Distributed Engine Control Working Group

Presentation to Propulsion Controls and Diagnostics Working Group

September 16, 2015

Bruce Wood – DECWG™ Chairman

The DECWG™ Vision…

Vision

Enable affordable distributed engine controls for dual use gas turbine and aerospace vehicle applications that are environmentally robust, scalable, provide lower life cycle cost, mitigate obsolescence, reduce weight, support advanced control algorithms, and creates an ecosystem that sustains future engine control infrastructure.

Objectives

- Provide a forum for the US government and aerospace industry to collaborate, in a pre-competitive environment, to advance technologies required to implement distributed controls in aerospace propulsion systems.
- Align the efforts of the US government and private industry, both large and small businesses, to provide the technical skills and funding required to design, build and test representative hardware required for these systems.
- Advance fundamental high temperature electronics and packaging required to implement affordable distributed control systems.

DECWG™ *Consortium* Organization

Industry Led Collaboration with Government Advisors

DECWG Distributed Engine Controls Working Group consortium

General Electric

Honeywell

Pratt & Whitney
A United Technologies Company

Rolls-Royce LibertyWorks™

BAE SYSTEMS

UTC Aerospace Systems

OAI[1]

U.S. Government[1]

Advisors[1]

Invited Affiliates[1]

Administrator
- Legal
- Fiscal
- Facilitator

OAI Ohio Aerospace Institute

Governing Board
- Consortium Oversight
- Strategy
- Advocacy

Advisory Board
- Airframers
- Universities
- Regulatory

Government Liaisons

DIRCT

- Program Interests
- Technology Guidance
- Program Support

Technology Focus Groups
- Identify Gaps/Technology
- Initiation of Focus Groups
- Monitor Progress

Strategy

Technical Direction

TFG Project Teams
- Technical Advancement
- Proposal Preparation
- Project Execution
- Share Results

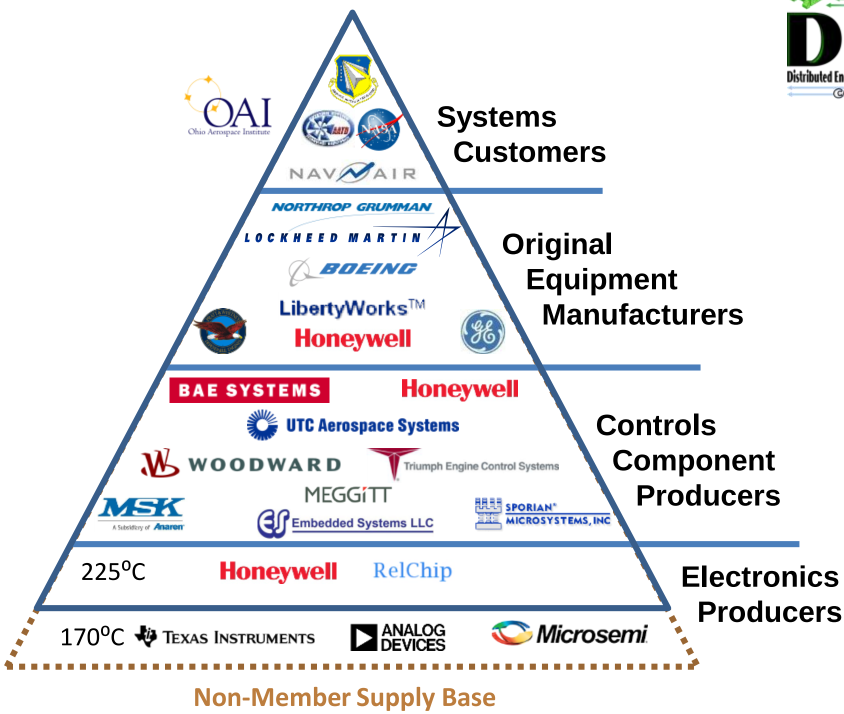
Invited Affiliates[2]
- Expertise
- Common Interests

