AFRL

An Air Force Perspective on the Application of Machine Learning for Microelectronics Design and Security

P. Len Orlando III

AFRL Sensors Directorate

Introduction

AI and Machine Learning applied to the Microelectronics Ecosystem (ME) should not be considered a disruptive technology, instead it is a valuable sustaining technology which provides a pathway for productivity enhancements while broadening capable users of ME.

- Production of High Quality work with Human-Machine Hybrid AI teams
- Derive the Best Solutions Faster
- Abstraction and automation of complex systems

Effective Humans need to make intelligent decisions

National Security Commission on Artificial Intelligence (NSCAI)

03-2021 Final Report: “integrated national strategy to reorganize the government, reorient the nation, and rally our closest allies and partners to defend and compete in the coming era of AI-accelerated competition and conflict”

Phase1: Defending America

…

P1: Scale up digital talent in government

P1: Establish justified confidence in AI systems

…

Phase2: Winning the Technology Competition

…

P2: Win the global talent competition

P2: Build a resilient domestic base for designing and fabricating microelectronics

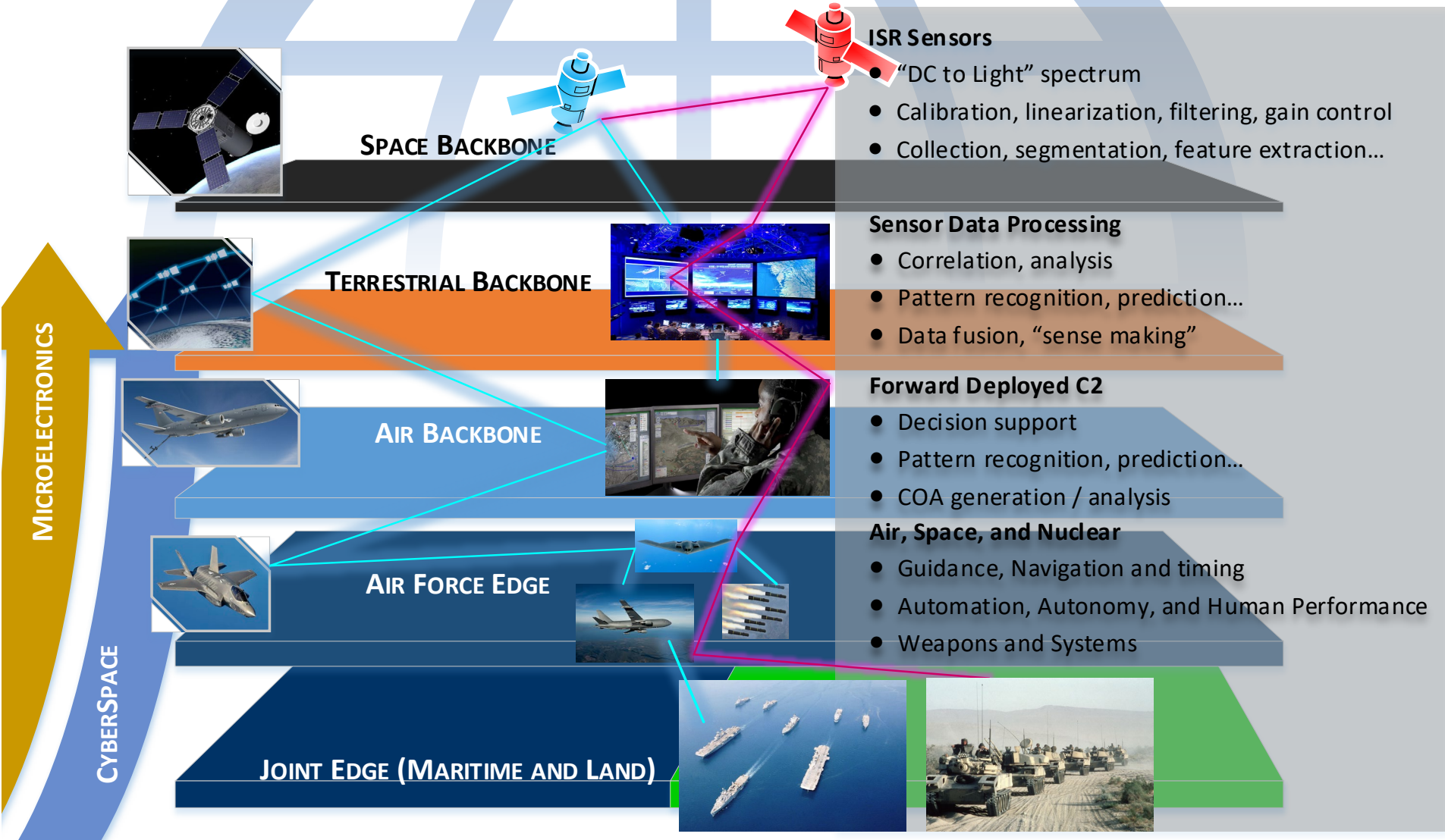
P2: Protect Americas technology advantages

