


L3HARRIS™

: LOW-COST, LARGE FORMAT, RADIATION RESILIENT, MID AND LONG WAVE INFRA-RED FOCAL PLANE ARRAYS

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L3Harris Space and Sensors Division, Mason, Ohio, US Facility

- Launch Vehicle and Spacecraft Avionics, IR Focal Plane Arrays (FPAs)
- 850 Employees and 245,000 ft^2 in Facilities
- Annual Sales of ~ $260 Million

Cleanroom - FPA assembly

Dewar/Cryocooler assembly & integration

Space Product Lines

AVIONICS

- Range safety receivers
- Power distribution & control
- TDRS telemetry transmitters
- Data acquisition
- Flight computers
- Navigation

COMMUNICATIONS

- Ka-, Ku-, X-, & S-Band transmitters/modulators
- S-Band & UHF transponders/tranceivers
- Common Communications for Visiting Vehicles (C2V2)

SPACE SENSORS

- ISR / IRST imaging & detection
- High definition cameras & video systems
- Large format FPAs
- MWIR, LWIR, dual band

Detection challenges

- Heritage Intelligence/Surveillance/Reconnaissance satellites in GEO look for bright missile plumes (high W/steradian signatures)

- Decreasing target signatures demand higher resolution sensors for robust detect-and-track solutions.
  - This drives the need for sensors with smaller Instantaneous Field Of View (IFOV) that don't sacrifice wide Field of View (FOV).

- Hypersonics: mid-course maneuvering is a deployed capability.
  - Boost phase state vector no longer adequate to predict flight path determination. Non-ballistic maneuvering no required precise knowledge of target state at all times is required for effective intercept or countermeasure engagement.
  - The sensor requirement is smaller IFOV for increased spatial and temporal resolution.
  - Cannot sacrifice FOV, because that leads to large regions of interest not under continuous surveillance.

The utilization of ultra-large format IR detectors is necessary to achieve small IFOVs while achieving continuous monitoring of the ROIs, enable the detect-and-track/assess capability.

Near-peers are developing space-domain dominance capabilities

- Disabling our space-based assets by:
  - Kinetic energy impact (direct, fragmentation)
  - Destruction of sensitive electronics by high-power RF
  - Disable Critical Systems: Power Generation, Sensors, Communications, Thermal Management
- Defense: utilizing guard satellites, self-defense systems
- However…engagement with other country's satellites risks escalation
  - Also, consider the “bar fight” analogy – the contest is fought and won or lost with the first punch…

Most military satellites were designed for a “benign environment, just like commercial satellites…I don’t want to buy any more fragile, un-defendable satellites.”

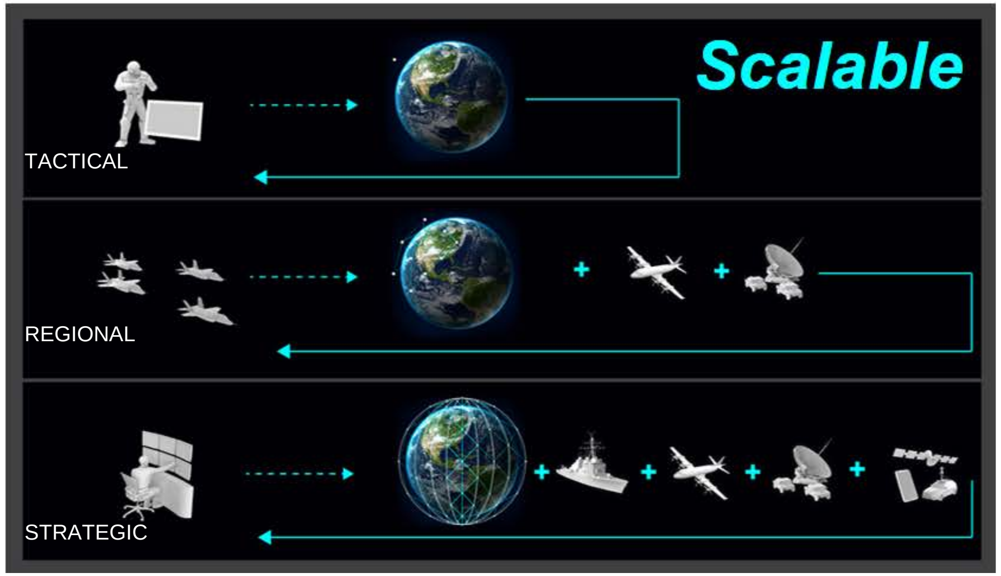
– Gen. John Hyten

Mitigation for adversarial action against NATO assets

- LEO/MEO Constellation – move from few high-cost assets in GEO, to many low-cost in LEO/MEO
  - Disaggregating assets provides ability to absorb loss of a significant number of assets, without a corresponding loss of capability
  - Rapid reconstitution from covert in-orbit spares or operationally responsive launch.
  - Rapid technology insertion
  - Lower launch costs to LEO

