Space-Qualified Radiation-Hardened FPGAs: A Successful Collaboration Continues

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The RHAX250-S product installation effort is sponsored by the Defense Threat Reduction Agency.

Introduction

- FPGA products are used extensively in space systems.
- A need exists to develop the next generation space-qualified radiation hardened FPGA (RH FPGA).
- Actel is a supplier of antifuse-based FPGAs.
- BAE SYSTEMS is a rad hard supplier with expertise in rad hard CMOS technologies.
- Actel and BAE SYSTEMS are continuing their decade-long collaboration as producers of rad hard FPGAs.

Background

- BAE SYSTEMS is Actel's rad hard foundry partner producing RH1020/RH1280 FPGAs and offering a RH 256K PROM employing Actel's Oxide-Nitride-Oxide (ONO) antifuse structure, as depicted in Figure 1.

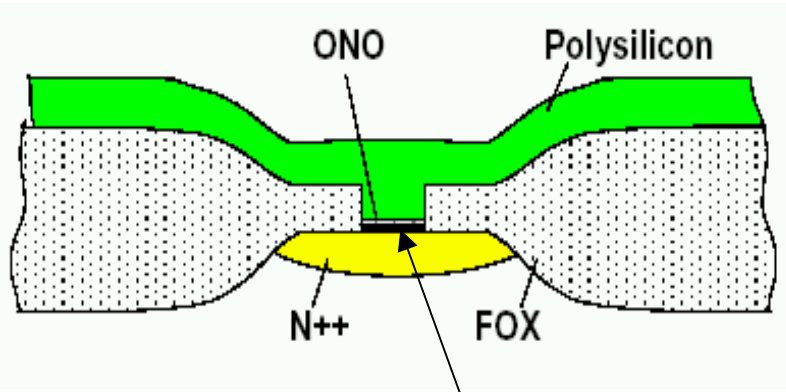
- Commercial product migration to the rad hard foundry is consistent with a rad hard development strategy proven successful across several technology generations. (Figure 2)

- BAE SYSTEMS' foundry is being modernized for fully QML qualified radiation hardened 0.15μm CMOS production on 150mm wafers (2005).

- BAE SYSTEMS and Actel have started development of the rad hard CMOS process to support RHAX250-S product, as depicted on our RH FPGA roadmap. (Figure 3)

RH (ONO) FPGA Product

ONO Antifuse Structure:



RH1020 and RH1280 FPGAs have ONO antifuses and were built in rad hard 0.8μm CMOS Technology.

Figure 1

RH FPGA Product Features:

Device	RH1020	RH1280
Capacity		
System Gates	3,000	12,000
Gate Array Equivalent Gates	2,000	8,000
PLD Equivalent Gates	6,000	20,000
TTL Equivalent Packages	50	200
20-Pin PAL Equivalent Packages	20	80
Logic Modules	547	1,232
S-Modules	0	624
C-Modules	547	608
Flip-Flops (Maximum)	273	998
Routing Resources		
Horizontal Tracks/Channel	22	35
Vertical Tracks/Channel	13	15
PLICE Antifuse Elements	186,000	750,000
User I/Os (Maximum)	69	140
Packages (by Pin Count)		
Ceramic Quad Flat Pack (CQFP)	84	172

Radiation Specifications[1, 2]

Symbol	Characteristics	Conditions	Min.	Max.	Units
RTD	Total Dose			300K	Rad(Si)
SEL	Single Event Latch-Up	$-55°C \le T_{case} \le 125°C$		0	Fails/Device-Day
SEU1[3]	Single Event Upset for S-modules	$-55°C \le T_{case} \le 125°C$		1E-6	Upsets/Bit-Day
SEU2[3]	Single Event Upset for C-modules	$-55°C \le T_{case} \le 125°C$		1E-7	Upsets/Bit-Day
SEU3[3]	Single Event Fuse Rupture	$-55°C \le T_{case} \le 125°C$		<1	FIT (Fails/Device/1E9 Hrs)
RNF	Neutron Fluence		>1E+12		N/cm^2

Notes:

