Radiation-Susceptibility of Display Technologies for Manned Missions

2REDPANDAS

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To be presented by Landen Ryder at the 2022 NASA Electronic Parts and Packaging Electronics Technology Workshop, Greenbelt, MD; June 14 2022

Acronyms

- 2REDPANDAS: Radiation tolerant and Reliable Electronic Displays: a Preliminary Assessment Necessary for Deep-spaceflight ApplicationS
- AES: Advanced Exploration Systems
- COTS: Commercial Off The Shelf
- DCM: Display and Control Module
- EMU: Extravehicular Mobility Units
- GSFC: Goddard Space Flight Center
- HEO: Human Exploration and Operations
- IC: Integrated Circuit
- JSC: Johnson Space Center
- LARC: LAngley Research Center
- LCD: Liquid Crystal Display
- LED: Light Emitting Diode
- LET: Linear Energy Transfer
- NEPP: NASA Electronic Parts and Packaging
- OLED: Organic Light Emitting Diode
- RWS: Robotic WorkStation
- SBIR: Small Business Innovation Research
- SEE: Single Event Effects
- SEFI: Single Event Functional Interrupt
- SEL: Single Event Latch-Up
- STTR: Small business Technology Transfer
- TFT: Thin Film Transistor
- RAM: Random Access Memory

Displays in Space

- **International Space Station**
  - 100+ COTS Laptops
  - Robotic Workstation (RWS)
  - Medical equipment, wearables
- **Extravehicular Mobility Unit (EMU)**
  - Display & Control Module (DCM)
    - 12-character LCD provides basic parametric and fault information
- **SpaceX Crew Dragon**
  - 3 Touchscreen Display Units
  - Display Button Panels
  - Armrest Seat Panels
  - COTS Crew Tablets




Humans Love Screen Time!



2REDPANDAS

Available: https://www.nasa.gov/sites/default/files/thumbnails/image/ltv-climbinghill-viper.jpg

Available: https://www.toyota-europe.com/world-of-toyota/articles-news-events/2019/toyota-jaxa

- **2021 Polaris Project – two-year AES-HEO funded project managed by early careers**
  - Address the knowledge gap for radiation-tolerant displays for future manned missions

- **Cross-Center Collaboration:**
  - JSC: **Justin Bautista**, **Tyler Garrett**, Brian Schwing, Razvan Gaza
  - GSFC: **Landen Ryder**, Ed Wyrwas, Michael Campola, Jonny Pellish, Wesley Powell
  - LARC: **Sharon Xu**, Lisa Simonsen

Radiation Environment Modelling

Define Environments

Mission Parameters:
- Duration
- Date
- Trajectories
- Shielding

Particle Populations

- Trapped Particles
- Solar Particles
- Galactic Cosmic Rays
- Secondary Particles

Radiation Transport

- Total Ionizing Dose
- Displacement Damage Dose
- LET Spectra (SEEs)

Radiation Analysis

- "…10 krads with 100 mils of Aluminum…"
- "Is 10% reduction in those solar cells acceptable?"
- "Expect a FPGA reset every 200 days"

- **Radiation environment modelling bridges measurements and mission environments**
  - Single experimental datasets can be generalized to many mission environments through modelling

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Commercial Off the Shelf Displays