…

P2: Win the associated technologies competitions

https://www.nscai.gov/

Our Mission: Technology to make and keep the fight unfair!



Combination of Manned, Unmanned, and Autonomous platforms working cooperatively to achieve mission objectives

Quick decision on-board processing necessary at the edge for optimal decision making

High bandwidth data exchanges for cloud and remote processing

Resilient systems capable of operating under duress in contested environments

Microelectronics – a technical edge in warfighting capability

To Stabilize New Technology

"Highly stealth aircraft like the F-117 Nighthawk are aerodynamically unstable … and require constant flight corrections from the flight system to maintain controlled flight" – *Skunk Works*, B. Rich and L. Janos

Remotely Piloted Systems

"Utilizing state-of-the-art equipment… these experts perform surveillance and reconnaissance…" – airforce.com

SkyBorg is Here!

Skyborg AI Kratos Drone Launch 05-2021 The Air Force recently demonstrated the ability for **autonomous unmanned aircraft** to operate **alongside** tactical aircraft like the F-35 and F-15EX.

The intent is for **manned-unmanned teaming** where the drones learn and train with the pilot and take on missions deemed to risky for human pilots.

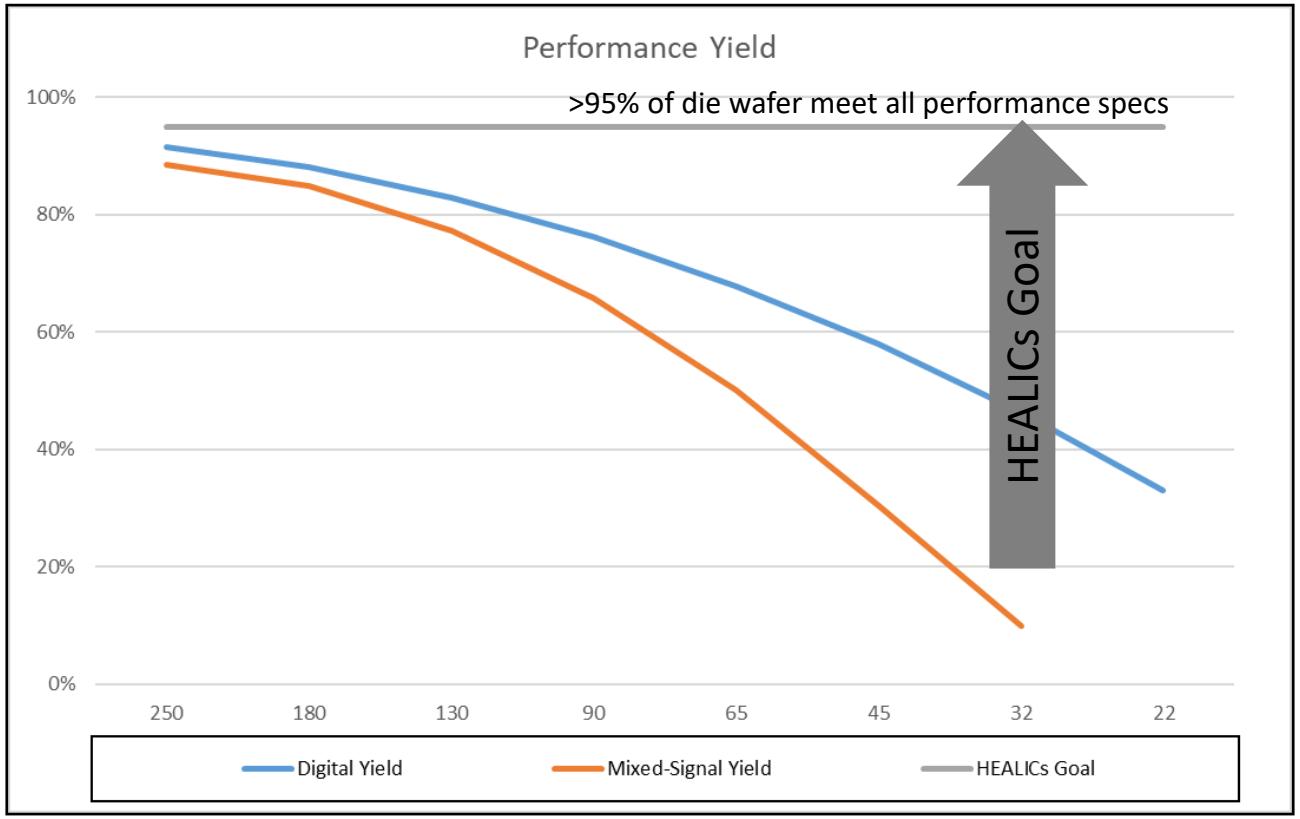
R2-D2-Style

Un-crewed Semi-Attritable

Role of AI/ML in Intelligent Decision Making

Analog Performance Recovery

DARPA Self-HEALing Mixed-Signal Integrated Circuits (HEALICs)



Regain lost performance by adding sensing and control circuitry that will compensate for the process, environmental, and ageing variations in situ, which will ultimately allow designers to focus on performance goals and not on yield-related issues.