1. *Measured at room temperature unless otherwise stated.*
2. *Device electrical characteristics are guaranteed for post-irradiation levels at 25°C.*
3. *10% worst-case particle environment, geosynchronous orbit, 0.025" of aluminum shielding. Specification set using the CREME code upset rate calculation method with a 2μ epi thickness.*

RH Technology Development Strategy

- **Establish Radiation Hardened Technology and Products from Commercial Off The Shelf (COTS) Base**
  - ***Lower Risk (starts with a proven process/design)***
  - ***Cost Effective (reduced development effort)***

COTS
- Design
- Process

+

Radiation Hardening Enhancements (Design and Process)

=

BAE SYSTEMS RH Products

- **Successfully Implemented through Seven Technology Generations over the past 25 Years**

1.2 μm → 0.5/0.35 μm → 0.25/0.15 μm

We have demonstrated the ability to successfully integrate radiation hardened technology into COTS products and processes (over 100 rad hardening patents and trade secrets)

Figure 2

RH FPGA Roadmap

BAE SYSTEMS

Past

- Heritage: Actel RH1280 and RH1020
  - Anti-fuse technology, non-volatile
  - 0.8µm RH CMOS
  - 5V Supply

> 20,000 die+modules shipped since 1996

Current

- Anti-fuse Technology:
  - 250K-gate (RH AX250-S)
  - 0.15µm RH CMOS
  - 1.5V Internal / 3.3V I/O

Future

- Re-programmable Technology (e.g., C-RAM):
  - ≥1M-gate, Re-programmable, non-volatile
  - 0.15µm RH CMOS
  - 1.5V Internal / 3.3V I/O

Rad Hard FPGA Product

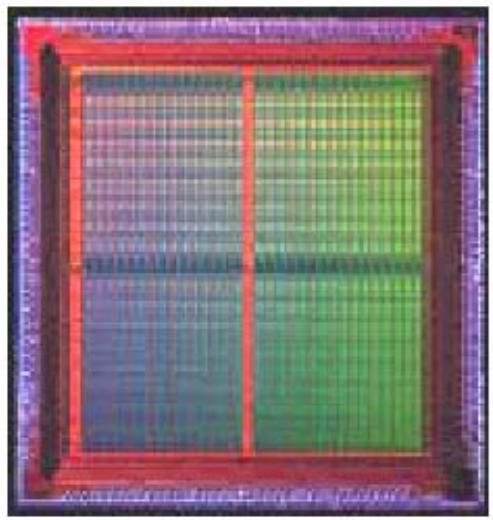


Figure 3

BAE SYSTEMS Foundry Modernization

Depicted in Figures 4 - 6.

- Ceased production with older legacy rad hard CMOS technologies (≥ 0.5 μm nodes) after an end of life product build-out.

- Retooled the foundry with new state-of-the-art process equipment for 150 mm wafers, extendible to 200 mm.

- Licensed, installed, radiation hardened, and is now qualifying advanced CMOS process technologies.
  - 0.25 μm - achieved.
  - 0.15 μm - in 2005.
  - 0.13 μm - on roadmap.