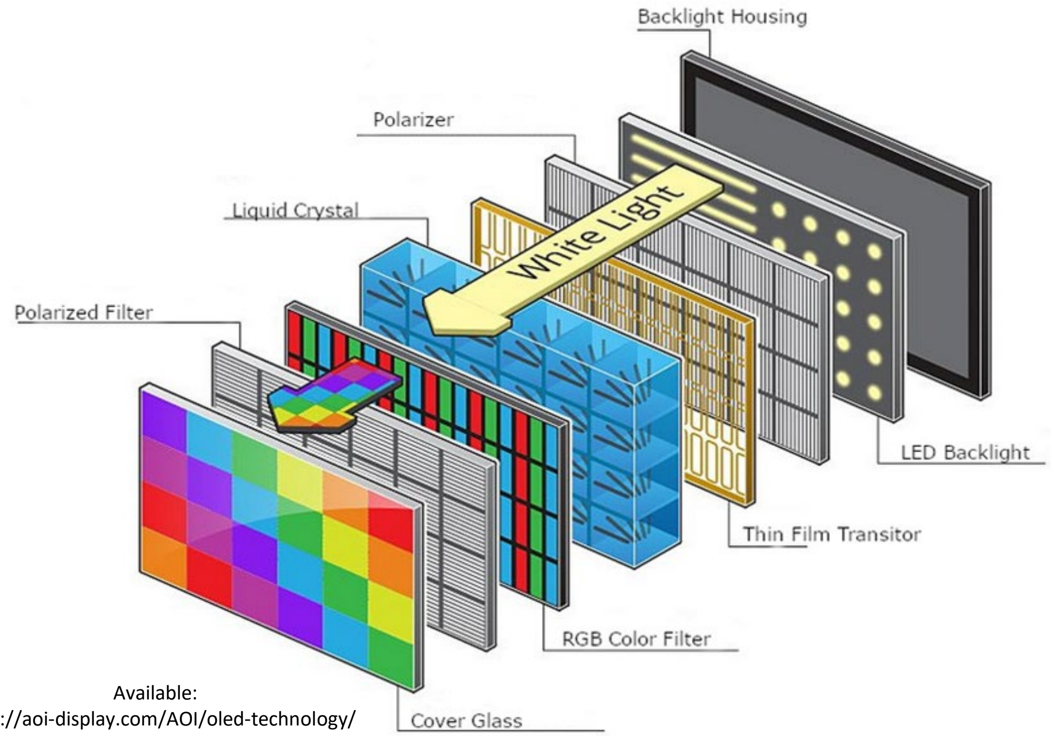
- **Variety of Commercial Pixel Technologies**
  - Light Emitting Diodes (LED)
  - Liquid Crystal Displays w/ LED backlight (LCD)
  - Electronic Ink (reflective or LED backlight)
  - Organic LEDs

- **Common Key Performance Indicators:**
  - Brightness, Contrast Ratio, Color Mixing
  - Pixel Density, Viewing Angle, Uniformity
  - Size, Weight, Rigidity, Thermal Stability
  - Refresh Rate, Power Draw, Resolution

- **Pixel technologies for display-integrated products vary based on performance/price**
  - LEDs and LCD for cost effectiveness
  - OLED for maximum performance