- Advantage for advanced threats
  - Low SNR (hypersonic weapon system) detect and track due to closing the detection range…
  - …while maintaining missile launch detection ability

Constellation capabilities



Challenges of Proliferated Low Earth Orbit (pLEO)– a Gedanken experiment

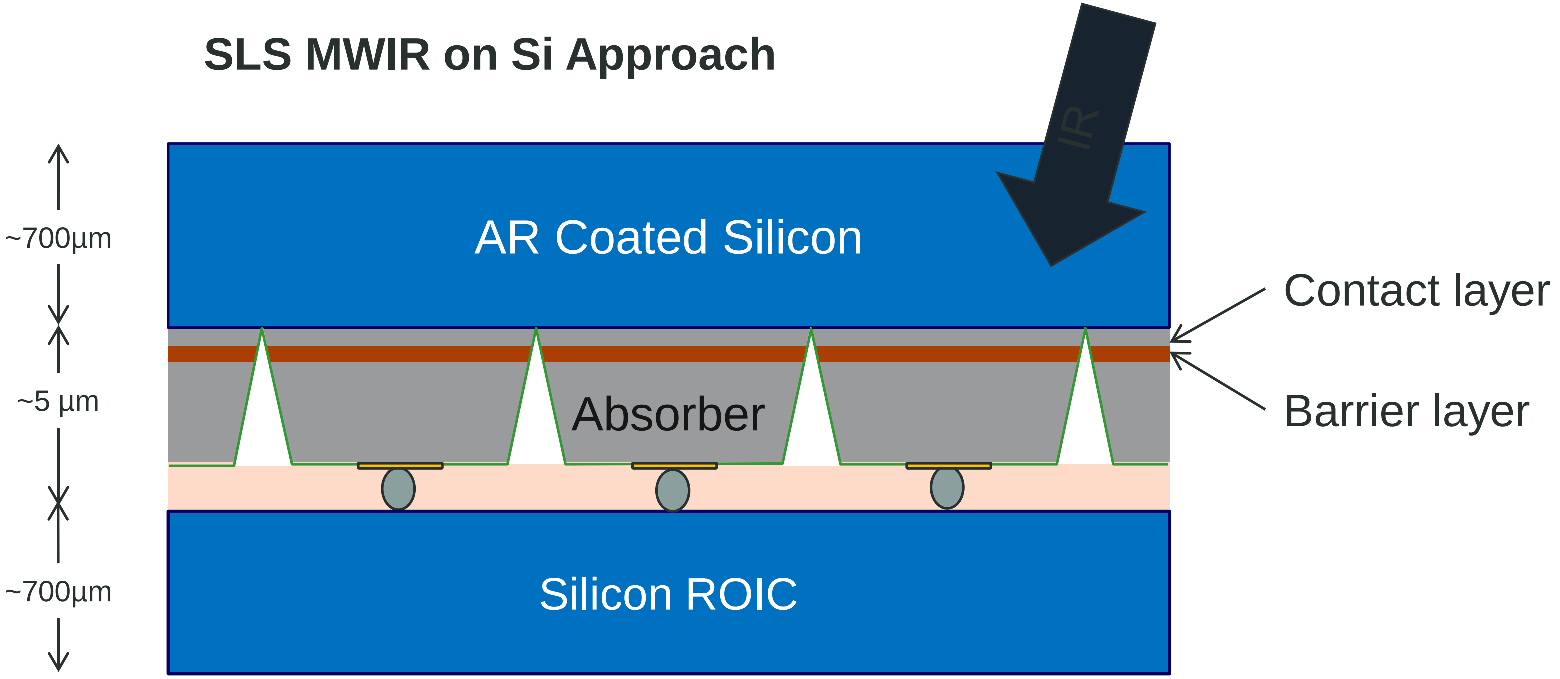
- Constellation of 200 satellites w/ target cost <€2B (not including initial engineering)
  - €10M per satellite, including launch costs
- €75M per launch vehicle; 20 satellites per launch = €3.75M per satellite launch costs
- Therefore, the satellites must be low SWaP (space, weight & power) and <€6.25M / unit.