FOUNDRY MODERNIZATION

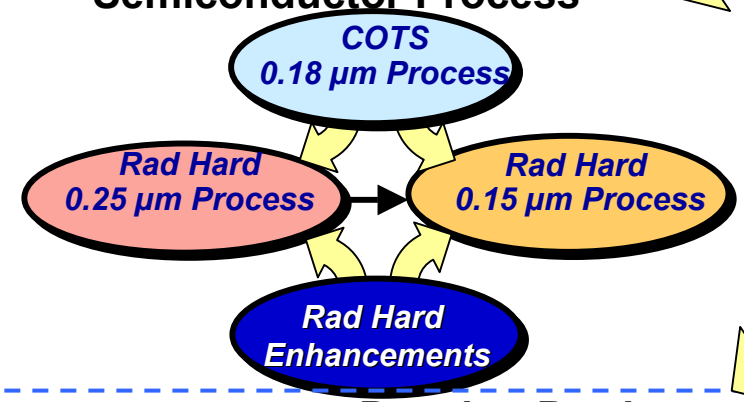
Actel

BAE SYSTEMS

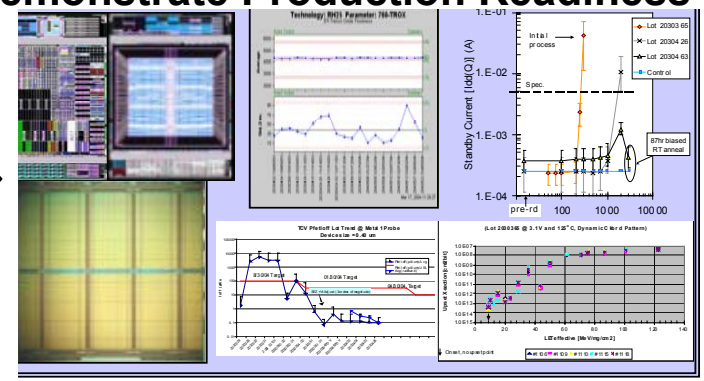
Remove Obsolete Tools

Purchase and Install New Tools
Upgrade Existing Tools

Install and Qualify Semiconductor Process



Design/Build/Test Complex Circuits to Demonstrate Production Readiness



Develop Products and Insert Technology into Systems

Figure 4

Key Technology Features

Key Features:	0.25µm	0.15µm
Isolation	STI	STI
DGO Devices	50A* / 70A	35A / 70A
Vdd Options	2.5V* / 3.3V	1.5V/1.8V / 3.3V
Metal Levels	≤ 6	≤ 7
Linear Capacitor	Yes	Yes
C4 / Wirebond	Y/Y	Y/Y

* Per Business Need

Typical Radiation Hardness Targets for BAE SYSTEMS' SRAM product

Environment	Target
Total Dose (rad(Si))	≥ 1M
SEU (errors/bit-day)	< 1E-12
SEL (MeV-cm^2/mg)	> 120
Neutron Fluence (n/cm^2)	> 1E13
Prompt Dose Upset (rad(Si)/s)	≥ 1E9
Prompt Dose Survival (rad(Si)/s)	≥ 1E12

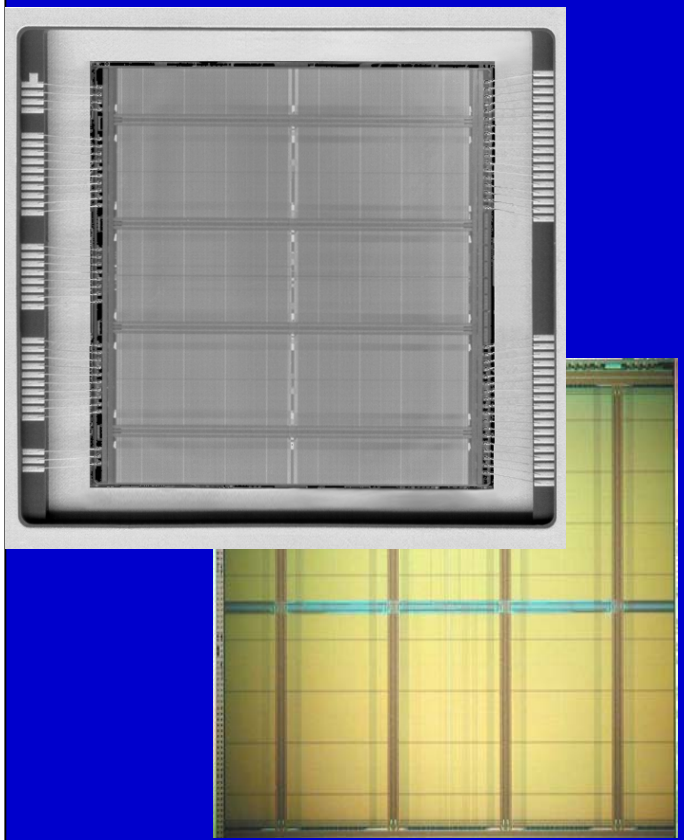
Figure 5

0.25μm Production Readiness Vehicle

Actel

BAE SYSTEMS

- Achieved first fully functional 0.25 μm 4M SRAM on modernized foundry in December 2003.