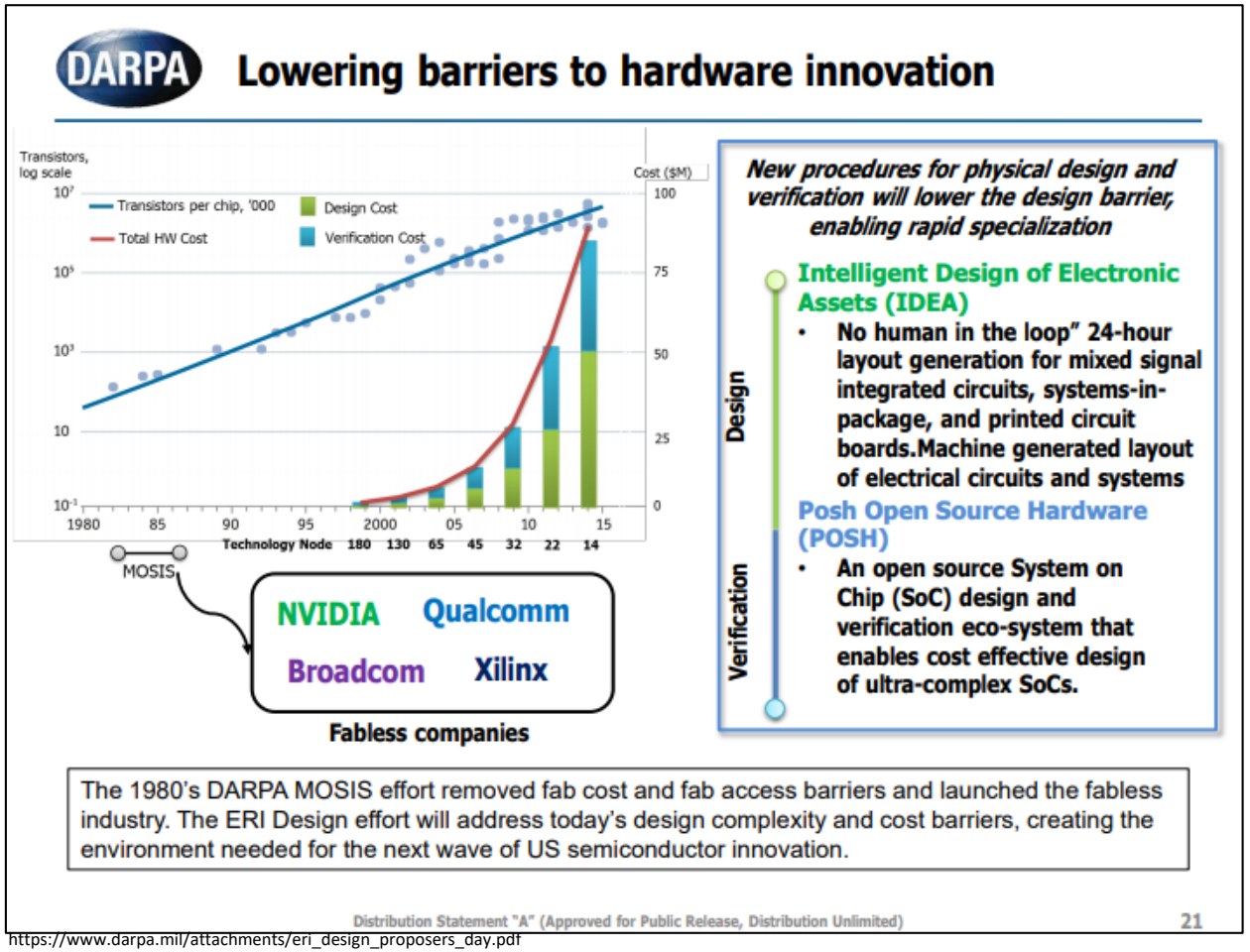
- Compensate for intra-wafer and intra-die process variation of advanced node scaling
- **Implementation of Sensors and Actuators** within Mixed Signal ICs and having minimal overall impact to power and area.

Not limited to any particular type of circuit or control approach; rather, it aims to develop techniques and technologies that allow **any mixed-signal design to be runtime-corrected** at the SoC level