DECWG
DISTRIBUTED ENGINE CONTROLS WORKING GROUP (DECWG)
DRAFT
JOINT COLLABORATION AGREEMENT

Organization Defined By **Joint Collaboration Agreement**

This Slide Contains No Technical Information Subject to the ITAR or EAR

DECWG™ Consortium



DECWG Distributed Engine Controls Working Group consortium

Pre-Competitive Development …

Enablers for Next Generation Engine Controls

- 225°C Digital Electronics
- High Thermal Cycle Packaging

Distributed Control Architectures Standards

- Propulsion / Airframe Integration
- Communication Protocols
- Electrical Power Distribution
- Certification

Leveraging Progress in Adjacent Markets

- Downhole Oil & Gas (Sustained High Temp)
- Automotive (High Thermal Cycle)

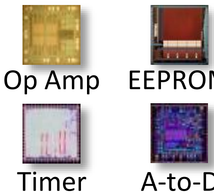
Expected Benefits

- More Computing Power for Advanced Control Laws
- Reduce Controls Weight / Size / Cost Impacts
- Improve Controls Reliability via Digital Networks
- Mitigate Need For Fuel-Cooled Engine Controls
- Enable Modularity and Reuse Across Programs

DECWG™ Distributed Engine Controls Working Group consortium

Technology Collaboration and Standards

Six Technical Focus Areas



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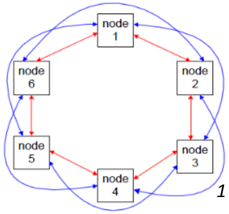

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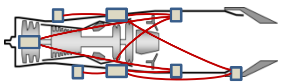

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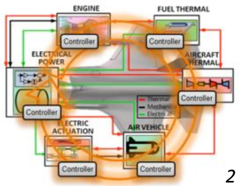

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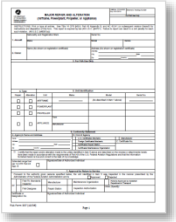

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High Temperature Electronics | **High Temp High Cycle Packaging** | **Communication** | **Power Distribution** | **Propulsion Airframe Integration** | **Certification**

Pre-Competitive Technology: High Temperature Electronics; High Temp High Cycle Packaging

Standards: Communication; Power Distribution; Propulsion Airframe Integration; Certification