"Magnum" 4M SRAM

SRAM Description

- Technology: RH25
- Vehicle: 4M RH SRAM
- Die Size: 17.7mm x 18.7 mm
- 16 Design Mask levels
- 10 Transistor base cell
- 44M Transistors
- 92M Contacts
- 16M Vias
- Three levels of metal
- Total metal wiring: 1Km

Figure 6

Actel-BAE Collaboration Continues

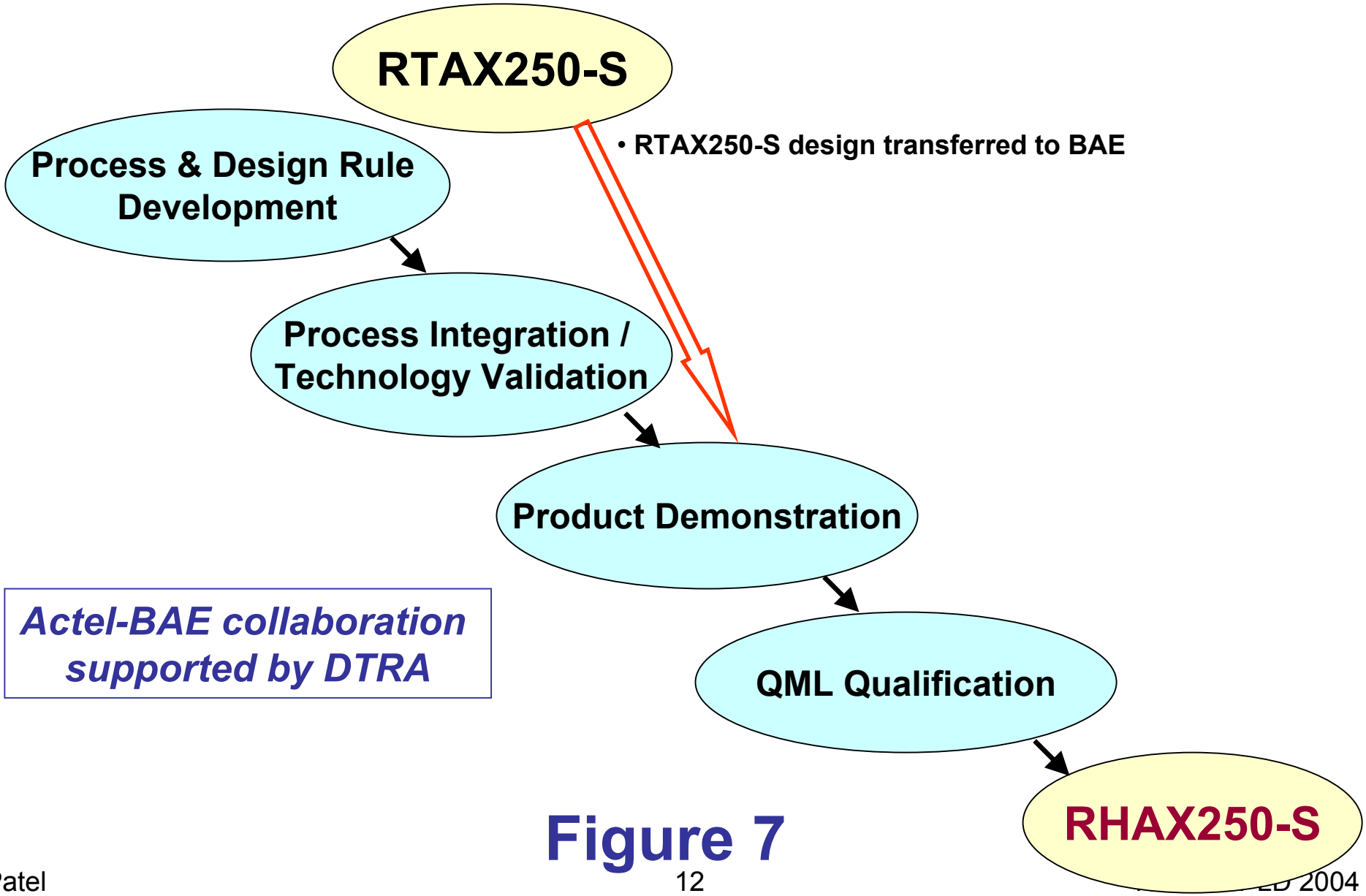
- BAE SYSTEMS and Actel selected 0.15 μm RTAX250-S FPGA as the first FPGA product to be ported to the upgraded foundry.