https://www.darpa.mil/program/self-healing-mixed-signal-integrated-circuits
IEEE Design & Test, Dec.2012, Mixed-Signal SoCs with In-Situ Self-Healing Circuitry, C. Maxey et.al.

Digital Design Space Exploration

DARPA Intelligent Design of Electronic Assets (IDEA)



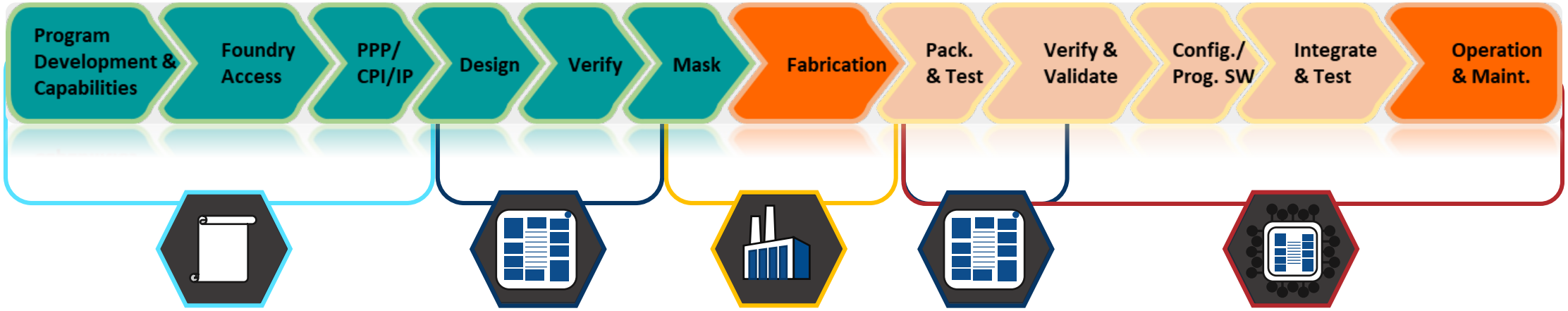
https://www.darpa.mil/attachments/eri_design_proposers_day.pdf

