The NASA Electronic Parts and Packaging (NEPP) Program:
Roadmap for FY15 and Beyond

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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMOLED</td>
<td>Active Matrix Organic Light Emitting Diode</td>
</tr>
<tr>
<td>CBRAM</td>
<td>Conductive Bridging Random Access Memory</td>
</tr>
<tr>
<td>CGA</td>
<td>Column Grid Array</td>
</tr>
<tr>
<td>CIGS</td>
<td>Copper Indium Gallium Selenide</td>
</tr>
<tr>
<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off The Shelf</td>
</tr>
<tr>
<td>DDR4</td>
<td>Double Data Rate Four</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>DRAM</td>
<td>Dynamic Random Access Memory</td>
</tr>
<tr>
<td>EEE</td>
<td>Electrical, Electronic, and Electromechanical</td>
</tr>
<tr>
<td>EPC</td>
<td>Efficient Power Conversion</td>
</tr>
<tr>
<td>ESL</td>
<td>Electronic System Level</td>
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<tr>
<td>FeRAM</td>
<td>Ferroelectric RAM</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
</tr>
<tr>
<td>FY</td>
<td>Fiscal Year</td>
</tr>
<tr>
<td>GaN</td>
<td>Gallium Nitride</td>
</tr>
<tr>
<td>Gen</td>
<td>Generation</td>
</tr>
<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center</td>
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<tr>
<td>HALT</td>
<td>Highly Accelerated Life Test</td>
</tr>
<tr>
<td>HAST</td>
<td>Highly Accelerated Stress Testing</td>
</tr>
<tr>
<td>HEMTs</td>
<td>High-electron-mobility transistors</td>
</tr>
<tr>
<td>HP Labs</td>
<td>Hewlett-Packard Laboratories</td>
</tr>
<tr>
<td>HW</td>
<td>Hardware</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
</tr>
<tr>
<td>IR</td>
<td>Infrared</td>
</tr>
<tr>
<td>IR/Infineon</td>
<td>International Rectifier/Infineon Technologies</td>
</tr>
<tr>
<td>LCoS</td>
<td>Liquid-Crystal-on-Silicon</td>
</tr>
<tr>
<td>MEMS</td>
<td>Micro Electrical-Mechanical System</td>
</tr>
<tr>
<td>MOSFETS</td>
<td>Metal Oxide Semiconductor Field Effect Transistors</td>
</tr>
<tr>
<td>MRAM</td>
<td>Magnetoresistive Random Access Memory</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NAVY</td>
<td>Naval Surface Warfare Center, Crane, Indiana</td>
</tr>
<tr>
<td>NEPP</td>
<td>NASA Electronic Parts and Packaging</td>
</tr>
<tr>
<td>Occam</td>
<td>Open Conditional Content Access Management</td>
</tr>
<tr>
<td>OLED</td>
<td>Organic Light Emitting Diode</td>
</tr>
<tr>
<td>PBGA</td>
<td>Plastic Ball Grid Array</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RERAM</td>
<td>Resistive Random Access Memory</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>SEE</td>
<td>Single Event Effect</td>
</tr>
<tr>
<td>SERDES</td>
<td>Serializer/Deserializer</td>
</tr>
<tr>
<td>SiC</td>
<td>Silicon Carbide</td>
</tr>
<tr>
<td>SOC</td>
<td>Systems on a Chip</td>
</tr>
<tr>
<td>TI</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>VNAND</td>
<td>Vertical NAND</td>
</tr>
<tr>
<td>WBG</td>
<td>Wide Band Gap</td>
</tr>
</tbody>
</table>
Technology Selection Criteria for NEPP Investigation

• The technologies should satisfy all or most of the following criteria:
  – Wide applicability,
  – Product level or in productization, and,
  – No distinction: COTS to hi-reliability aerospace.

• Partnering arrangements with other organizations preferred.

• In general, we avoid:
  – Laboratory technologies, e.g., <TRL3,
  – Limited application devices with certain exceptions (critical application or NASA center specialization).
Technology Investigation Roadmap

Discussion

• Technology assurance efforts are not explicitly included except on “Small Missions” chart.
  – Guidelines are a product of many technology evaluation tasks.

• Only major product categories shown.

• Technology areas not on Roadmap but under consideration include:
  – Electro-optics (fiber optics),
  – Advanced analog and mixed-signal devices,
  – Imaging sensors,
  – Modeling and simulation,
  – High-speed communication (SERDES, fast data switches), and,
  – Adjunct processors (eg., graphics, signal processing)

• Note 1: Advanced CMOS technologies not explicitly included:
  – NEPP leverages samples from ongoing DoD and/or commercial sources.
  – 14nm is current target.