- RTAX250-S employs a novel Metal-to-Metal (M2M) antifuse structure.

- The RTAX250-S design built using the BAE SYSTEMS' proprietary rad hard 0.15μm CMOS process will result in a rad hard product offering (RHAX250-S) with the identical form/fit/function of its rad tolerant equivalent but with enhanced radiation hardness.

- RHAX250-S product installation flow and schedule are shown in Figures 7 and 8, respectively. The RHAX250-S targeted features are shown in Figure 9.

RHAX250-S Product Installation



Actel-BAE collaboration supported by DTRA

Figure 7

RHAX250-S Installation Schedule

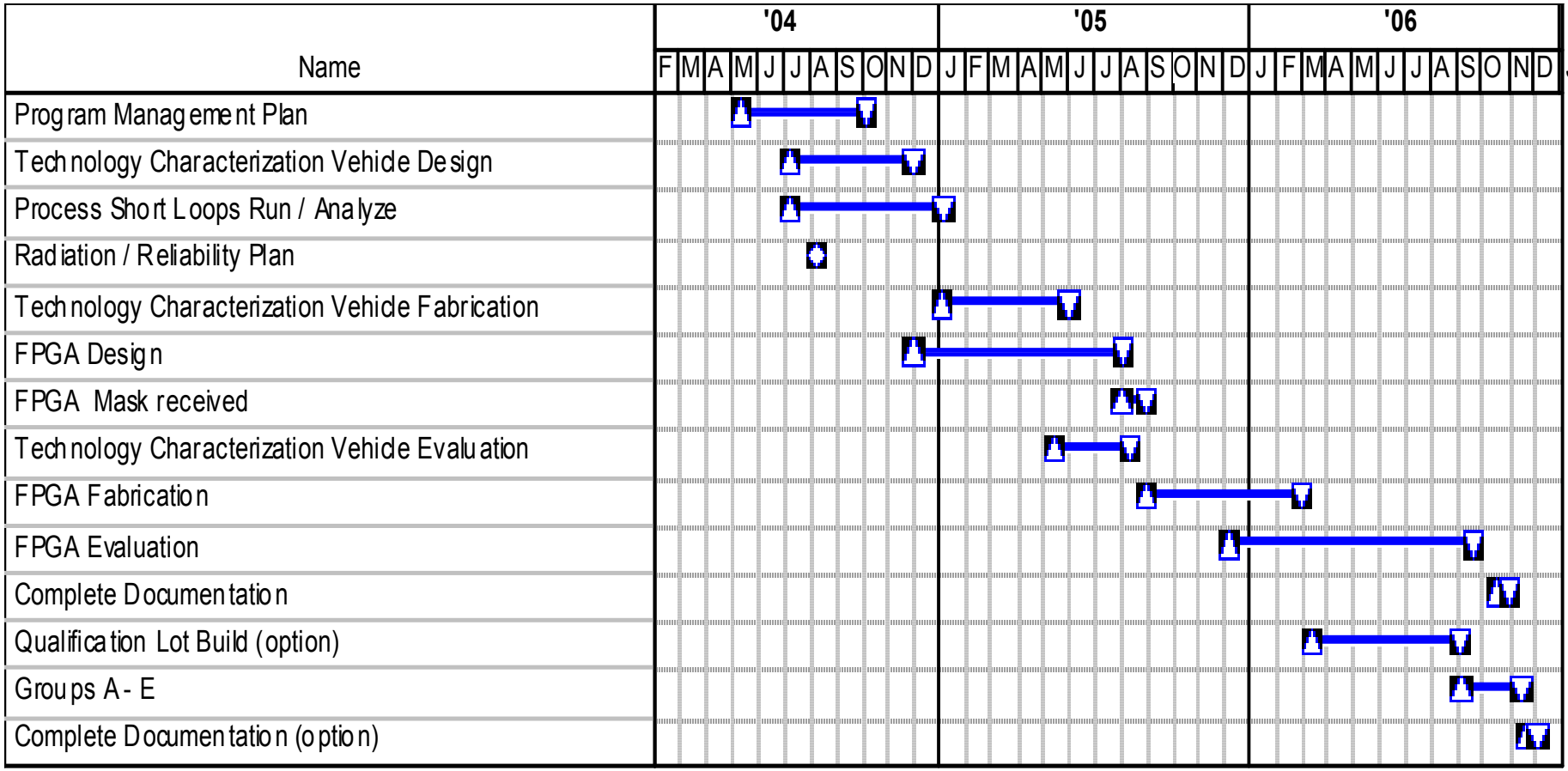
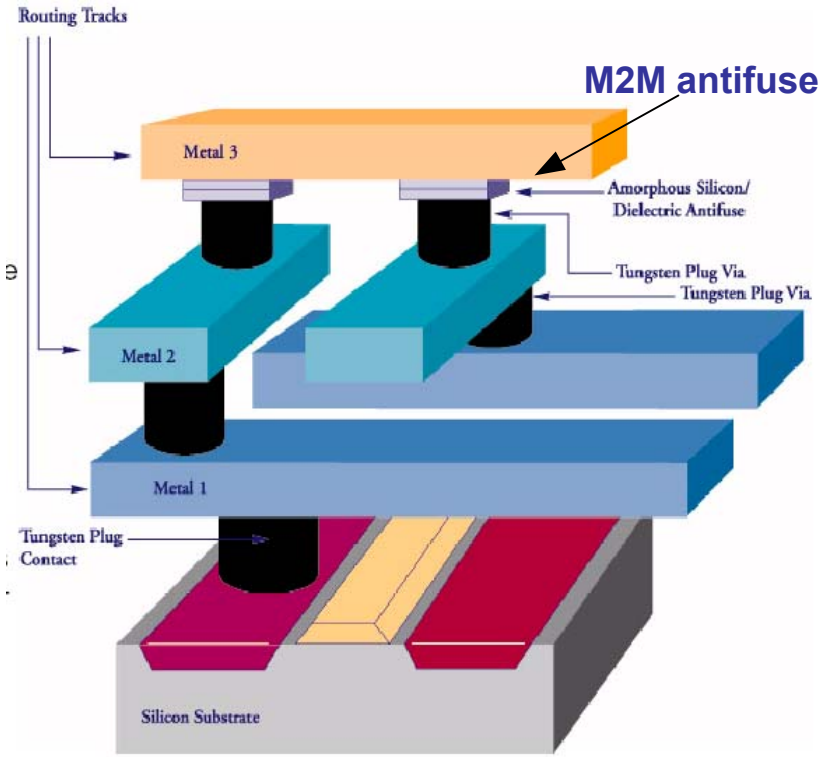