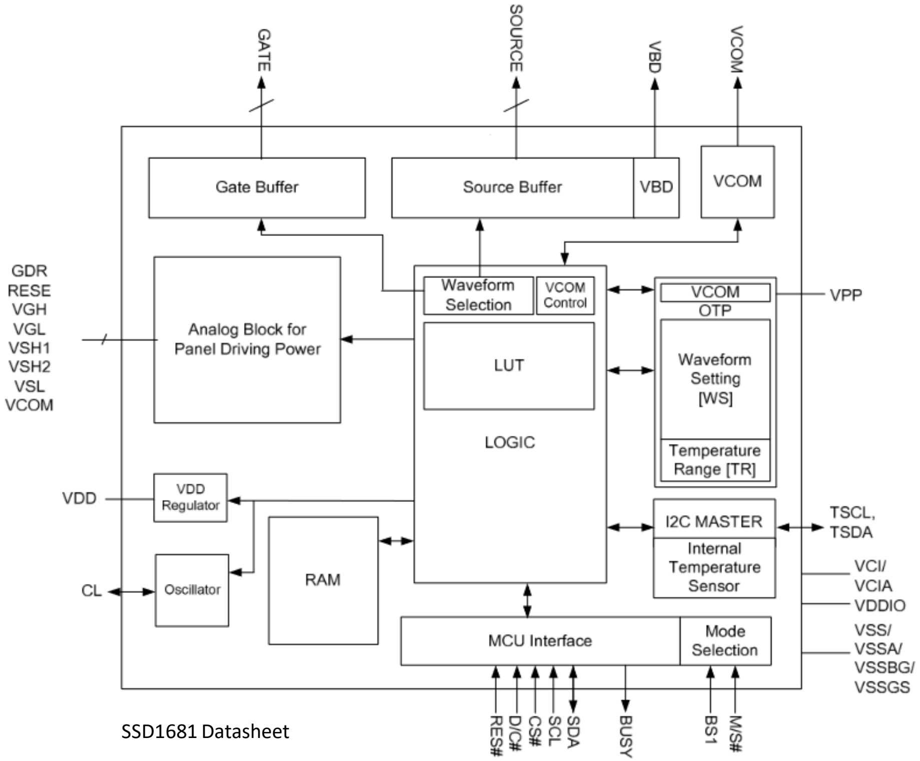
Breaking Down Displays

Screens



Available:
https://aoi-display.com/AOI/oled-technology/

Support Circuitry



SSD1681 Datasheet

- **Notional display pixel screen material stack consists of structural support, polarizers, passivation layers, thin-film transistors (TFT), light emission/modulation layers**
- **Support electronics are packaged with displays to manage input signal, drive the pixels**
  - Row/column drivers, timing circuits, power management, RAM, microcontrollers, transceivers, etc.

Developing Display Test Capabilities

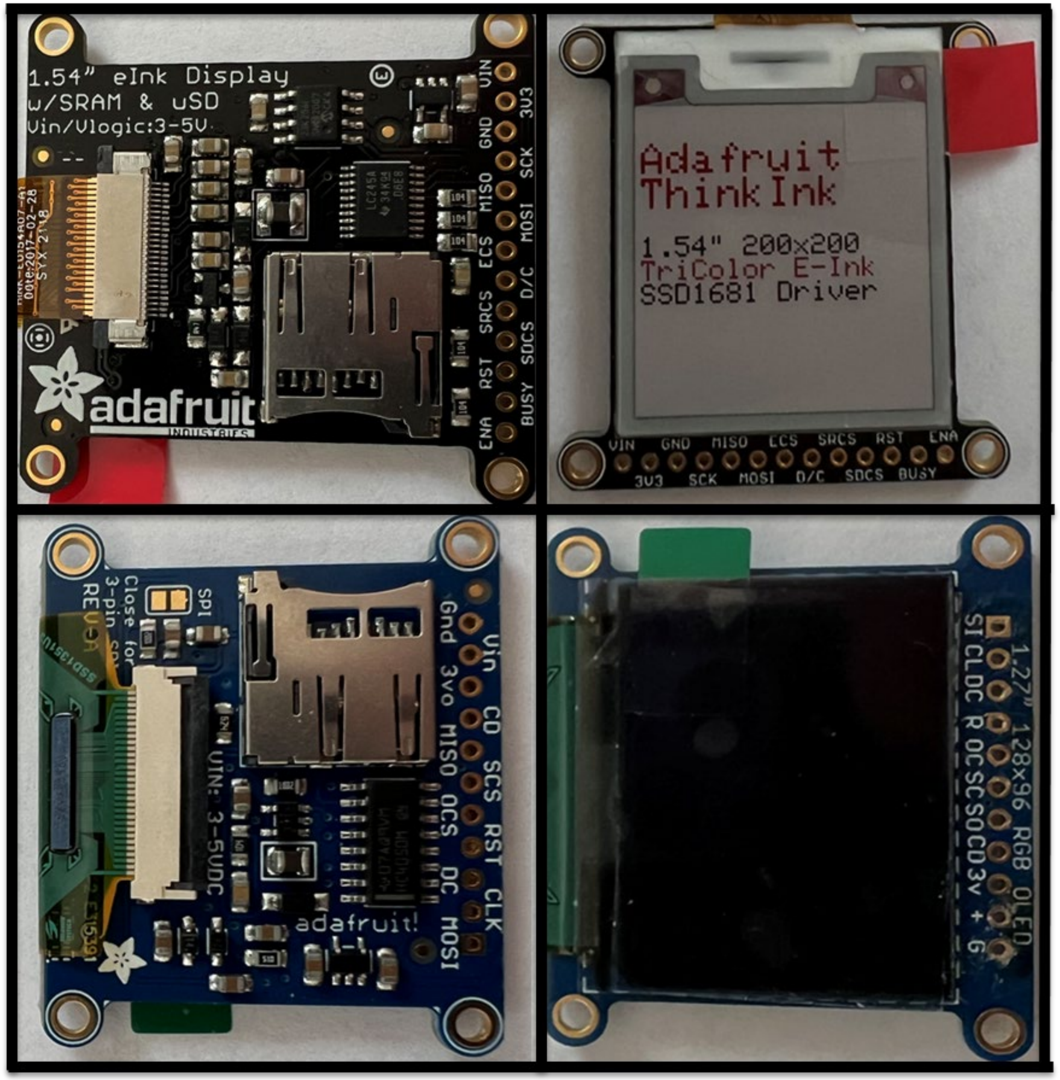
- **Testing and Characterization Techniques – Idealism vs. Pragmatism**
  - Industry standard performance metrics often necessitate complex, time-intensive characterization
  - On-site testing requires adaptable, transportable, efficient characterization equipment and techniques
- **Utilize existing NEPP capabilities/expertise, procure additional equipment when required**
  - 3D printing for prototyping test harnesses for irradiation and characterization (e.g., light boxes)
  - Industry experience with displays for reconfiguring display packaging, testing pitfalls
  - Procuring handheld optical meters to assess spectral information, brightness for test campaigns
- **Testing displays requires techniques not associated with typical EEE parts**
  - Post-processing images with ImageJ – open source, scriptable software for analyzing image files
  - Develop an approach for end-user SEE testing – single pixels, frame drops, SEFIs, Latch-up