• Note 2: “Reliability testing” may include product and/or package testing.
Gartner Hype Cycle Concept

- **Technology Trigger**
  - R&D

- **Peak of Inflated Expectations**
  - First-generation products, high price, lots of customization needed
  - Startup companies first round of venture capital funding

- **Trough of Disillusionment**
  - Early adopters investigate
  - Mass media hype begins
  - Supplier proliferation
  - Activity beyond early adopters
  - Negative press begins
  - Supplier consolidation and failures
  - Second/third rounds of venture capital funding

- **Slope of Enlightenment**
  - Second-generation products, some services
  - Third-generation products, out of the box, product suites
  - Methodologies and best practices developing

- **Plateau of Productivity**
  - High-growth adoption phase starts: 20% to 30% of the potential audience has adopted the innovation
Gartner Hype Cycle for Electronics 2013

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### NEPP and Gartner Electronics Hype Cycle 2013

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Years to adopt:</th>
<th>Transformational</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCoS</td>
<td>less than 2 years</td>
<td>Silicon Photonics</td>
<td>CIGS Thin-Film Solar Cells</td>
<td>Resistance Phase-Change Memory</td>
<td>DDR4 DRAM</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>2 to 5 years</td>
<td>Software-Defined Radio for Mobile Devices</td>
<td>CMOS RF Power Amplifier</td>
<td>Through Silicon Vias</td>
<td>Electronic Paper</td>
</tr>
<tr>
<td>Network on Chip</td>
<td>5 to 10 years</td>
<td>Memristor Memory</td>
<td>ESL Design Tools and Methodologies</td>
<td>AMOLED</td>
<td>Lithium Ion Phosphate</td>
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<tr>
<td></td>
<td>more than 10 years</td>
<td>Nanotube Electronics</td>
<td>HW Reconfigurable Devices</td>
<td>Electronic Paper</td>
<td>Batteries</td>
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<tr>
<td></td>
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<td>DNA Logic</td>
<td>IC Subsystem Reuse</td>
<td>MEMS Displays</td>
<td>MEMS Gyroscopes</td>
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<td></td>
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<td>Molecular Transistors</td>
<td>Multicore Programming</td>
<td>Occam Process</td>
<td>Metamaterial Antennas</td>
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<td>Organic/Polymer Solar Cells</td>
<td>Nanomaterial Supercapacitors</td>
<td>OLED Lighting</td>
<td>Wireless Power</td>
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<td>Quantum Computing</td>
<td>Post-193 nm Lithography</td>
<td>Photonic Crystal Displays</td>
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<tr>
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<td></td>
<td>Resistance Polymer Memory</td>
<td>Printed Semiconductors</td>
<td>Quantum Dot Displays</td>
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<tr>
<td></td>
<td></td>
<td>Terahertz Waves</td>
<td>Reusable Analog IP</td>
<td>Silicon Thin-Film Solar Cells</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Cognitive Radio</td>
<td>Silicon Anode Batteries</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holographic Storage for Consumer Electronics</td>
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</tr>
</tbody>
</table>

After Gartner 2013 Electronics Hype Cycle

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Field Programmable Gate Arrays (FPGAs)

Trusted FPGA
- DoD Development

Altera
- Stratix 5 (28nm TSMC process commercial)
- Max 10 (55nm NOR based commercial – small mission candidate)
- Stratix 10 (14nm Intel process commercial)

Microsemi
- RTG4 (65nm RH)

Xilinx
- 7 series (28nm commercial)
- Ultrascale (20nm commercial – planar)
- Ultrascale+ (16nm commercial - vertical)
- Virtex 5QV (65nm RH)

FY14 FY15 FY16 FY17
Xilinx Zynq UltraScale+ Multi-Processor System on a Chip (MPSoC) family

From Xilinx.com

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Advanced Processors

Next Generation Space Processor (NGSP)
- Joint NASA-AFRL Program for RH multi-core processor
- TBD architecture/process

RH Processor
- BAE Systems RAD5510/5545
- Replacement for RAD750

Intel Broadwell Processors
- 14nm FinFET commercial
- 1st high-performance sans heatsink (lower power for performance)

Freescale P5020/5040
- Commercial 45nm network processor
- Preparation for RH processor

Note: Future considerations under discussion include automotive “self-driving” processor options.
Preliminary Radiation testing of 14nm Intel with Navy Crane
Microcontrollers and Mobile Processors (Small Missions)

