

The main title of the presentation, "RadHard Mixed-Signal Overview", displayed in a large, bold, black sans-serif font. To the left of the text is a vertical collage of images related to aerospace and electronics, including a fighter jet, a computer monitor and keyboard, a circuit board, a satellite, and a mobile phone, all set against a background of a globe and a starry space scene.

# RadHard Mixed-Signal Overview

Aeroflex Colorado Springs

April 2007

[www.aeroflex.com/RadHardASIC](http://www.aeroflex.com/RadHardASIC)

# Mixed-Signal Product Line

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## ▼ What we do....

- We connect real world, analog signals to digital systems
- We provide the critical link between sensors and information systems
  - ▼ Medical Imaging
  - ▼ Satellite Sensors & Actuators
  - ▼ Flight Systems
  - ▼ Financial and Point-of-Sale Systems
- We provide highly integrated (many channels), high dynamic range (many “bits”), low noise (high fidelity) signal conversion solutions in integrated Plug & Sense™ modules

# Mixed-Signal Product Line

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The logo for AEROFLEX, featuring a stylized blue swoosh above the word "AEROFLEX" in a sans-serif font. The swoosh starts as a thick bar on the right and tapers to a thin line on the left, curving around the text.

AEROFLEX

## ▼ History

- Started in 2000 with acquisition of Mixed-Signal design group of former Raytheon Microelectronics Division (Newport Beach, CA)
- Opened first design center in Aliso Viejo, CA in 2000
- First Medical Imaging Product 2001
- First Space RadHard Mixed-Signal Chip in 2002
- Opened Colorado Springs design center in 2002
- Opened Nevada City, CA design center in 2004
- First RadHard Medical Chip in 2005
- Officially announced RadHard Mixed-Signal ASIC offering September 2006
- Today operate out of 6 offices in 5 states in the USA

# Mixed-Signal Product Line

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The logo for AEROFLEX, featuring the word "AEROFLEX" in a sans-serif font. The letter "A" is stylized with a blue triangle pointing downwards. The logo is positioned to the right of a horizontal blue line that spans the width of the slide.

AEROFLEX

- ▼ **Current Staff = 36 ( with more than 350 person-years of Analog Design Experience)**
  - 17 Analog Designers
  - 4 Digital Designers
  - 7 Layout Designers
  - 1 Modeling Engineer
  - 1 Test
  - 1 CAD
  - 4 Program Managers/Business Development
  - 1 Administrative Assistant
  
- ▼ **Same Aeroflex Colorado Springs QML-V approved Manufacturing, Quality, Reliability, and Failure Analysis**