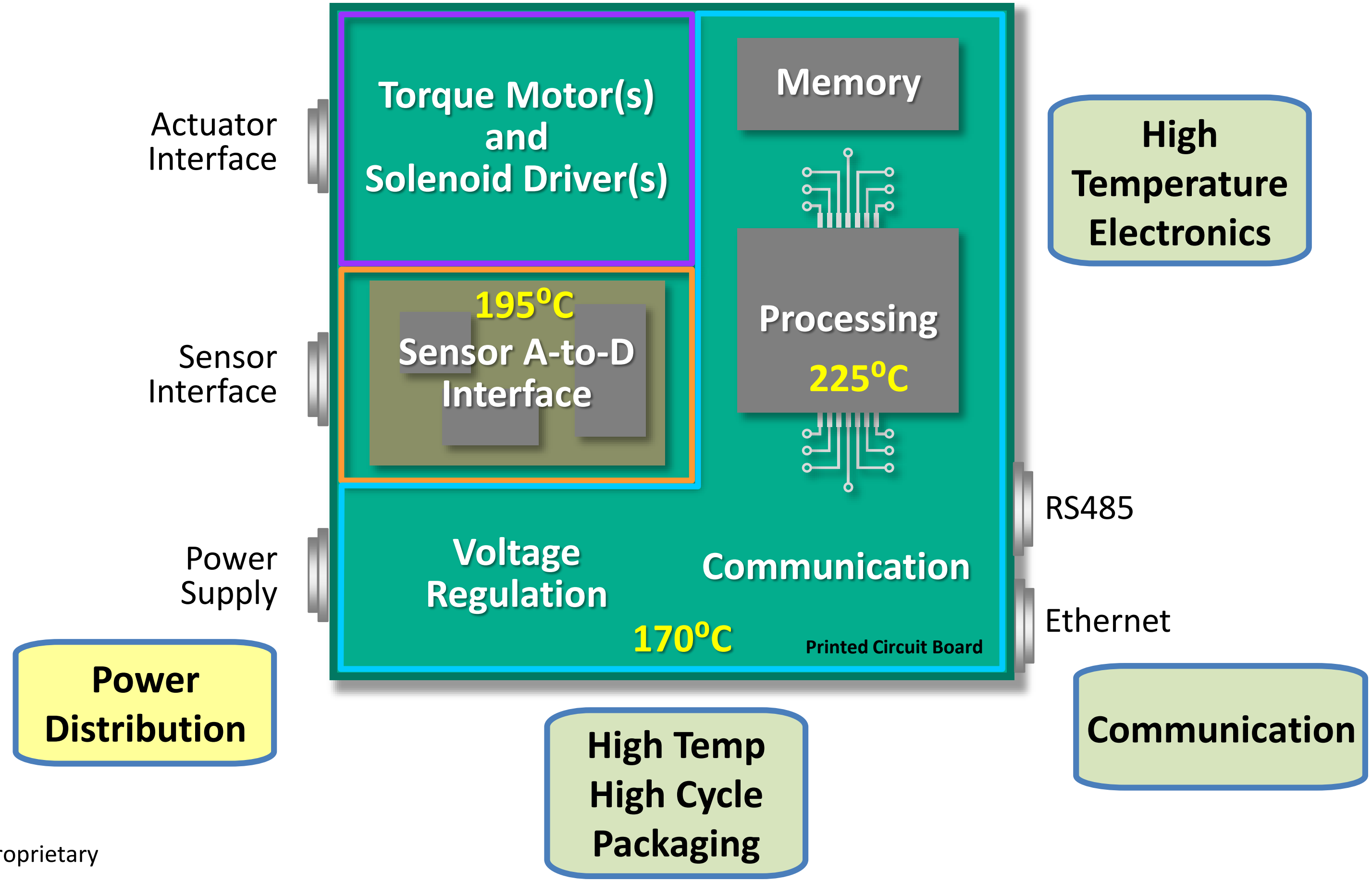
Technical Focus Group Status

- TFG Operational (green): High Temperature Electronics, High Temp High Cycle Packaging, Communication
- TFG Forming (yellow): Power Distribution, Propulsion Airframe Integration, Certification

Image Credits:
1 DECWG™
2 AFRL Public Release
3 FAA Public

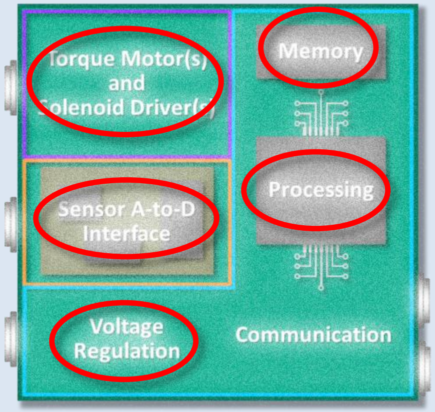
High Temp “Smart Node”

Technology Development



Not to Scale
Details DECWG™ Proprietary

High Temp Electronics



TECHNOLOGY CHALLENGES

- High Temperature Engine Environment
- Life Expectancy and Reliability Requirements
- Affordability of High Temp Electronics
  - High Density SOI Manufacturing Processes
  - Commonality w/ Existing Processes
- Trade Performance (Speed) vs. Leakage
- New Tools/Models Supporting Specific Designs