Test Articles

- **LCDs, LEDs, OLED, and E-Ink displays units are being procured for irradiation**

- **Display candidates for testing**
  – Commercially available, part-to-part variation
  – Small footprint to optimize beam overlap
  – Modifiable packaging for radiation testing
  – Compatibility with common microcontrollers
  – Public facing software libraries for prototyping
  – No additional thermal mitigation required

- **Results will be “generalizable” to larger displays**
  – Pixel degradation will be normalized, per pixel
  – Duplicate ICs often required for larger displays, susceptibility will scale with number of ICs



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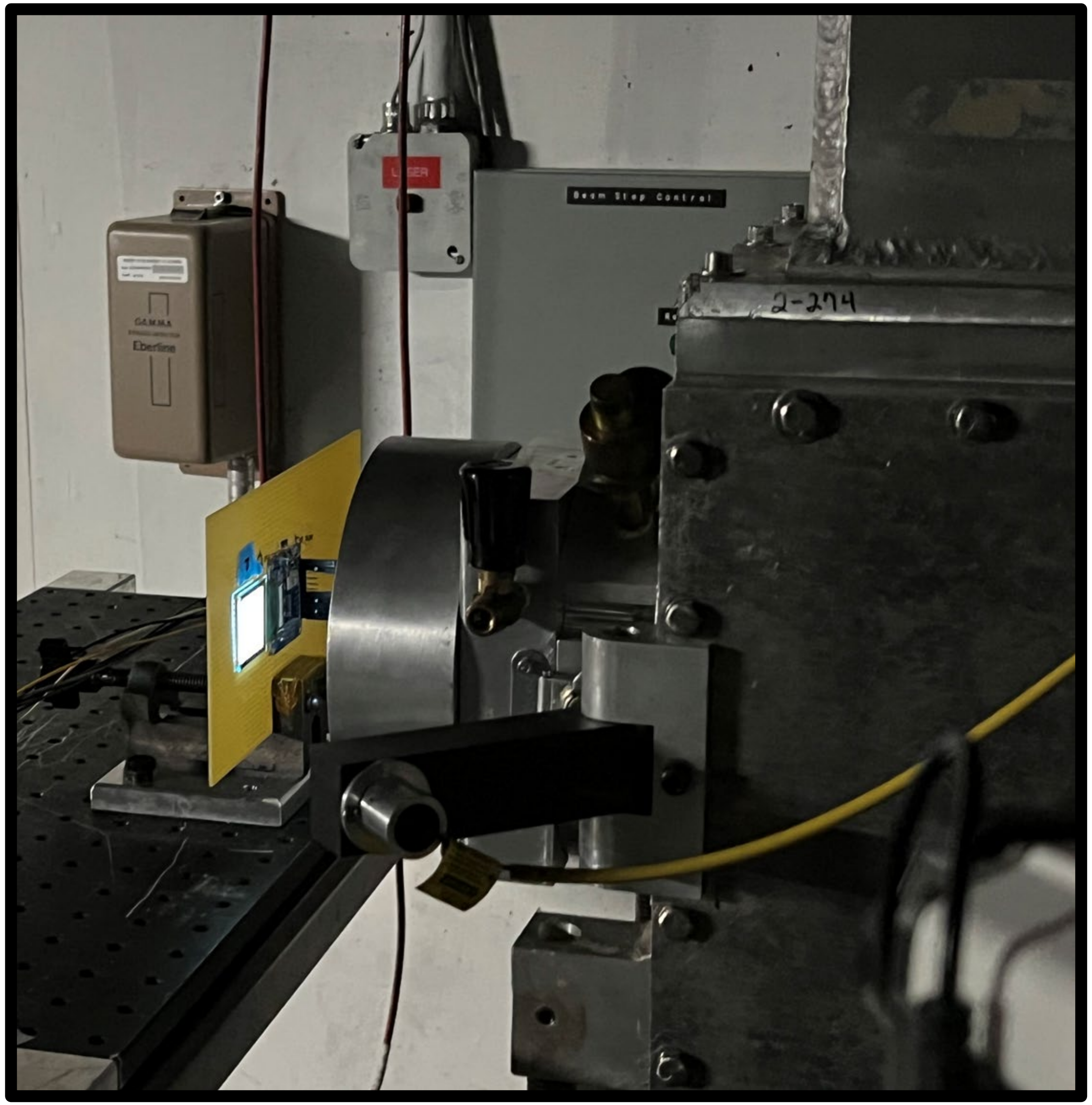