Figure 8

RHAX250-S FPGA Product

M2M Antifuse Structure:



RHAX250-S Product Features:

Device	RTAX250S
Capacity (in Equivalent System Gates)	
Typical Gates	250,000
ASIC Gates	30,000
Modules	
Register (R-cells)	1408
Combinatorial (C-cells)	2816
Flip-Flops (Maximum)	2816
Embedded RAM/FIFO (without EDAC)	
Core RAM Blocks	12
Core RAM Bits (K=1,024)	54k
Clocks (Segmentable)	
Hardwired	4
Routed	4
I/Os	
I/O Banks	8
User I/Os (Maximum)	248
I/O Registers	744
Package	
CCGA	–
CQFP	208,352

Radiation Hardness Features

TID:	**≥ 1Mrad**
SEL:	**Immune**
SEU_{LET}:	**> 37MeV-cm^2/mg**
$SET_{e\text{-}RAM}$:	**< 1E-10 e/b-d (EDAC)**
TMR-hardened registers.	

Figure 9

Summary

- BAE SYSTEMS and Actel are continuing their successful decade-long collaboration for producing radiation hardened FPGAs.

- RHAX250-S product development will include assessments of all vital rad hard FPGA issues, including:
  - unprogrammed antifuse heavy ion rupture
  - programmed antifuse reliability
  - single event transients
  - sso, ground bounce, signal integrity, package parasitics
  - clock skew management

- The RHAX250-S will be the first space-qualified radiation hardened FPGA product to be manufactured in the BAE SYSTEMS modernized foundry.