OBJECTIVES

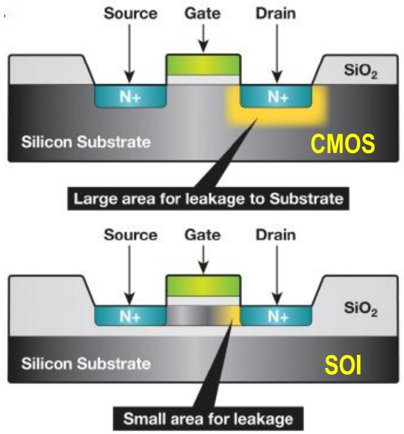
- *Identify* Needed High Temp Components
- *Leverage* State-of-the-Art Electronics
- High Temp Component *Specifications*
- Mature High Temp Electronics Solutions
- Cost Effective *Manufacturability*
- Qualification / *Certification* Compliance
- Ensure Dual Use

VALUE PROPOSITION:

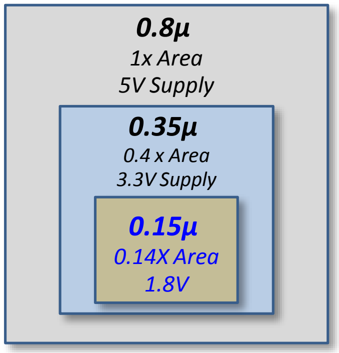
- Enhanced Component Durability Using SOI Chip
  - Smaller Transistor Size
  - Smaller Size → Reduce Manufacturing Cost
  - Lower Power Demand
- Reduce/Eliminate FADEC Cooling Requirement
- Improve Control System Reliability
- Enable Compact Control System Architectures
- Enhance Fault Isolation
- Industry Wide Commonality To Reduce Cost

High Temp Electronics

Bare Die



High Temp **Silicon On Insulator** CMOS



Relative Chip Size for 1MB RAM

Image Credit: Honeywell

High Temp Chip Set

Components

- Oscillators
- Passives
- Spike Suppression
- Transistors
- Power Regulators
- Op Amps / Analog
- A-to-D & D-to-A
- Processing
- Memory

TECHNOLOGY DESCRIPTION

What

- There is a need for integrated circuit technology that can allow smaller feature sizes and yet retain reliable capability for operation at 225°C and higher.

How

- Leverage ongoing Honeywell work in HT SOI Bare Die.
- Define new design process for 150nm SOI fabrication.
- Manufacturing process leveraging current capabilities

Complementary Metal-Oxide Semiconductor (CMOS)

TECHNOLOGY DESCRIPTION

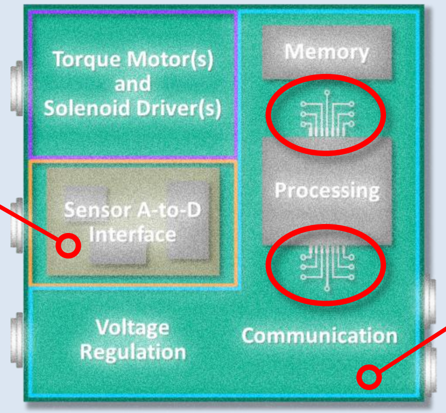
What

- There is a need for suite of high temperature capable electronics to enable distribution of controls into high temperature engine environment.

How

- Generate detailed specifications for components required to build *High Temp* "smart" control nodes.
- Identify existing / emerging sources of high temperature capable components relevant to Distributed Controls.
- Drive for development of new components.

High Temperature Packaging and Assembly



Die Attach
Solders
Vias
Wire Bonds
Substrates
Voltage Isolation
Board Materials
Housing

TECHNOLOGY CHALLENGES

- Extended Operation at High Temperatures
- Thermal Expansion Due To Temperature Cycling
- Combination High Temp and Vibration
- Solder / Interconnect / Substrate Fatigue
- Life Expectancy and Reliability Requirements
- Few Options for High Temp Packaging Materials
- Balance Capability with Affordability