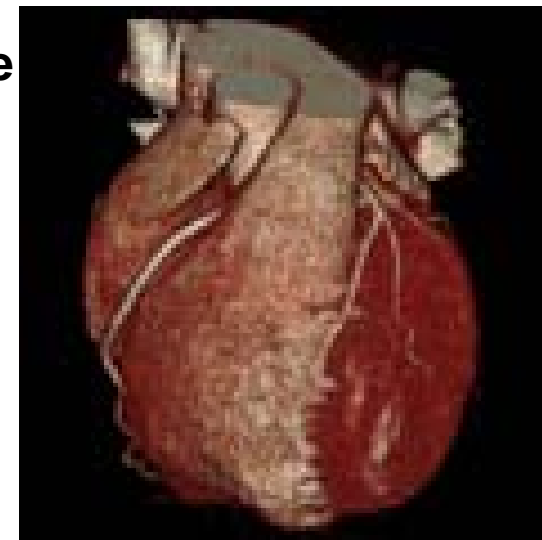
# Examples: RadHard X-Ray Detectors

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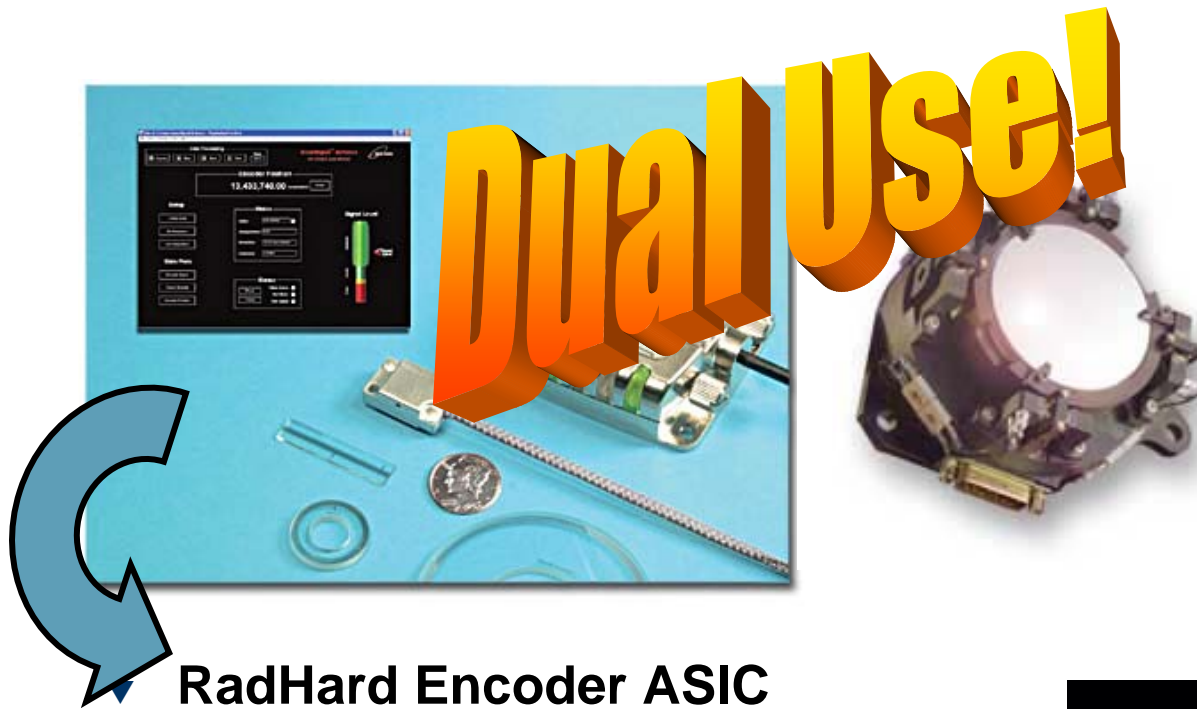
## ▼ X-Ray Detector ASIC

- Photodiode Array – Aeroflex IC – Image Reconstruction System – *Accurate Diagnosis of your illness!*



# Examples: RadHard Optical Encoders

AEROFLEX



## RadHard Encoder ASIC

- VCSEL/Photodiode – Aeroflex RadHard Encoder ASIC – Comm. Control – *Reliable optical link!*

***DUAL-USE: Industrial Equipment (Wire-bonders, Disk Drive Manufacturing, etc.)***

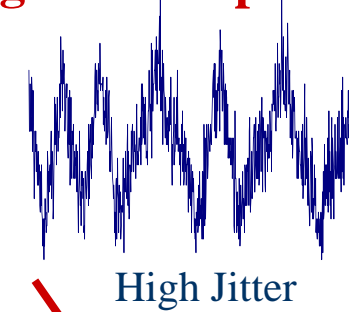
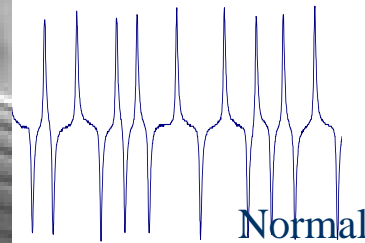


# Examples: Magnetic Stripe Readers

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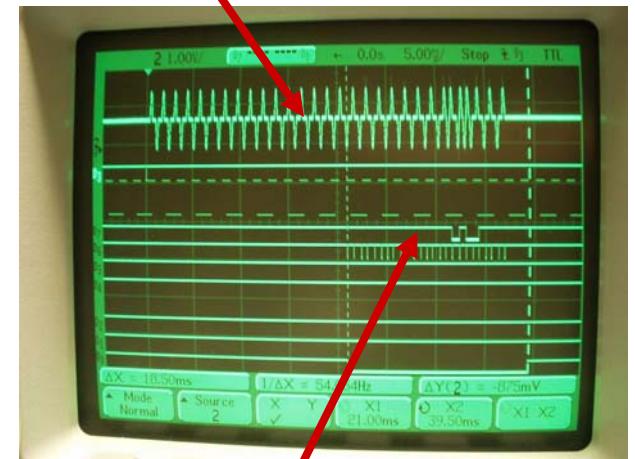