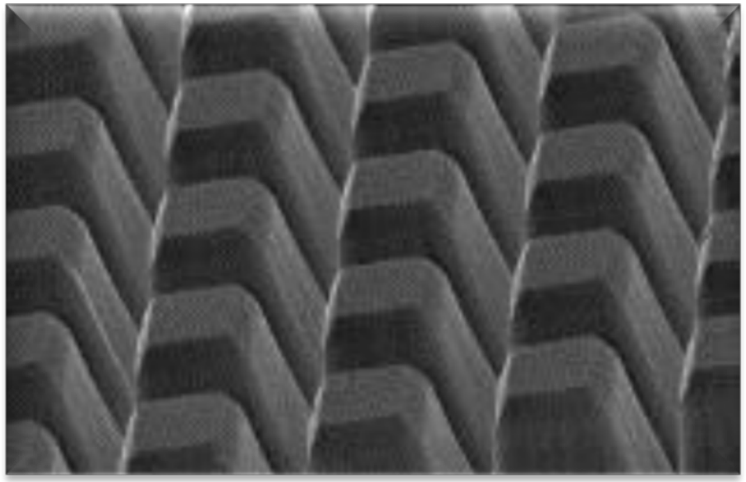
- €6.25M per satellite includes:
  - Processor
  - Communications (RF and optical)
  - Power generation and management
  - Thermal control
  - Assembly, Integration & Test
  - End-of-life / deorbit
  - Sensor

Strained Layer Superlattice detector material for Space

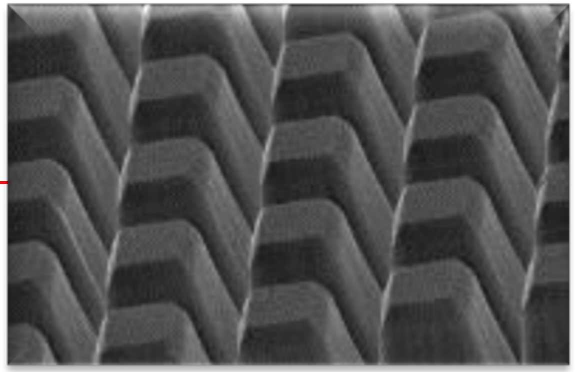
- SLS is manufactured by commercial foundries (decentralized, no single-point manufacturing failure)
- ~600 to 800 alternating layers of material with slightly mismatched crystal lattice matching (hence the "strained" part) with an overall thickness of ~5 microns