TBD – other
- Atmel AT91SAM9G20, and TI Sitara AM3703,
- ARM (Snapdragon), Intel Atom mobile

TI MSP430
- Popular CubeSat microcontroller
- Several varieties

Freescale MPC56XX
- 90nm on-shore fab
- Automotive Grade
- Being used for both part and board level testing

Radiation Testing (limited)
Reliability Testing
Radiation Testing
Reliability Testing
Radiation Testing

FY14    FY15    FY16    FY17

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Commercial Memory Technology

Other
- MRAM
- FeRAM

Resistive
- CBRAM (Adesto)
- ReRAM (Panasonic)
- ReRAM (Tezzaron)
- TBD (HP Labs, others)

DDR 3/4
- Intelligent Memory (robust cell twinning)
- Micron 16nm DDR3
- TBD – other commercial

FLASH
- Samsung VNAND (gen 1 and 2)
- Micron 16nm planar
- Micron Hybrid memory Cube
- TBD - other commercial

TBD – (track status)
Small Missions

EEE Parts Guidelines
- Small missions (Class D, CubeSat – 2 documents)
- System on a chip (SOC) single event effects (SEE) guideline

Guideline development

Commodities evaluation
- See commodities roadmaps for processors, power
- CubeSat Star Tracker

Radiation Testing
Reliability Testing

Automotive grade electronics
- Multiple classes of electronics (passives, actives, ICs)
- Testing by NASA and Navy Crane

Reliability Testing

Alternate test – board level
- Freescale MPC56XX
- Automotive Grade
- Both part and board level reliability testing

Reliability Testing

FY14 FY15 FY16 FY17
Automotive Processors and Systems for Self-Driving Cars?

From Freescale.com

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Wide Band Gap (WBG) Technology

GaN Class V development
- Microsemi with EPC

GaN Enhancement Mode HEMTs
- EPC Gen 2-3, 200 V - 600 V
- GaN Systems 100 V, 650 V
- Panasonic 600 V (target)
- IR/Infineon 600 V (target)

SiC MOSFETs
- Cree Gen 1-2 1200 V - 1700 V
  Gen 3- narrower neck
- STMicro baseline SEE test
- Rohm Trench design

SiC Diodes
- Manufacturer X SEE baseline and hardening efforts

SiC ICs
- Ozark IC
- Manufacturer X

FY14  FY15  FY16  FY17

TBD – (track status)
Radiation and Reliability Testing
Radiation Testing  Reliability Testing
Radiation Testing
TBD – (track status)
Radiation Testing
Radiation Testing
Radiation Testing
Radiation Testing

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Silicon Power Devices

MOSFETs – Rad Hardened
- Microsemi i2MOS
- Infineon superjunction 100 V, 600 V (target)
- IR/Infineon R8 trench 20 V

Schottky Diodes
- Multiple vendors, reverse voltage ratings, and forward current ratings

Radiation Testing (track status)

FY14 FY15 FY16 FY17
Packaging Technologies (1 of 2)

High Density, Non-hermetic Column Grid Array (CGA)
- Xilinx CN/Kyocera Daisy Chain
- Microsemi Daisy Chain
- Materials analysis, long term stress, root cause failure

HALT Methodology/Qualification
- HALT/HAST comparison
- Plastic BGA matrix

Area Array Column
- Selection guide

Thermal Interface Materials
- Selection guide

PBGA Thermal Cycle Evaluation

Reliability Testing

Guideline development

Reliability Testing

Guideline development

Reliability Testing

Reliability Testing

FY14 FY15 FY16 FY17
Bump Reliability
- Technology review
- Test vehicle options

3D Packaging Technologies
- Technology review
- Test vehicle options

QFN package reliability
- Reliability/Qualification metrics

Guideline research

Reliability Testing

FY14 FY15 FY16 FY17
And Just When You Think
Your Roadmap is Set,
New Parts are Released

• Examples
  – More complex processors
    • TI Multicore DSP+ARM KeyStone II System-on-Chip (SoC)
  – Integrated “instruments”
    • TI DLP2010NIR – near IR sensing and controller
Summary and Comments

• NEPP Roadmaps are constantly evolving as technology and products become available.
  – Like all technology roadmaps, NEPP’s is limited to funding and resource availability.
  – Not shown are TBD passives and connector roadmaps under development.
  – NEPP is working to develop preliminary plans on interfacing to the NASA Reliability and Maintainability Program and its work on Model Based System Engineering (MBSE) approaches.

• We look forward to further opportunities to partner.

https://nepp.nasa.gov