## Signals from Magnetic Stripe



### ▼ Magnetic Stripe Reader ASIC

- Magnetic Head – Aeroflex IC – Transaction Terminal – *Secure Access to Financial Institution Account!*



Decoded Data

# Examples: Intellibus Sensor Network Device Interface (NDI)

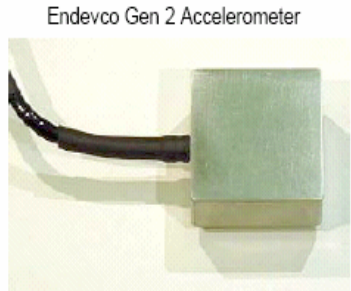


## ▼ Sensor Interface Bus: Boeing Intellibus

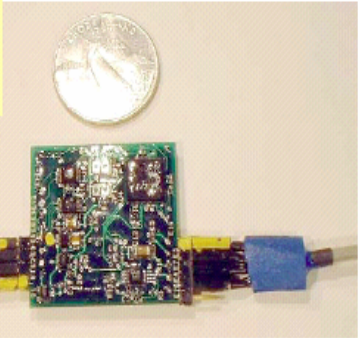
*Intellibus Status Update*

### *IntelliBus Interface Module (IBIM) & Smart Sensors*

- Intellibus NDI & Signal Conditioning
- Optional uP or DSP for local processing
- Sensor & actuator element stands alone
- Allows all sensors/actuators to be networkable
- Boeing IBIM supports 4 - 64 independent signal conditioners
- Target IBIM Package size 1 x 1 x .5 inches (greater for larger channel counts)
- IBIMs located based on environmental or other installation constraints



Endevco NDI/Signal Conditioning Board



**Aeroflex licensed by Boeing for ASIC implementation of Intellibus NDI core.**

### **Current Products:**

- 1. NDI with up to 9 channels SPI interface for ADC peripherals**
- 2. 16-channel D-S ADC with embedded NDI interface (non-RadHard aerospace).**
- 3. RadHard use possible!**

# RadHard Analog Library Examples

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## ▼ Design Blocks

- Band-gap/Voltage Reference
- Switched capacitor circuits
- Comparators
- (Dual) Integrators, S/H
- 10 to 19 bit ADC's
  - ▼ Flash
  - ▼ SAR
  - ▼  $\Sigma$ -D/Over-sampling with noise shaping
  - ▼ Pipeline
- 10 to 16 bit DAC
- Differential Amplifier
- Analog Switches/MUX
- Peak Detect/ Hold
- LNA's
- Charge pre-amps/Transimpedance amps