Leverage **algorithms and computational scalability** to replace the human in the loop to achieve an end-state faster, management of complex design functions across multiple domains

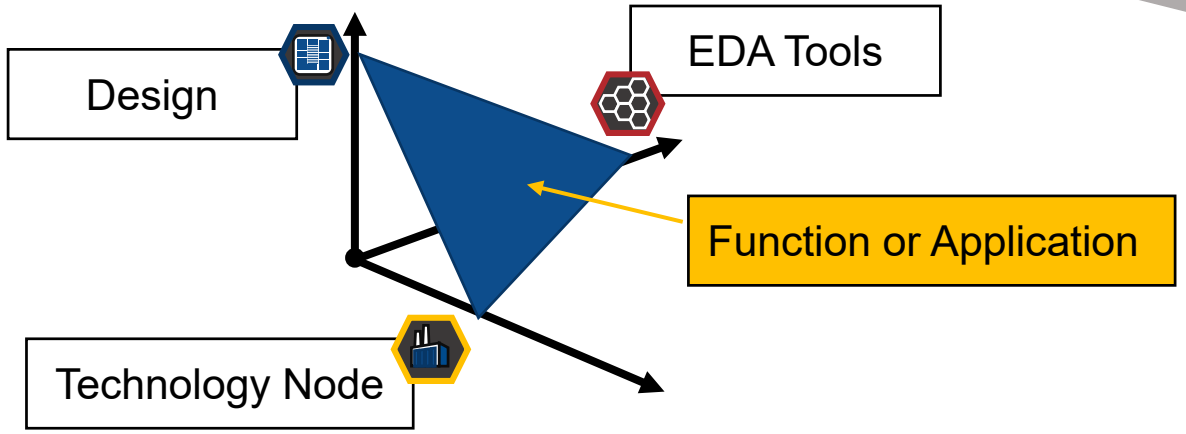
Embedded **ML-AI frameworks** in which the user provides the training data.