Displacement Damage/Total Ionizing Dose Measurements

- **64 MeV proton irradiation at UC Davis Crocker National Lab's 76" Cyclotron**
  - Preliminary test in May, Full scale test in September

- **Units will be configured to irradiate display screens, avoid support electronics**
  - Facility provide apertures used confine exposure region to a region of the screen, cameras to monitor displays for irregular behavior during irradiation
  - Displays will be driven with test pattern to capture impact of the on/off state of the pixel
  - Additional test routines to manipulate/stress displays without resetting displays

- **Irradiation is conducted in discrete steps with characterization between each step**
  - Handheld optical meters capture display brightness, optical spectrum for post-processing
  - Current draw for a benchmark operation for increased power consumption
  - Post-anneal measurements for estimation of permanent degradation

Single Event Effects Measurements

- **Heavy ion testing is targeting in air at Lawrence Berkley National Lab's 88" Cyclotron**
- **Units will be configured to irradiate support electronics, shield off-board controllers**
  - Test setups include remote power cycling to clear persistent error states between runs
- **Power supplies/cameras will be monitored to identify error signatures**
  - Pixel/Line/Screen dropouts will be captured via camera monitoring
  - Current draw can be used differentiate errors (Functional Interrupts vs. Latch Up)
- **Tabulation of error counts with particle fluence used to produce error cross-sections**
  - Cross-section curves can be used to estimate error rates (e.g. power cycle every five minutes)
  - Identify sensitive ICs that span display technologies for potential radiation-hardened substitutes
  - Investigate potential trade spaces for display operation (e.g. error rate vs. frame rate)

Conclusions

- **Next generation manned mission will require radiation-tolerant displays to ensure consistent, accurate human interfacing for the duration of long-term missions**

- **Develop the body-of-knowledge, testing capabilities for future manned mission needs**
  - Broad characterization of technologies sensitivities – "Should we use LCDs or OLEDs?"
  - Impact of design features on radiation tolerance – "Edge-coupled or back-lite LCD screens?"
  - Refine techniques for radiation testing of displays – "We have already bought these displays, so…"

- **Engage with industry via existing partnerships, SBIR/STTR proposals, conferences**
  - Identification of common susceptibilities in the support hardware chain for potential hardening
  - Understand manufacturer's fabrication, integration processes and availability of modification

- **Development of NASA Early Careers via mentorship, cross-center collaboration**