# Mixed-Signal Design Experience

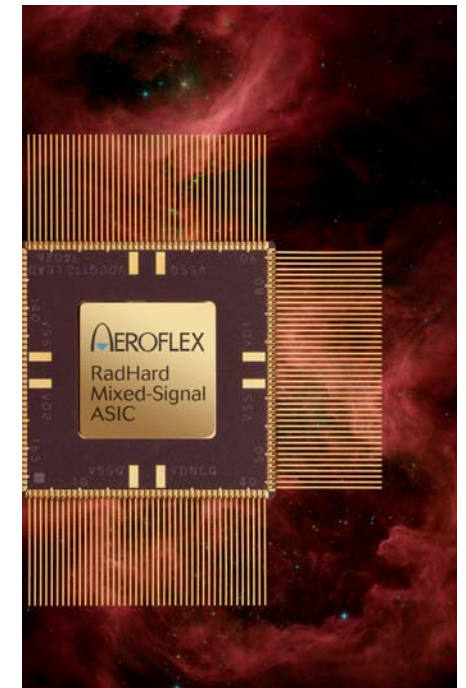


- ▼ **Band-gap references**
- ▼ **Switched capacitor circuits**
- ▼ **Data conversion**
  - speeds to 100 MHz bit resolution to 20 bits
  - Sigma Delta ADCs to 22 bits
  - Flash ADCs
  - Successive approximation
- ▼ **Voltage regulators**
- ▼ **Amplifiers**
- ▼ **Oscillators**
- ▼ **Bias generators**
- ▼ **Phase-locked loops**
- ▼ **Frequency generators**
- ▼ **Self-powered circuits for tags**
- ▼ **Watchdog circuits**
- ▼ **Digital signal processors**
- ▼ **Digital phase-locked loops**
- ▼ **Custom I/O cell design**
- ▼ **Microcontrollers**
  - ARM920T + various versions
  - ARM7TDMI, ARM720T
  - 8051 (various versions)
  - 68HC11 (various versions)
- ▼ **Memories**
  - ▼ All available in custom compiled width, depth, sector sizes, etc.
  - SRAMS
  - Multi-port RAMs
  - FIFOs
  - ROMs
  - EEPROMs
  - Flash
- ▼ **Interface circuitry**
  - USB device version 1.1 and 2.0
  - IEEE1394
- ▼ **Physical Layer (I/O transceivers)**
  - PCI receivers, drivers, LVDS, PCI, USB, IEEE1394

# Mixed-Signal RadHard Products

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- ▼ **Custom Mixed-Signal ASIC's**
  - 0.5um CMOS, Twin-Well
  - 0.35um CMOS, Triple-Well, MiM Capacitors
  - 0.18um CMOS, Triple-Well, MiM Capacitors
- ▼ **Data Converters**
  - TID > 100krad(Si) (condition A – high dose rate)
  - SEL immune > 110 MeV cm<sup>2</sup>/mg @ 125°C, Max Vdd
  - **ADC Product Family:**
    - ▼ 8-bit, 20MSPS Flash ADC
    - ▼ 8-bit, 10MSPS Pipeline ADC
    - ▼ 10-bit, 250KSPS SAR ADC
    - ▼ 10-bit, 6MSPS Pipeline ADC
    - ▼ 12-bit, 3MSPS Pipeline ADC
    - ▼ 14-bit, 1MSPS Pipeline ADC
    - ▼ 16 to 19-bit 5KSPS  $\Delta$ - $\Sigma$  ADC
  - **DAC Product Family**
    - ▼ TBD



# Mixed-Signal Standard ADC Products



**Aeroflex is planning to launch a family of RadHard data converter products based upon existing IP:**

Resolution \ Speed	0.01	0.1	0.2	0.5	1	2	5	10	20	50
8	SAR	SAR	SAR	SAR	FLASH	FLASH	FLASH	FLASH	FLASH	○
10	SAR	SAR	SAR	SAR	PIPE	PIPE	PIPE	PIPE	○	
12	SAR	SAR	SAR	SAR	PIPE	PIPE	PIPE	○	○	
14	$\Delta$ - $\Sigma$	PIPE	PIPE	PIPE	PIPE	PIPE	○	○		
16	$\Delta$ - $\Sigma$	○	○	○						
18	$\Delta$ - $\Sigma$									
20	$\Delta$ - $\Sigma$									

**1. Aeroflex Medical/Industrial Converter Experience that can be (or already is) RadHard**

**2. Near term extensions of Aeroflex Data Converter IP**

# RadHard Package Development

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- ▼ **RadHard package development for both ASIC and Sensor**
  - Hermetic photonic sensors and sources (e.g. Pin Diode arrays, laser diodes, VCSEL's)
  - QML-V Flat-pack, Column Grid Array ceramic ASIC packages
    - ▼ Chip capacitors, bias resistors on package for low noise/higher packing density
  - Rigorous Class-S/QML-V screening and testing
- ▼ **Light weight, Flexible Packaging Solutions**
  - Chip on flex (wirebond)
  - Chip on flex (flip chip)
  - Integrated with photonic sensor (wirebond on ceramic, flip-chip on laminate, etc.)
  - Space qualified epoxies; rigorous screening and testing

# Mixed-Signal Product Line



- ▼ **RadHard Expertise:**
  - ***RadHard Data Conversion***
    - ▼ Solutions for medical, space, and harsh-environment industrial applications
    - ▼ Highly integrated, Low Noise, High Dynamic Range with Low Cross-Talk
  - ***RadHard SPICE Models***
    - ▼ PhD physicist on staff for post-rad model extraction
  - ***Rapid RadHard analog and digital library development***
    - ▼ SET “grading” of each cell for optimization of upset rate and power
    - ▼ SEU hardened flop design
    - ▼ SEL immune (process + design)
  - ***Proprietary RadHard One-Time Electrically Programmable (OTEP) Metal Fuse***
    - ▼ Analog Trim and/or Serialization
    - ▼ Completely passivated, even after programming
    - ▼ RadHard POR to load fuse values into SEU hardened flops
  - ***Plug & Sense™ Solutions***
    - ▼ Integration of Sensor + Readout Electronics
    - ▼ RadHard Medical Imaging (X-Ray) module (256 channels)
    - ▼ RadHard, Hermetic photonics sensor package for optical encoders