OBJECTIVES

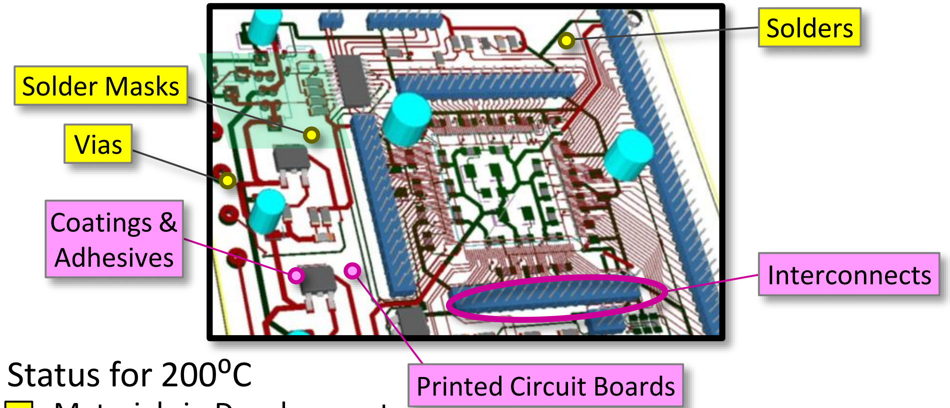
- *Identify* High Temp Board Level Needs
- *Leverage* Power Electronics Packaging
- High Temp Packaging *Specifications*
- Develop High Temp Packaging Techniques
- Cost Effective *Manufacturability*
- Qualification / *Certification* Compliance
- Dual Use

VALUE PROPOSITION:

- Reduce FADEC Size by Remote I/O Hardware
- Enable Digital Harnesses for Lower Cost/Weight
- Enable Modular Controls; “Smarts” w/ Actuator
- Thermomechanical Cycling Robust PCBs
- Uncooled Printed Circuit Boards
- Enhanced Durability and Reliability of Controls
- *Head Start Towards Proprietary Node Designs*

High Temp Packaging: Board Materials Design

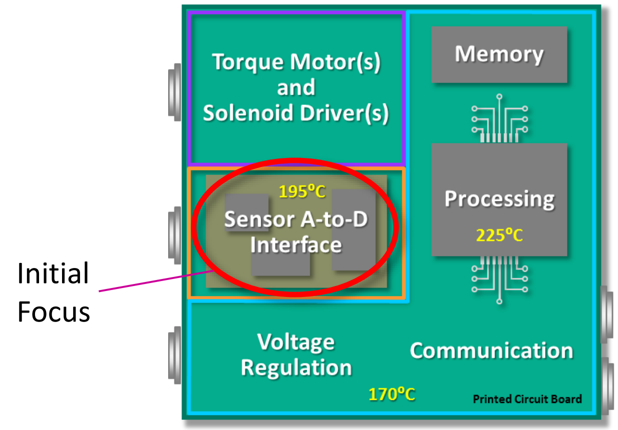
Materials



Status for 200°C
- Materials in Development (yellow)
- New Materials Needed (pink)

Public Image Courtesy Wikipedia Commons

Reference Node Build



TECHNOLOGY DESCRIPTION

What

- There is need for Printed Circuit Board (PCB) materials and packaging assemblies suitable for extended use at temperatures and thermal cycling across a range from -55°C to 225°C.

How

- Identify emerging sources of large temperature range robust boards and materials, leveraging Downhole and Wide-Band Gap Power Electronics advances.

TECHNOLOGY DESCRIPTION

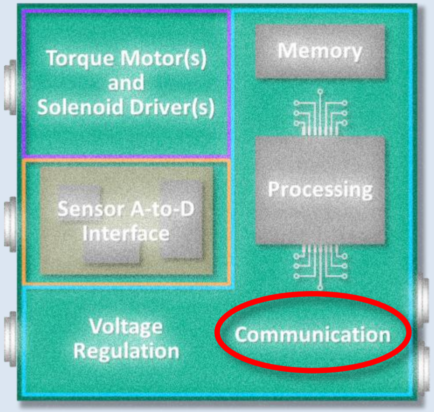
What

- There is a need for High Temperature Capable Smart Nodes to host computing and memory local to sensors, actuators, pumps, generators, etc. for Distributed Engine Control architectures.