Dimensionality and Complexity of Microelectronics

Temporally



Implementation



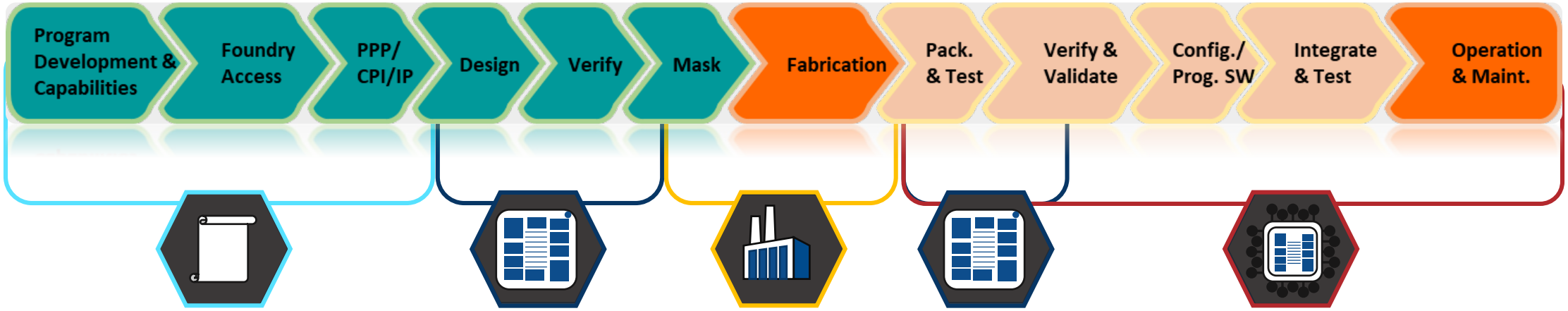
Industrial Revolution

Industry 3.0: Automation

Industry 4.0: Automating the Automation

Air Force and Space Force Interests: Temporal

Temporally



<u>Application of Machine Learning and AI:</u>

Requirements Traceability

Processing of large amounts of data generated throughout the ecosystem
- Anomaly detection
- Surrogate modeling
- Identification of data gaps

Predictive Analysis for Maintenance and Upgrades

Managed complexities of large composed systems

More Data is just the beginning… Access to the Right Data is better… <u>Ultimately High quality data is necessary</u>

Air Force and Space Force Interests: Implementation

Application of Machine Learning and AI:

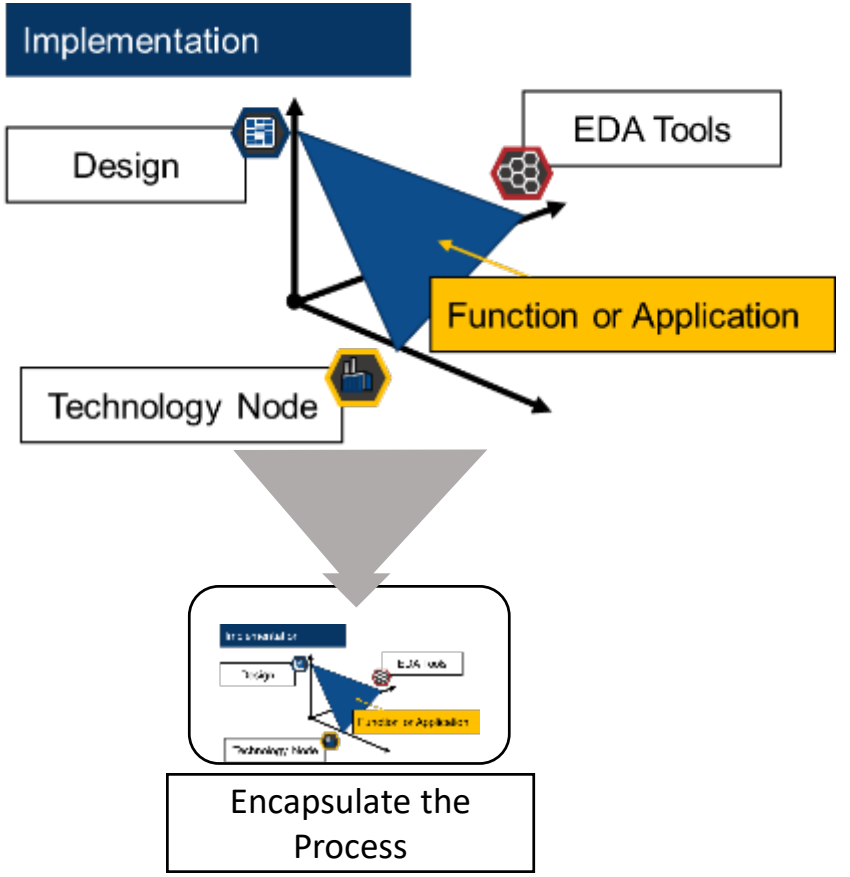
Simultaneous optimization of multiple parameters

Process for small teams to produce High Performance and High Quality Designs

- Hybrid implementation of complimentary human machine activities
- Acceleration of efficiencies to produce working EDA flows
- Combine with Agile methods for multiple iterations of a design
- Identify and close on verification gaps
- Tradeoff of Performance, Power, and Thermal

Technology Independence

Compose-able designs that span chip, package, and board



Provide a unique **strategic advantage** to unleash human creativity on critical areas of design