# Mixed-Signal Product Line



- ▼ **QML Approved Technologies:**
  - **0.6um Twin-Well 3LM CMOS with PiP Capacitors**
    - ▼ **AMI Semiconductor (Pocatello, ID)**
      - QML-V and QML-Q approved as vendor to Aeroflex
  - **350nm Triple-Well 4LM CMOS with MiM Capacitors**
    - ▼ **MagnaChip (Cheongju, Rep. of Korea)**
      - QML-V and QML-Q approved as vendor to Aeroflex
      - US Dept of State license in place
  - **250nm Twin-Well 5-6LM CMOS**
    - ▼ **WaferTech (Camus, WA)**
      - QML-V and QML-Q approved as vendor to Aeroflex
  - **180nm Triple-Well 5-6LM CMOS with MiM Capacitors**
    - ▼ **WaferTech (Camus, WA)**
      - QML-V and QML-Q approved as vendor to Aeroflex
      - Twin-Well CMOS only
    - ▼ **MagnaChip (Cheongju, Rep. of Korea)**
      - QML-V and QML-Q approved as vendor to Aeroflex
      - US Dept of State license in place
    - ▼ **Dongbu Electronics (Bucheon, Rep. of Korea)**
      - QML-Q certified as vendor to Aeroflex
      - US Dept of State license in place

# Mixed-Signal Product Line



## ▼ Some Key Technology Features:

### – 350nm:

- ▼ 3.3V Core, 5.0V I/O
- ▼ 10V (+10V/0V, +5V/-5V, etc.), self-aligned Aeroflex Commercial RadHard™ transistors
- ▼ Aeroflex Proprietary RadHard, One-Time Electrically Programmable (OTEP) metal fuse for trim, serialization, and other low-density, one-time programmable, non-volatile memory applications
- ▼ Aeroflex RadHard digital library (SET “graded” for optimization of SET during synthesis)
- ▼ RadHard reset synchronizer + POR

### – 180nm:

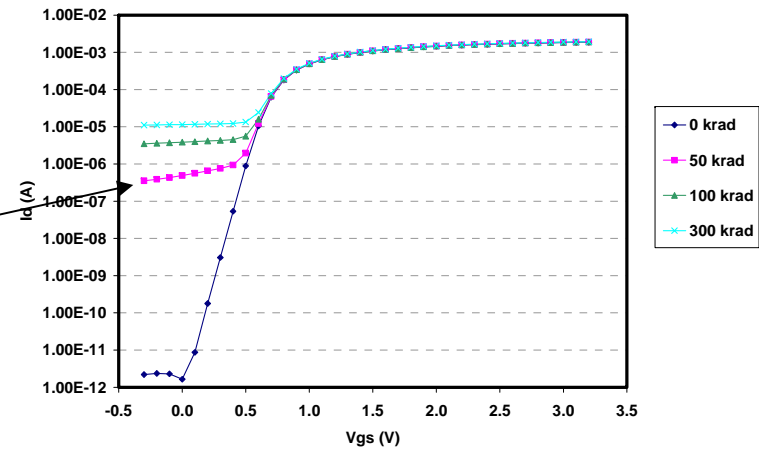
- ▼ 1.8V Core, 3.3V or 5.0V I/O (fully compliant, not just “tolerant”)
- ▼ 5V (+5V/0V, +2.5/-2.5V, etc.), self-aligned Aeroflex Commercial RadHard™ transistors
- ▼ Aeroflex RadHard OTEP metal fuse