SLS MWIR on Si Approach



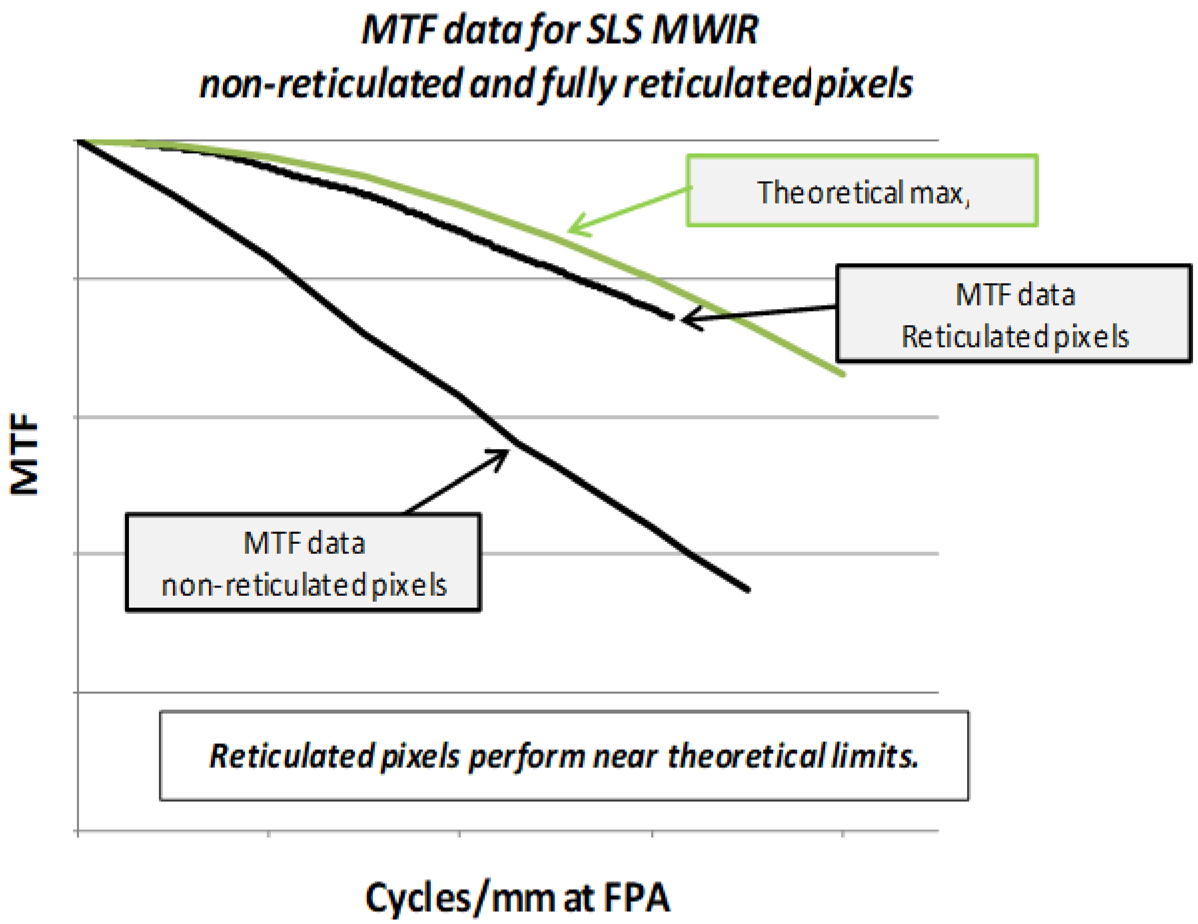


Structural and Performance Advantages of Reticulated Pixels



- Performance – Modulation Transfer Function (MTF)
  - Electrical and photonic isolation; no photon or photocarrier cross-talk
  - Modulation Transfer Function (MTF) approaches the theoretical limit
  - Maximized SNR & NIIRS is attained

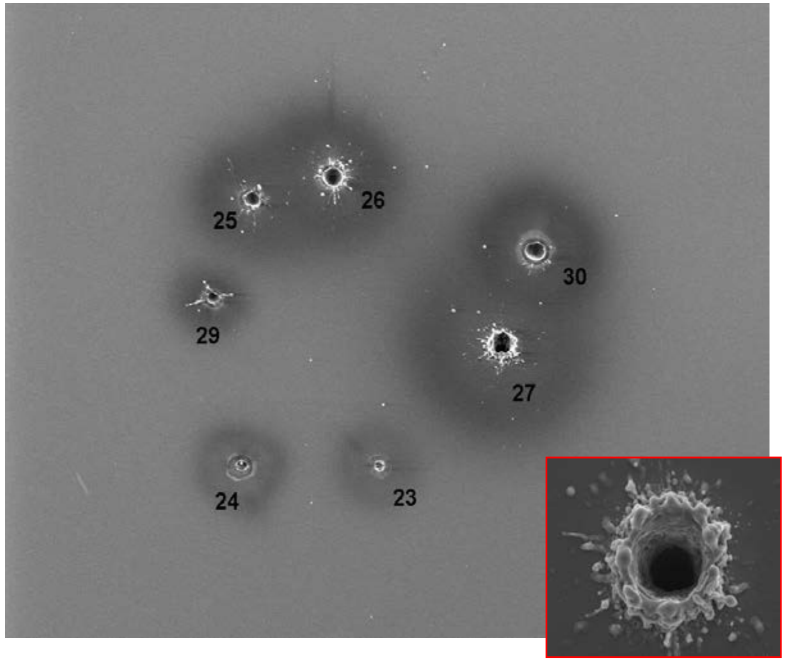
- Structural – decoupling and stress reduction
  - Avoid FPA warping during cool down due to CTE mismatch; <10μm displacement
  - Stress relief, repeated temperature cycles do not lead to cracks in the detector material and FPA failure
  - Long lifetime for ultra-large format FPAs



Laser Resilience

- Laser resilience is a consideration for LEO optical sensors.
- The first FPA layer is transparent silicon and behaves as an optical fuse.
- At fluences high enough to cause damage, energy deposited in this layer deforms it.
- The incoming beam is scattered, reducing the areal energy density in the subsequent detector and ROIC layers.