How

- Design, build and test non-proprietary *reference* Smart Node using available components and packaging, with understanding that size and temperature capability will likely not meet ultimate targets.

Communications



TECHNOLOGY CHALLENGES

- High Temp Capable Chips to Host Protocol(s)
- Trade of Capability and Robustness vs. Simplicity
- Ensuring Fault Tolerance and Failure Isolation
- Electromagnetic Interference
- Communication Networks Security
- Low Cost Solution

OBJECTIVES

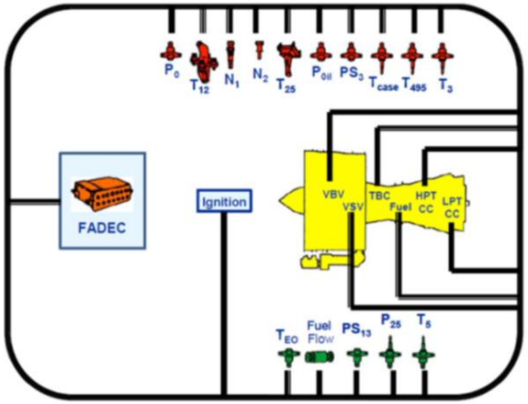
- *Identify* Local and Wide Area High Temp Propulsion Communication Needs
- *Modify* Existing Communication Standards
- *Establish* New Communication Standards
- Qualification / *Certification* Compliance for Safety Critical Airborne Systems
- Network *Demonstration* and Evaluation

VALUE PROPOSITION:

- Digital Harness - Reduced Size, Weight and Cost
- Enhanced Fault Detection And Isolation
- EMI Robustness
- High Availability Communication Networks
- Control System Flexibility w/o FADEC Redesign

Communication Protocol Standards

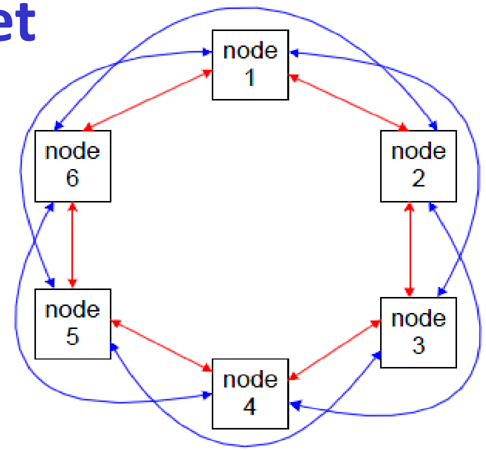
RS485



Engine Area Distributed Interconnect Network (EADIN)

Image Credit: NASA

Ethernet



Braided Ring Availability Integrity Network (BRAIN)

Image Credit: Honeywell

TECHNOLOGY DESCRIPTION

What

- There is a need for Standardized Engine Area Databus with low circuit gate count for compatibility with High Temperature Electronics for Distributed Control.

How

- Design new digital network communication protocol providing adequate bandwidth w/ minimal (~1000) circuit gates, based on expected capability of high temp smart nodes. Ensure compliance with industry standards for robustness against error and jitter.

TECHNOLOGY DESCRIPTION

What

- There is a need for Ethernet-based communication protocol and topologies enabling high integrity, high availability distributed engine control networks compatible with IEEE 802.3 and SAE AS6802 standards.

How

- Development of fault-tolerant Ethernet-based Braided Ring Availability Integrity Network (BRAIN).