# Switching Characteristics of Aeroflex CRH™ CMOS

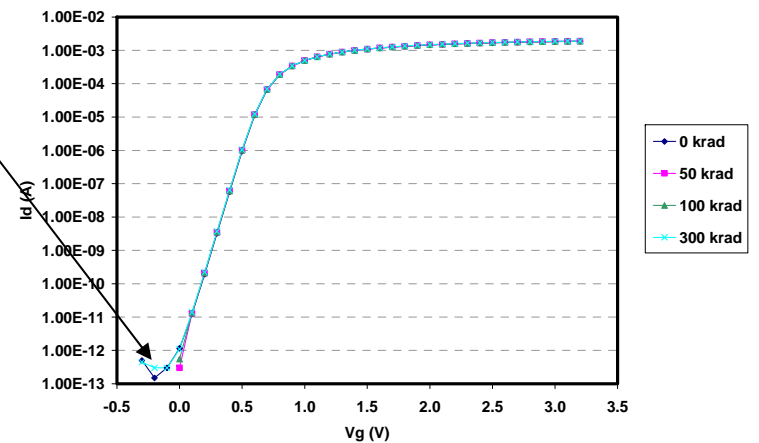


- ▼ **Non-CRH™ version shows excessive leakage after only 50krad(Si) total ionizing dose**
- ▼ **Aeroflex CRH™ version shows little change in leakage after 300krad(Si) total ionizing dose**

Id vs Vg for L=0.35 micron Standard Transistor



Id vs Vg for L=0.35 Aeroflex CRH Transistor

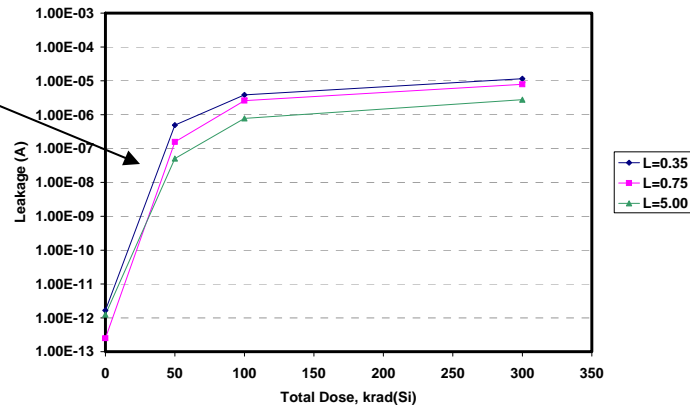


# Aeroflex CRH™ CMOS: Acceptably Low Leakage

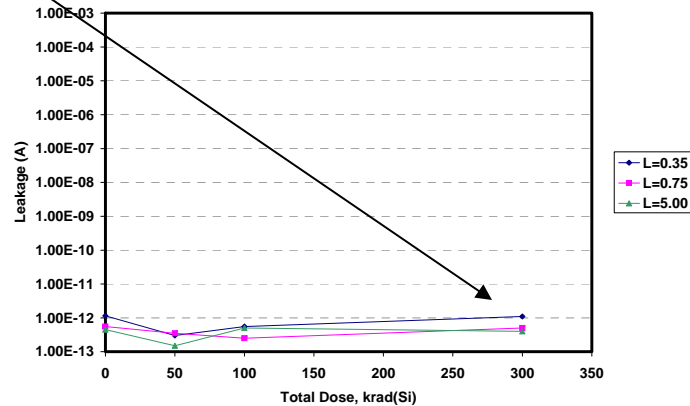


- ▼ **Standard CMOS shows quick rise in leakage at low total ionizing dose**
- ▼ **Aeroflex CRH™ technology has acceptably low leakage at 300krad(Si)**