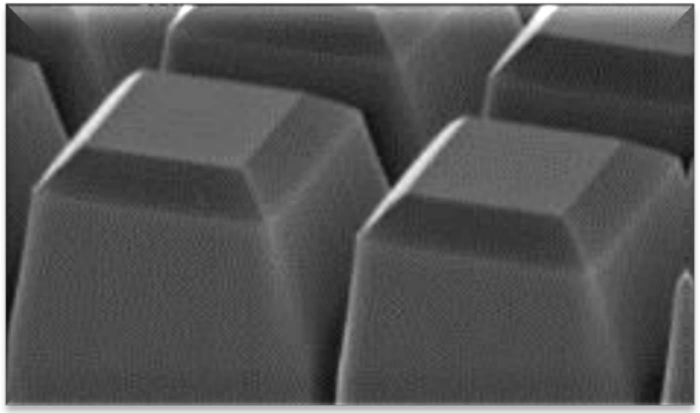
- Since 2000, laser tests conducted on InSb FPAs with the same structure, have not been able to disable an L3Harris focal plane completely.
  - Only small regions, rows or columns have been rendered inoperative



Silicon surface damage; optical fusing

Strained Layer Superlattice detector material for Space

- Familiarity and emotional attachment to older technologies may be an impediment to changing paradigms.
- Performance metrics not usually considered need to be prioritized
  - Operability (>99.8% working pixels)
  - Uniformity (every pixel, nearly equal response)
  - Stability (recalibrations/day)
  - Detector Modulation Transfer Function
  - Cost

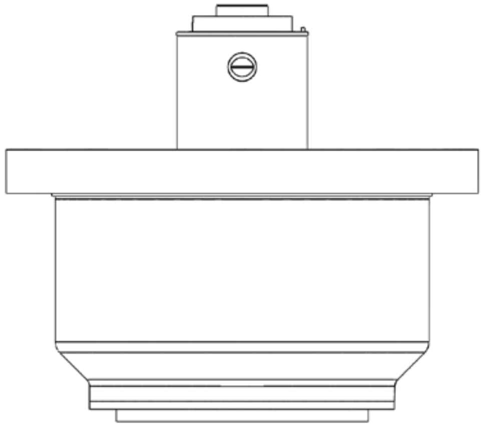


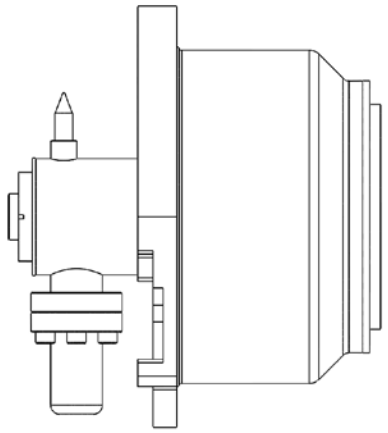
Reticulated Pixels – (InSb FPA)

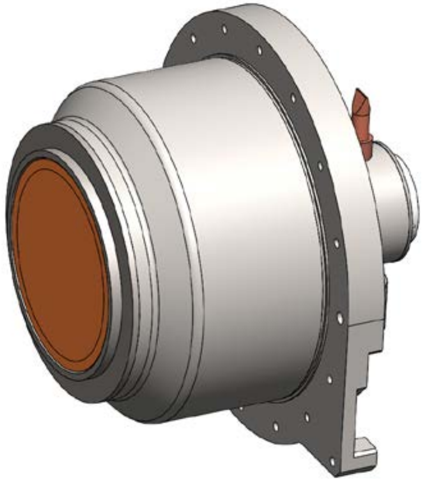
- Systems engineering approach:
  - “Design is based on requirements. There's no justification for designing something one bit "better" than the requirements dictate.”

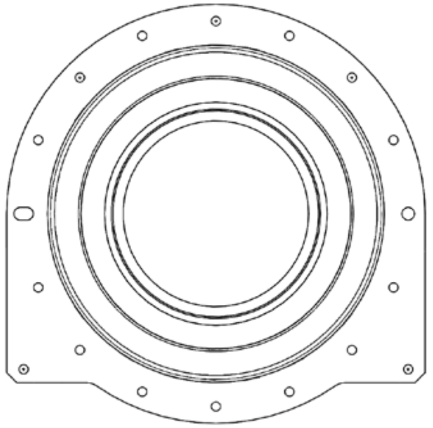
Characteristics

- SLS can sense MWIR and LWIR
  - –MWIR runs at 125°K
  - –LWIR runs at 77°K
- Delivered as an IDECA Module (Integrated Dewar, Electronics and Cooler Assembly).
- Facilitates testing at cryogenic temperatures and contamination while mitigating condensation of H_2O, CO_2, Ar, etc., out of air.







