integration with Advanced Optics** – Adaptive optics, larger apertures to exploit HWK4123’s sensitivity.

Mission Environment

It is more crucial than ever that space-bound electronic components used for Earth observation, terrain monitoring, agricultural applications, ocean observation, situational awareness and debris detection are characterized for extreme performance in the high radiation environment of space. Satellite missions have become more varied and complex. With the advent of increasingly high-resolution space optical imaging, it is particularly critical to understand how CMOS image sensors can tolerate the effects of various kinds of space radiation.

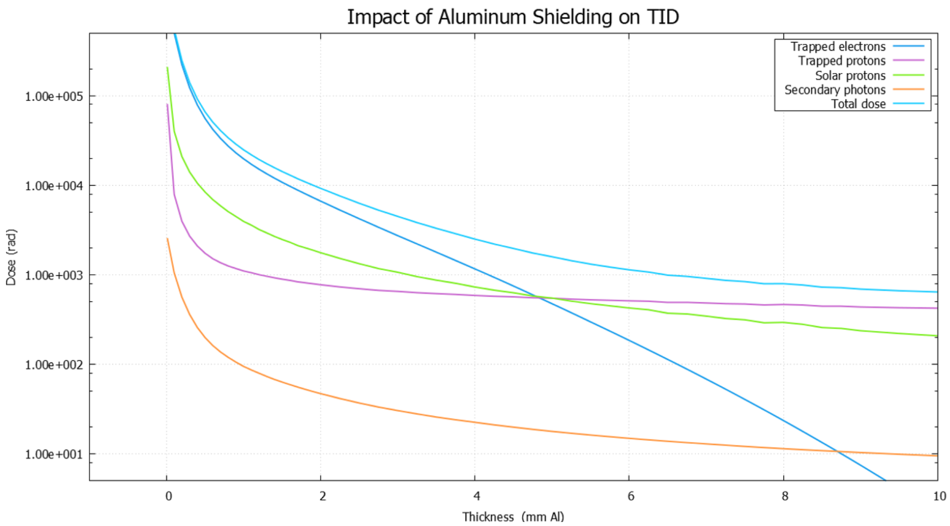


Figure 1: Total Ionizing Dose vs. Shielding

A typical mission will experience space radiation from three primary sources: solar particles, galactic cosmic rays (GCRs), and trapped particles. Solar particles are primarily protons from the Sun's coronal mass ejections and heavy ions from solar flares. GCRs are charged particles in free space of unknown origin. Trapped particles are protons, electrons, and heavy ions that are present in the Earth's magnetic field.

When we look at typical mission durations and radiation profiles we can see that even minimum amounts of shielding can help reduce exposure to all components.

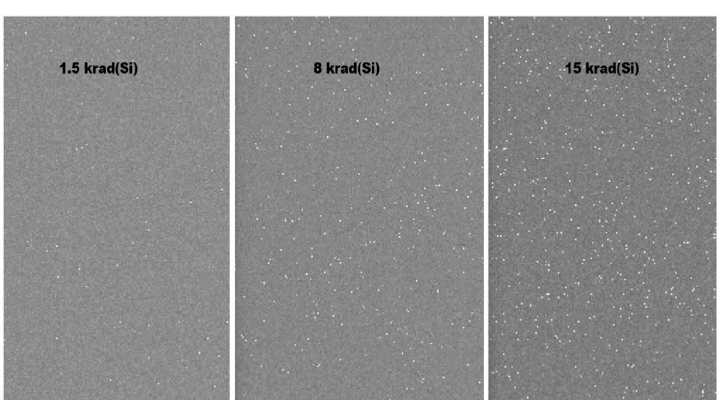
We prepare for this environment by conducting tests while still on Earth. We will go on to look at Total Ionizing Dose (TID) and Single Event Effects (SEE) and how they impact the HWK4123.

Total Ionizing Dose (TID)

TID gamma testing was conducted in 6 stages with a total dose of 15.3krad(Si). The HWK4123 sensor experienced little change in performance during this TID irradiation process. The mean dark current and noise appeared to increase slightly due to generation of bright pixels in the image, which is to be expected when an image sensor undergoes gamma irradiation. The uniformity of the dark current was not impacted due to the pinned photodiode flushing accumulated charge.

Step	Dose Rate (krad[Si]hr) (+/- 10%)	Step Dose (krad[Si]) (+/- 10%)	Total Dose (krad[Si]) (+/- 10%)
1	2.00	1.5	1.5
2	2.00	2.0	3.5
3	2.00	2.5	6.0
4	4.50	2.3	8.3
5	4.50	2.3	10.6
6	4.50	4.7	15.3

Table1: Irradiation steps for Gamma radiation – 15.3krad(Si) delivered over approximately 5 hours in steps. (Credit: Holland, 2025)



During TID testing, energetic electrons generated by Co-60 gammas create bulk displacement effects, translating to a minimal increase in isolated hot pixels as seen on the left.

A typical 12U CubeSat on a 3 year, 600km LEO mission has a TID of 0.48krad(Si), well below what the HWK4123 was tested to.

Figure 2, Bright pixel generation under gamma irradiation from 1.5 to 15 krads(Si). (Credit: Holland, 2025)

Single Event Effects (SEE)

A SEE that can occur is the Single Event Upset (SEU). An SEU occurs when a charged particle passes through a reverse-biased junction and changes its state, causing a disruption of data stored at that node, which may corrupt that data.
A more severe version of an SEU is the Single Event Functional Interrupt (SEFI). A SEFI does not lead to permanent damage; a SEFI is recoverable. This is a soft error that generally means the sensor resets, locks up, or generates image artifacts as described in the Fairchild Imaging white paper: "Radiation Tolerance of HWK4123 for Space Applications".