Leakage (Idoff) vs. Total Ionizing Dose for Standard Transistor



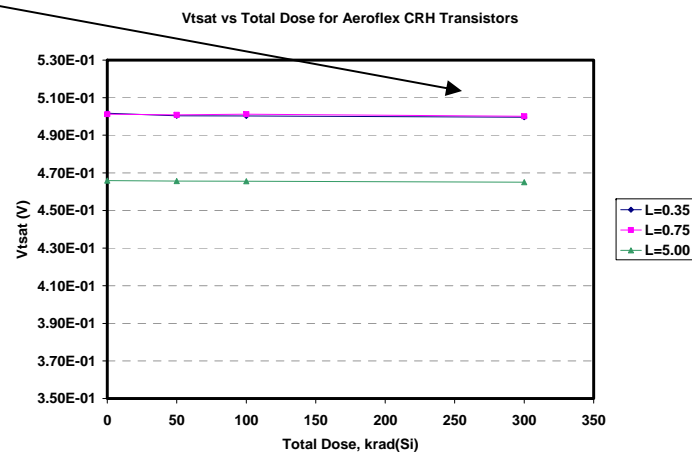
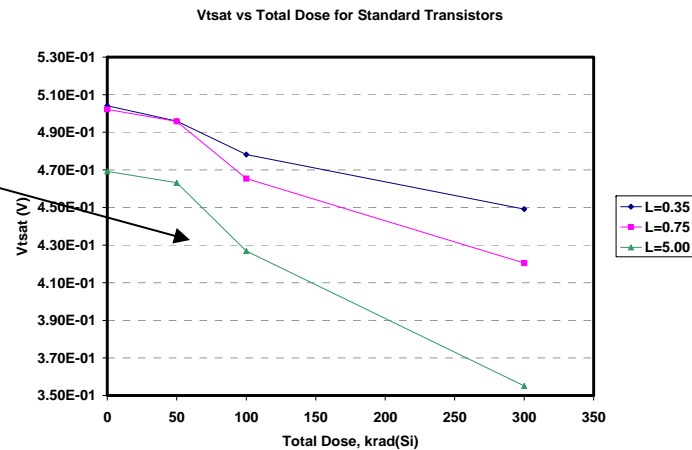
Leakage (Idoff) vs. Total Dose for Aeroflex CRH Transistor



# Aeroflex CRH™ CMOS: Practically No Vtsat Shift



- ▼ Standard CMOS Vtsat shift is unacceptable, especially at doses above 50krad(Si)
- ▼ Aeroflex CRH™ technology exhibits no discernable Vtsat shift even after 300krad(Si)



# 350nm Aeroflex CRH™ TCV Data Summary

The Aeroflex logo is located in the top right corner. It consists of a blue curved line that starts from the right edge and curves downwards and to the left, ending under the word "AEROFLEX". The word "AEROFLEX" is written in a blue, sans-serif font, with the letter "A" being slightly larger and more stylized than the others.

AEROFLEX

## ▼ Total Ionizing Dose:

- No Idoff leakage increase with total ionizing dose up to 300krad(Si)
- No Vtsat shift with total ionizing dose up to 300krad(Si)
- No appreciable change in subthreshold swing as a function of total ionizing dose up to 300krad(Si)

## ▼ Single Event Effects:

- No SEL observed in Aeroflex triple-well test structures up to maximum LET of 110 MeV cm<sup>2</sup>/mg at 125°C and maximum Vdd (Two separate test dates)
- No SEGR observed in Aeroflex triple-well gate oxide test structures at 125°C and maximum Vdd

# RadHard Mixed-Signal Technology Roadmap



Designs In Progress

IR&D Funded

Proposed

QML-V Qualification completed  
(3 lots, long-term L/T)

Design Starts

TCV, Library Development Begins

Tech Node	2006	2007	2008	2009	2010
0.6 um	QML-V Production				
350 nm	RH CMOS 4LM, 3 Well		QML-V Production		
350 nm	RH OTEP Metal Fuse		QML-V Production		
180 nm	RH CMOS 6LM, 3 Well		QML-V Production		
180 nm	RH OTEP Metal Fuse		QML-V Production		
130 nm			RH CMOS 7LM, 3 Well		

# RadHard Mixed-Signal Summary

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- ▼ **Aeroflex Mixed-Signal Product Line has developed a large portfolio of TID-hardened, data converter IP for the medical market**
  - Aeroflex shipping over ten thousand TID RadHard devices per month for x-ray detector applications
- ▼ **Aeroflex Mixed-Signal is leveraging its medical data-converter IP into the RadHard Space market**
  - Additional hardening for SEE using Aeroflex design and process techniques
- ▼ **Aeroflex has set-up extensive, QML approved foundry base for Mixed-Signal**
  - Other technologies can also be used for RadHard Mixed-Signal, if QML certification is not required
- ▼ **Aeroflex offers full-custom, RadHard Mixed-Signal solutions, which include integrated sensor-electronics packaging**
  - Custom sensor package design, specializing in photonics
  - Flip-chip on flex, and other packaging techniques to conserve weight and space