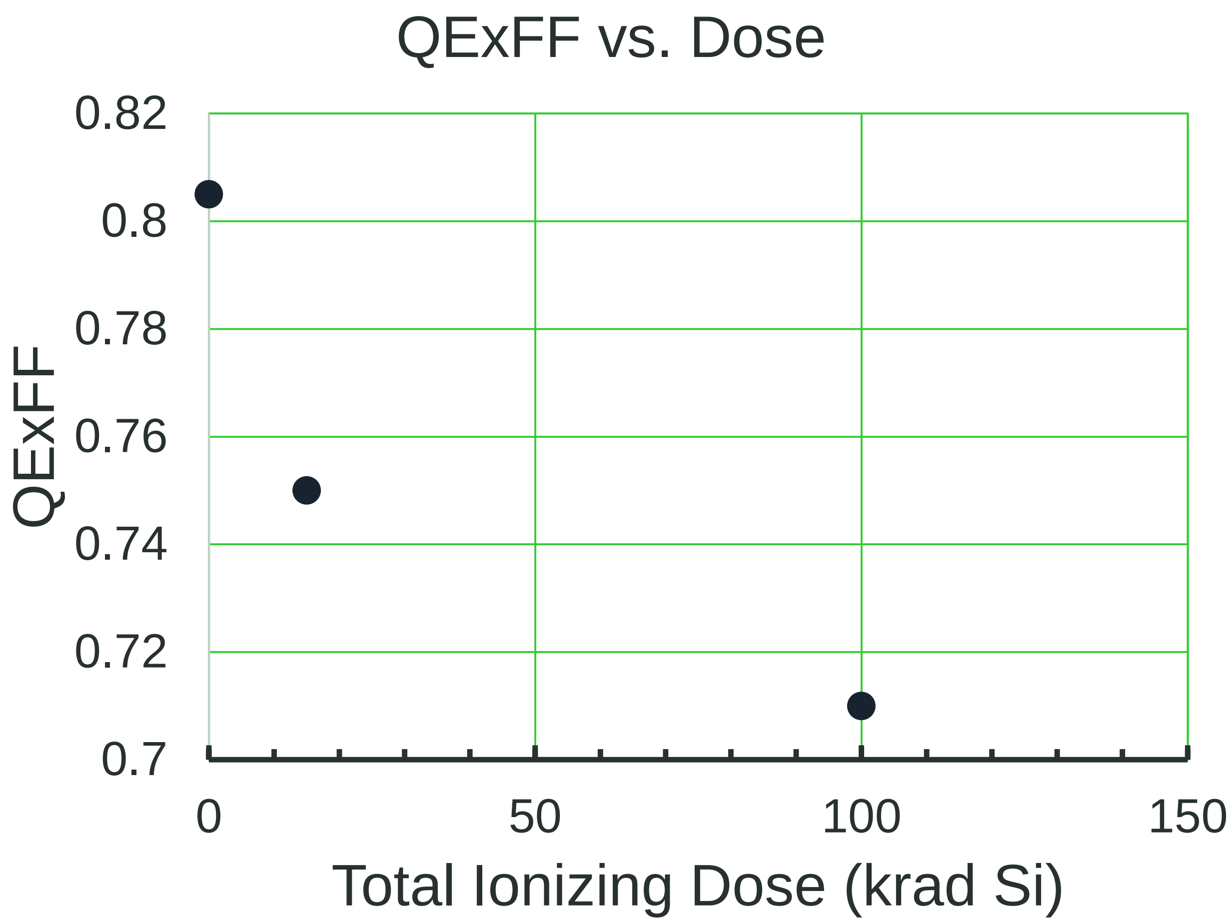


- Evacuated Dewar provides >100 mil Al shielding

SLS Sensitivity with Increasing Radiation

- QE = Quantum efficiency
- FF = Fill Factor (of pixel)
- With Dewar shielding, the QExFF expected to be >75% at EOL