Power, Integration and Certification TFGs

POWER SYSTEMS AND DISTRIBUTION TFG OBJECTIVES

- Definition of Electrical Bus Requirements for Regulated & Non-Regulated Systems
- Assess Applicability of FAR 33 - Section 28 *Compliance Criteria for Aircraft Engines, Electrical and Electronic Engine Control Systems*) to Distributed Controls
- Identify and Document Unique Certification / Qualification Considerations
- Work w/ Standards Organizations / Tech Experts to Modify or Set New Standards

SYSTEM PROPULSION INTEGRATION TFG OBJECTIVES

- Work w/ Key Airframe Partners to Understand Design Challenges and Constraints
- Create Set of Engine-Aircraft Architecture Guidelines and Boundary Definitions
- Identify Approaches for Implementing and Maintaining Distributed Controls
- Identify Methods to Address Any New Safety Challenges w/ Distributed Controls

CERTIFICATION TFG OBJECTIVES

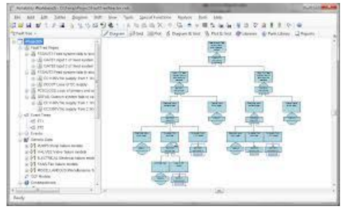
- Identify Qualification and Certification Challenges for Distributed Controls
- Inform and Interact with Certification Agencies (i.e. FAA and EASA)
- Coordinate Activities Between Regulatory Agencies and DECWG™ TFGs

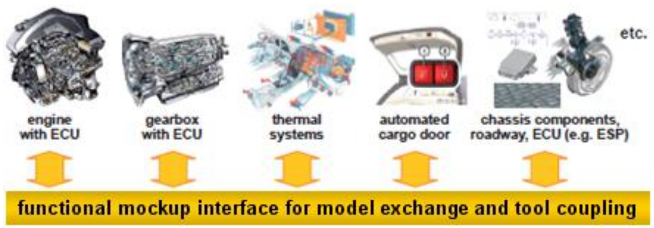
Starting Soon

Distributed Controls Architecture Tools

System Design

AADL



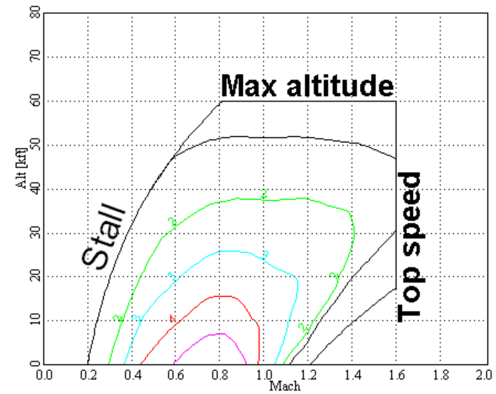


Architecture Analysis & Design Language (AADL)

Image Credit: Honeywell

Electronics Temperature Profile

Time At Temperature



Thermal Cycles

Public Image Courtesy Wikipedia Commons

TOOL DESCRIPTION

What

- There is a need for industry standard toolsets enabling design as well as functional and safety analysis of candidate Distributed Engine Controls architectures.

How

- Extend existing Architecture Analysis & Design Language (AADL) toolset platform to support to unique needs of Distributed Control design, using emerging Functional Mockup Interface (FMI) simulation standard.
- AADL is SAE Standard by Software Engineering Institute at CMU