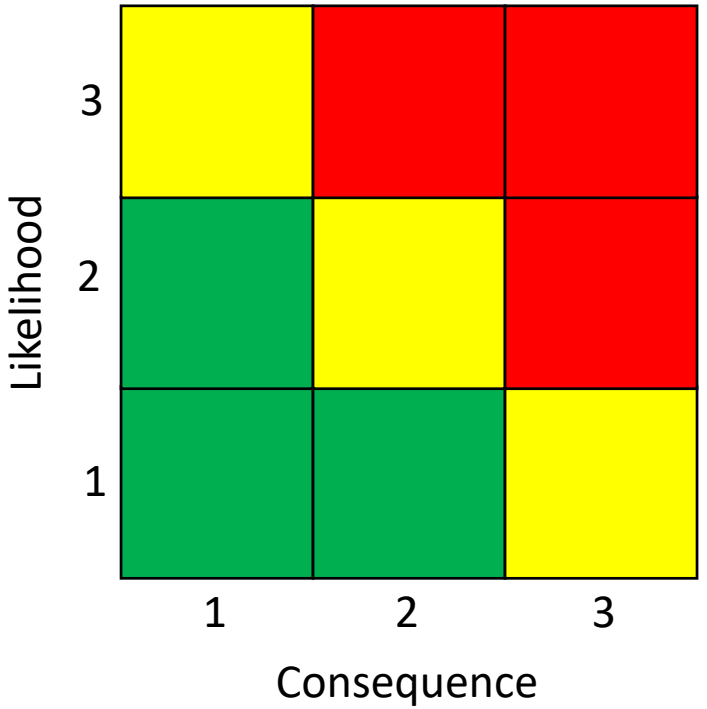
DoD Risk Matrix - Primer

3 Step Process

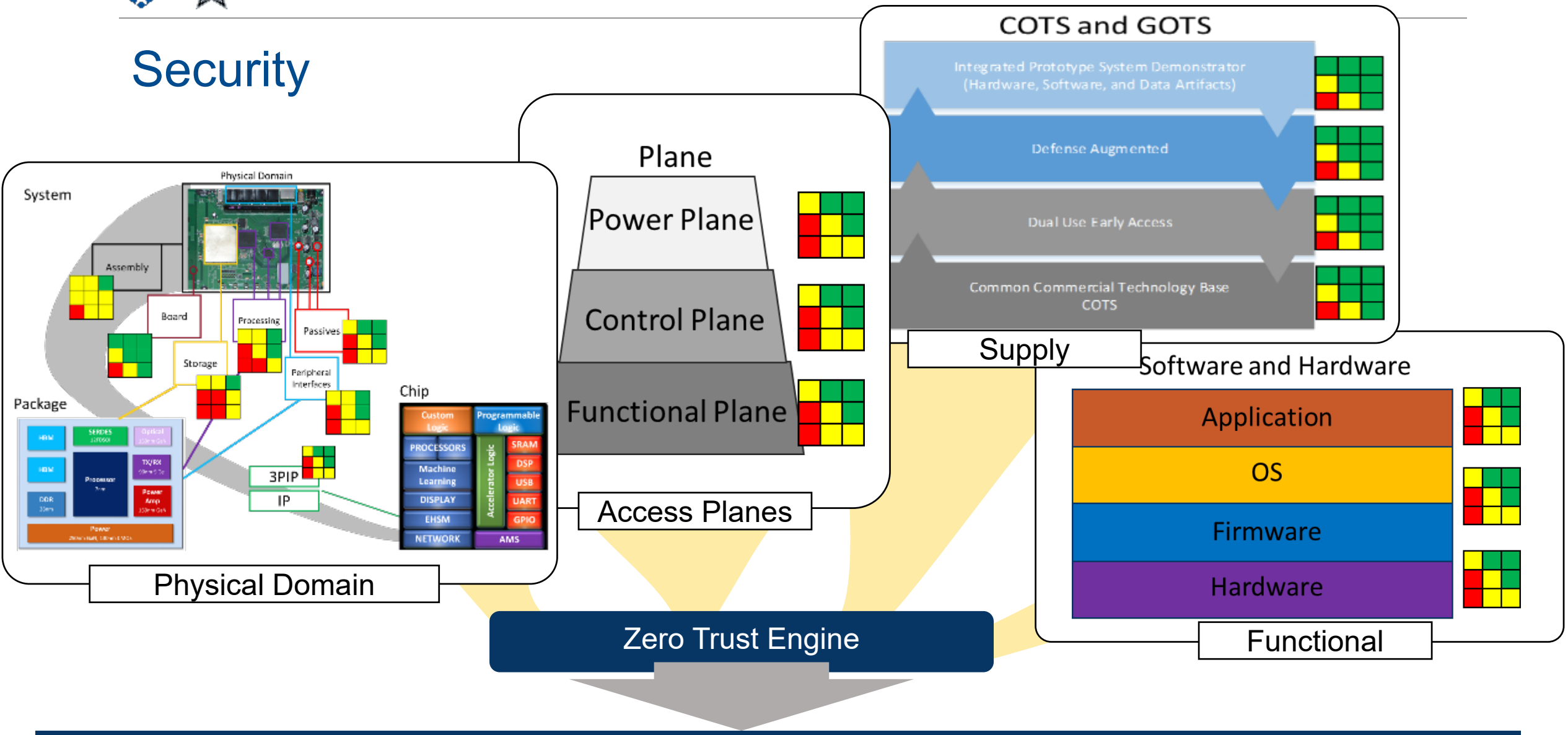
Step 1
Level of likelihood of a risk occurring (Probability of Occurrence)