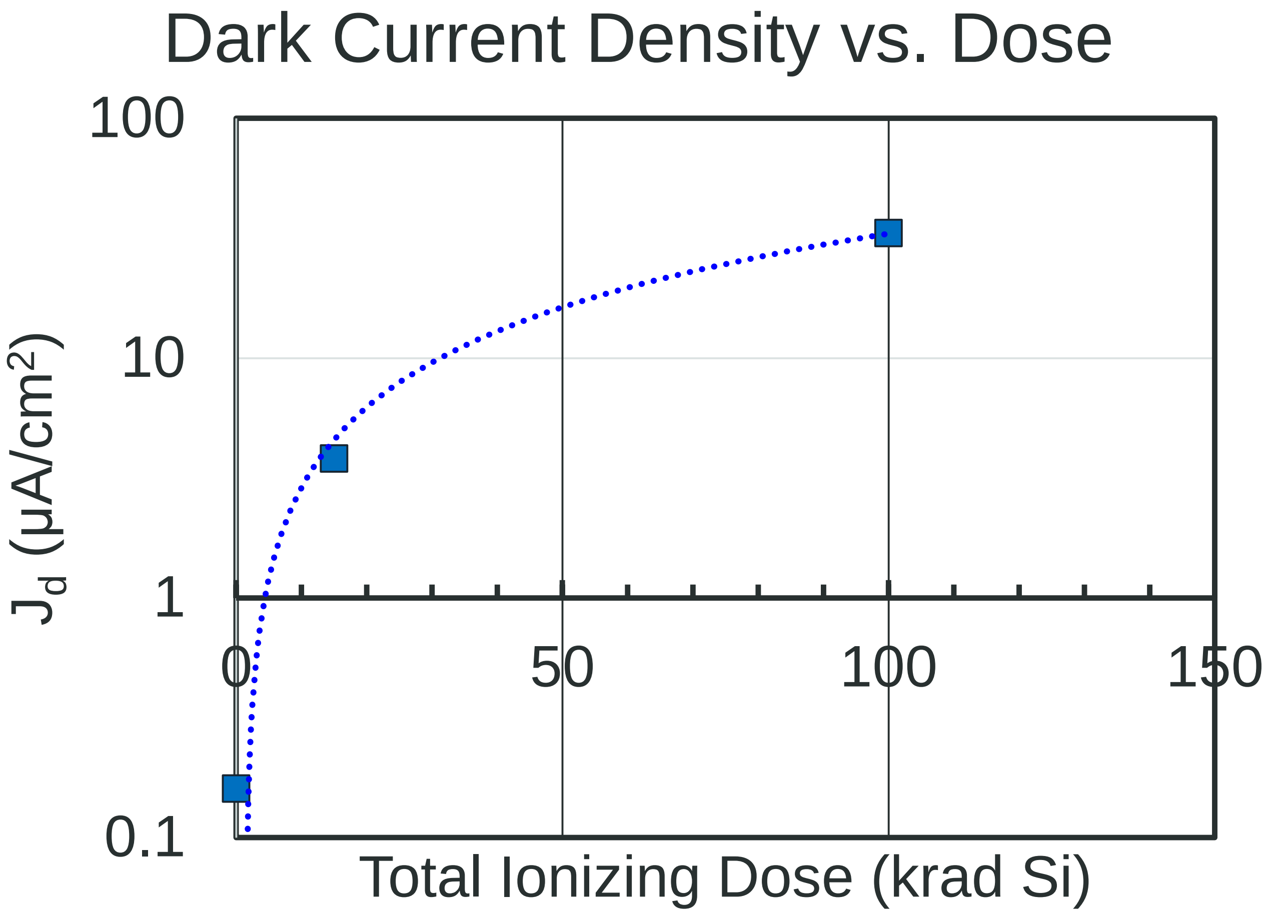
100 mils of Al shielding is sufficient to keep QE x FF >75%



Dark Current with Increasing Radiation

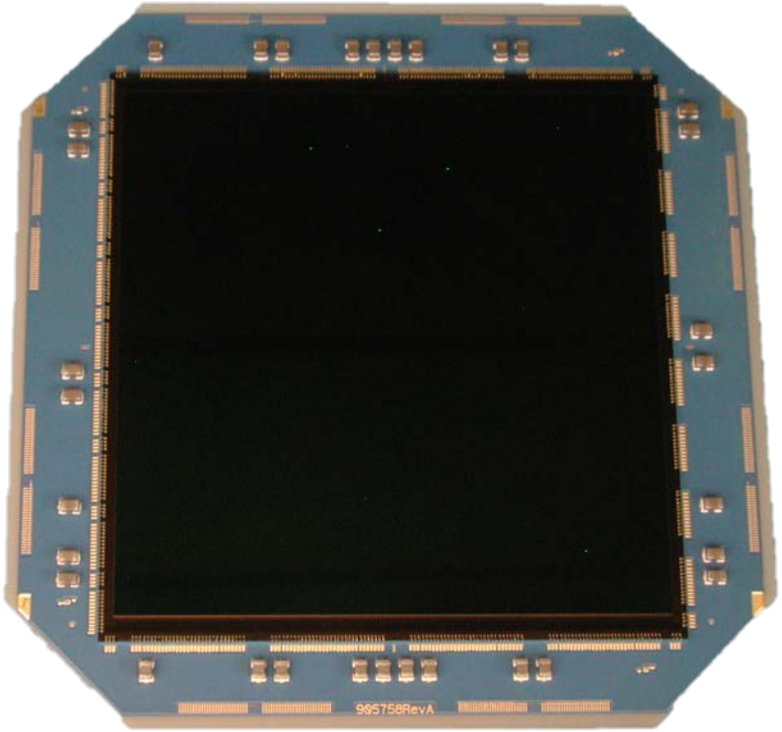
- 63MeV p+
- Un-irradiated J_d = 0.2 µA/cm2
- Growth rate: +0.34 µA/cm2-krad