Another common SEE that occurs in 65nm process CMOS circuits is the Single Event Latchup (SEL). Latchup occurs when a large current is injected into parasitic PNP and NPN bipolar transistors nested inside of the main transistor substrate. This can reverse the bias, leading to increased current draw on the external network, until the device fails from thermal stress (Fairchild Semiconductor, 1989). A Linear Energy Transfer (LET) is the primary source of injected current in the case of an SEL. SEL mitigation is primarily done at the chip circuit design level; limiting current in the electronic circuit can mitigate device burnout. It is critical that if a sensor does experience latch-up it can recover without damage.

Proton and heavy ion testing is undertaken to simulate space radiation environments and quantify radiation impacts for electronic components. A spacecraft in high LEO or MEO will be exposed to more protons than those of GEO, due to the inner Van Allen belt. The bright pixels generated by the heavy ions were of overall lower intensity, compared to that of TID testing. However, the total fluence was ~5000 ions/pixel, which meant that all the pixels were affected during heavy ion irradiation, leading to higher global dark current.
For proton testing, the sensor was exposed up to 105MeV with a manageable SEU rate of 2 per krad(Si) at 63MeV.

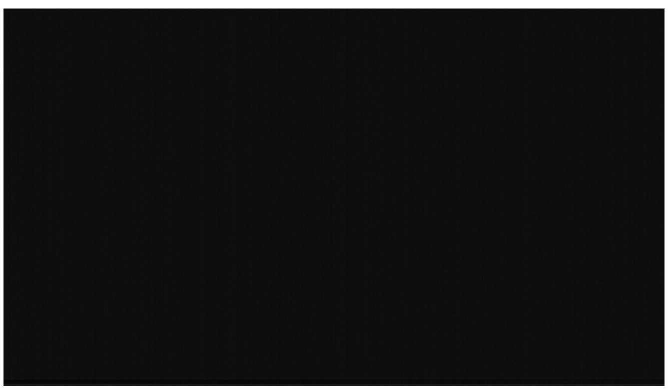


Figure 3: Pre-Irradiation Image with no Column Fixed Pattern Noise (CFPN) correction. (Credit: Holland, 2025)

Figure 4: Dark Current Image Post-Heavy Ion Testing. (Credit: Holland, 2025)

Results: The HWK4123 encountered SEFIs during heavy ion testing but did not experience any Single Event Burnouts (SEBs); i.e., catastrophic failures which lead to permanent damage. In the worst case, a simple power cycle was sufficient to recover the sensor and continue operation. For proton testing the sensor did not experience SELs, and an SEU rate of 2 per krad(Si) at 63MeV was measured.

Summary

Radiation planning is a crucial design consideration for space mission providers. It is critical that payload manufacturers and integrators account for all points of failure when it comes to radiation tolerance.

TID testing showed that over a total dose of 15.3krad(Si) delivered over 5 hours, the HWK4123's flatband dark current did not increase after irradiations.

A typical 12U CubeSat on a 3-year, 600km LEO mission has a TID of 0.48krad(Si), well below what the HWK4123 was tested to. Heavy ion testing produced functional interrupts to the sensor operation, but more importantly did not result in any catastrophic failure of the sensor. In the worst case, a power cycle was sufficient to recover the sensor.

Proton testing showed the SEU rate is easily manageable with 2 registered SEUs per krad(Si) at 63MeV while demonstrating no latch-ups or tangible increase in current drawn by the sensor.

Fairchild Imaging has a proven heritage of space ready COTS image sensors and providing custom upscreening services. This new data proves the HWK4123, the world's lowest read noise CMOS sensor, excels even in the harsh environment of space.

Summary and Product Specs

Specifications

Sensor

Optical format	4/3"
Configurations	Monochrome or Bayer RGB
Active array	4100 x 2300 (9.4MP)
Active area	18.9 mm x 10.6 mm
Active diagonal	21.6 mm
Frame rates	120 fps @ full frame rate 1000 fps @ 276 rows (ROI)
ADC resolution	12 bits @ ≤ 60 fps | 11 bits @ 120 fps
Programmable gain	LG: 1x | HG: 8x, 16x, 32x

Operating

Power	1.8W @ 120 fps
Operating temp	-30^{o}C to + 70^{o}C
Power supply	3.3V, 2.5V, 1.8V, 1.2V

Pixel

Pixel size	4.6µm x 4.6 µm
Shutter types	Rolling w/ Global Reset; Global Shutter
Peak Quantum Efficiency	90%
Read noise floor	0.25e- RMS @ 5 fps
Read noise at max frame rate	0.50e- RMS @ 120 fps
Dynamic range	89 dB
Dark current	0.01e-sec @ -20^{o}C
Non-linearity	<1%

Interface

Temperature sensor	Analog & Digital Outputs
Output data interface @ 1.2 Gbps	10 sub-LVDS @ 60 fps 20 sub-LVDS @ 120 fps
Data type	11 /12 bit RAW | 16 bit LG/HG merged
Control interface	SPI 20 MHz

Design Services

Fairchild Imaging's Design Services offer COTS+ devices. We can qualify our Component Off the Shelf (COTS) devices by applying mission-specific up-screening requirements for imaging in Space. This enables confidence in the performance of our devices in high-stress flight applications.

Our quality assurance process can adapt to custom up-screening needs, from custom characterizations to lot process controls to full MIL-SPEC requirements. Our team is ready to work with you.

Acknowledgements

Holland, Andrew (2025), XCAM Scientific

Hu, Hank (2026), "Radiation Tolerance of HWK4123 for Space Applications", Fairchild Imaging, Inc.

Daigle, Oliver, Ph.D. (2026), Nüvü Caméras, Inc.

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