Step 2
Determine Level and Types of Consequences (Impact on Performance, Schedule and Cost)

Step 3
Plot the results for each risk in a Risk Reporting Matrix



Security



Conclusion

- Microelectronics (ME) are a ubiquitous component of the Air Force and Space Force Mission

- Air Force and Space Force Key AI/ML ME enablers
  - Ability to perform Intelligent Decisions
  - Productivity and Efficiency Improvements
  - Solutions to Multi-dimensional problems (Performance, Technology, EDA, Security, Thermal), across Multiple Domains (Chip, Board, Package, System), and Software/Hardware Boundary
  - ME Lifecycle Analytics

Hybrid Human-AI design processes will spur a microelectronics renaissance where smaller teams are able to accomplish very large complex projects; humans are focused on critical areas of a design and relegate tasks to AI/ML processes.

Questions

Speakers Biography

P. Len Orlando III
AFRL RYD Digital Transformation Leas
OSD(T&AM) Quantifiable Assurance Lead for Emulation

Mr. Orlando graduated from the Ohio State University in 2001 with a Bachelor in Science in Electrical and Computer Engineering. After receiving his degree, Mr. Orlando joined the Air Force Research Laboratory Sensors Directorate developing next generation digital receiver exciter technologies in advanced SiGe bipolar, CMOS, and III-V foundry offerings. In 2008, received his Master's Degree in Electrical engineering from the University of Dayton with his thesis entitled "Digitally Controllable Variable Gain and Variable Slope High Performance X-Band Amplifier". Over the course of his AFRL career, Mr. Orlando has provided subject matter expertise participating as part of a select government team on DARPA TEAM, NeoCad, HEALICs, COSMOS, TRUST and IRIS programs. Mr. Orlando has served as the Air Force Hardware Assurance lead for the Office of the Secretary of Defense (OSD) Trust and Assured Microelectronics (T&AM) program, the OSD T&AM Secure Design Thrust Area Lead, and OSD T&AM Education and Workforce Development Co-Lead. Currently, Mr. Orlando serves as the OSD T&AM Quantifiable Assurance Emulation Lead contributing to the DoD's renewed interest in state of the art microelectronics for national security and was recently appointed to lead the AFRL Sensors Directorate, Aerospace Components and Subsystems Division on the Digital Engineering Transformation Line of Effort.