TOOL DESCRIPTION

What

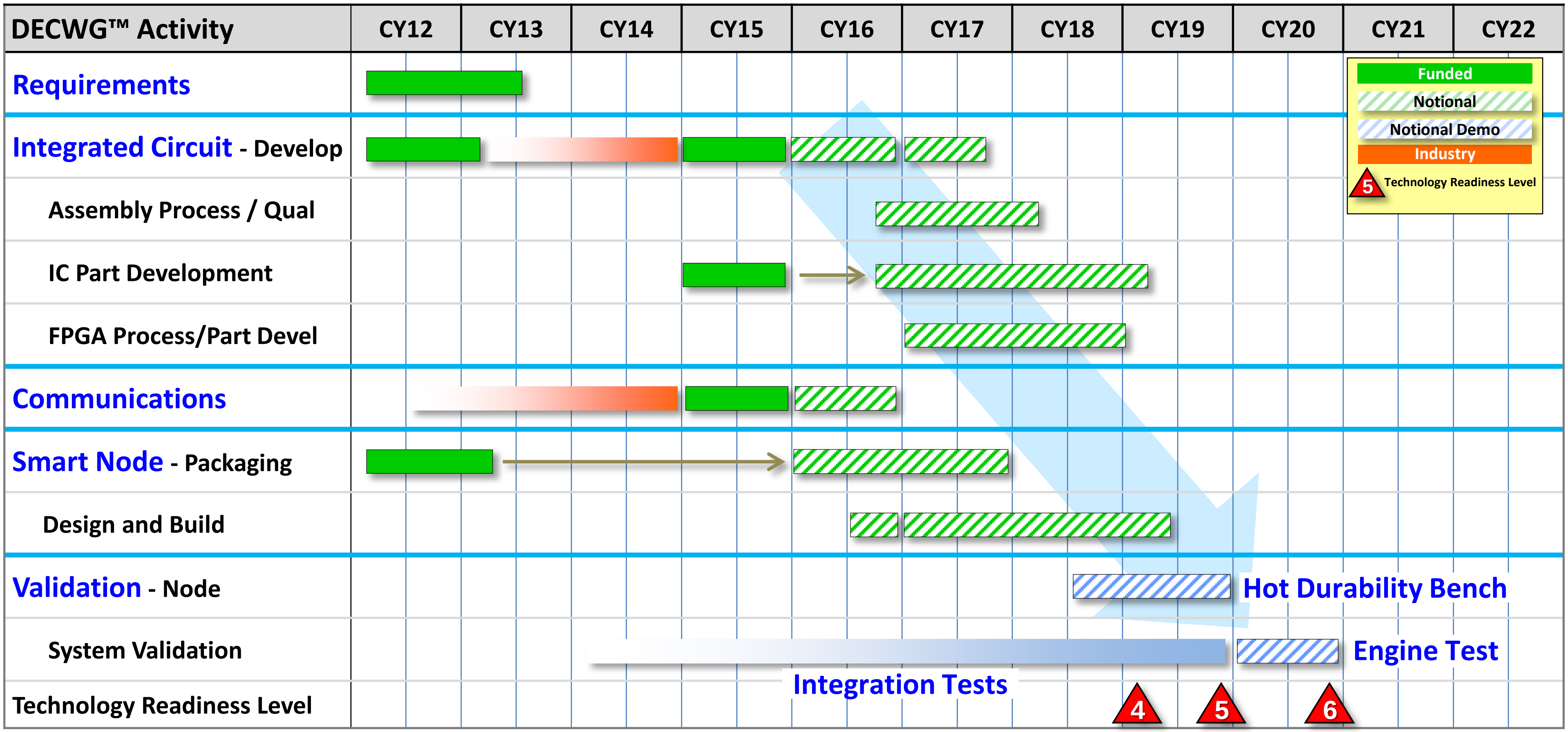
- There is a need for aeronautics industry standard flight profiles for engine controls in terms of time duration at temperature and thermal cycling, that can be used to specify life and reliability requirements for High Temp Electronics and Packaging.

How

- Collect, analyze and normalize measured or simulated engine case temperature data over range of aircraft applications to generate standard thermal duration and cycle profiles.

DECWG™ Roadmap

Enable Distributed Controls Capability by 2020 Timeframe



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Summary

- DECWG™ Making Progress Towards 2020 Goals
  - ✓ Consortium Formed
  - ✓ Technical Focus Groups Initiated
  - ✓ Roadmap w/ Government and Industry Funding
- Seeking Broader Collaboration
  - Leverage Relevant Industry Development
  - Coordinate with SBIRs
  - Take Advantage of Synergistic DoD Activities
  - Continued Proposals for Gov't Partnerships
- Invite Participation
  - If You Have Similar Interests … Talk with Us

DECWG™: Driving Transformational Change in Aerospace Propulsion Controls