100 mils of Al shielding can limit J_d increase to <2 µA/cm^2 due to solar protons, for a nominal 5 year mission life



SLS for Space

- Fabricated by commercial epitaxy foundries
- Radiation resilient
- Intrinsic laser protection
- Low cost due to high manufacturing yield:
  - 200 unit constellation deployment over 20 months →
  - 10 completed IR camera cores (focal plane array, cryocooler, Dewar, electronics) per month



SLS can provide large format FPAs congruent with the needs of pLEO constellations

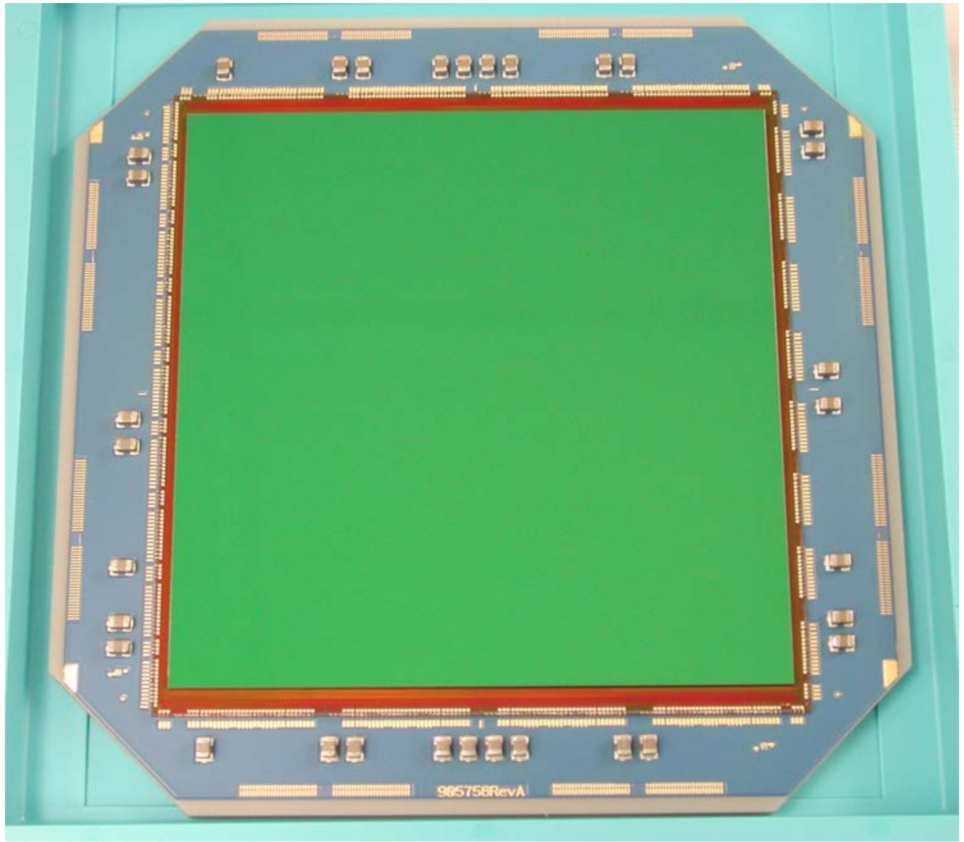
* Large quantities in a short period of time * High operability * Low cost per megapixel * High sensitivity * Excellent uniformity * Long-term stability

* 63MeV Protons, 5 krad/yr, LEO

SLS for Space

- Radiation resilient
- Intrinsic shielding
- Intrinsic laser protection
- Manufacturing yield
- Low cost per Mpixel

SLS will perform as required in many space applications, and offers a number of advantages over alternative FPA technologies for specific missions.



4K x 4K FPA

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