



Future Aircraft Power Systems- Integration Challenges

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Future Aircraft Power Systems- Integration Challenges

Outline

- Aircraft Electric Power Systems
 - Existing Systems
 - More-Electric-Airplanes (MEA)
 - 787 No Bleed System
 - Power Electronics
- Vision and Goals for Next Generation Electric Airplane (NGEA)
- Role of Power Electronics and System Simulation in NGEA
- Conclusions and Summary

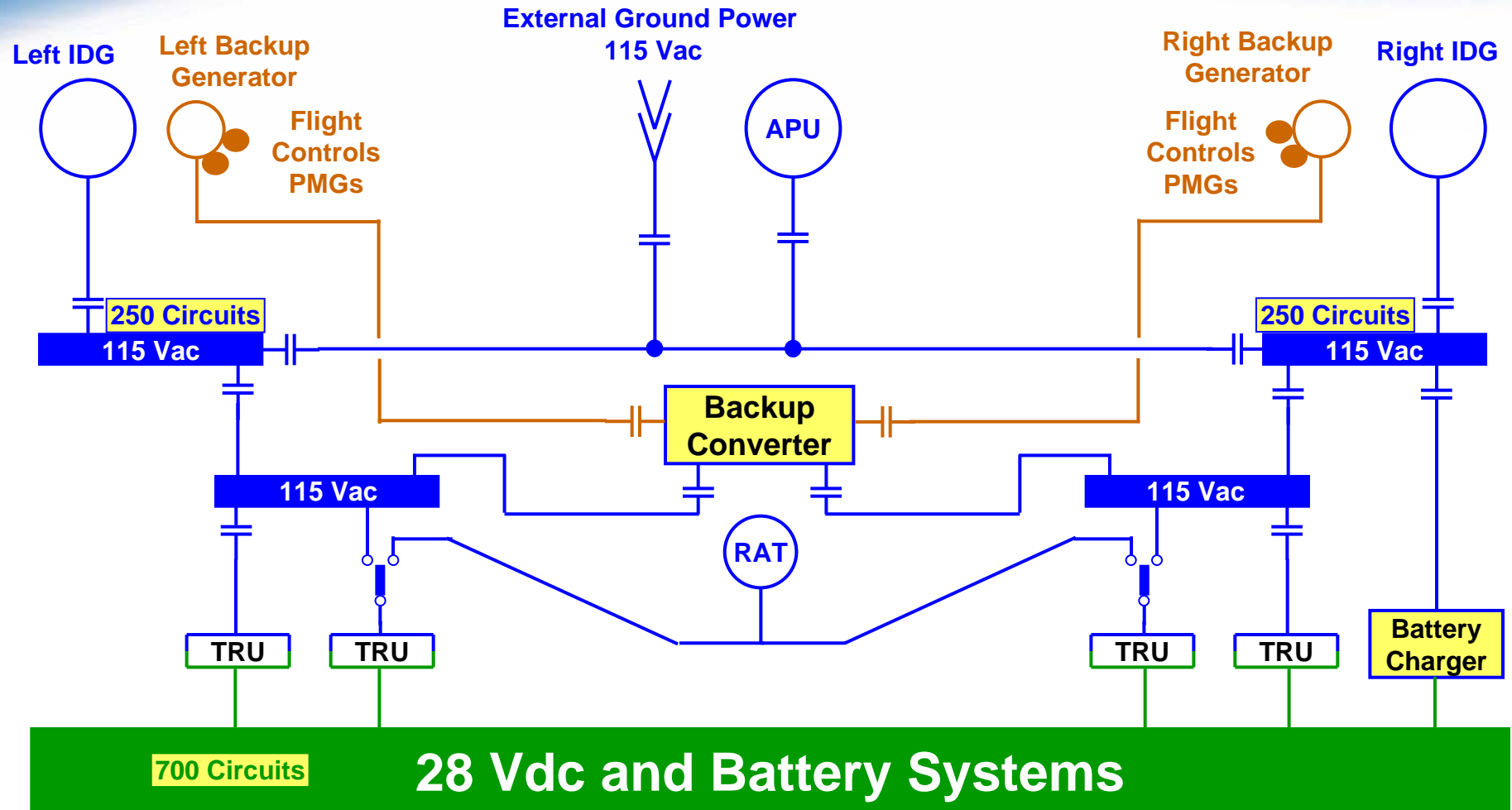
777 Electrical System

“Traditional” Hybrid – 115Vac & 28Vdc

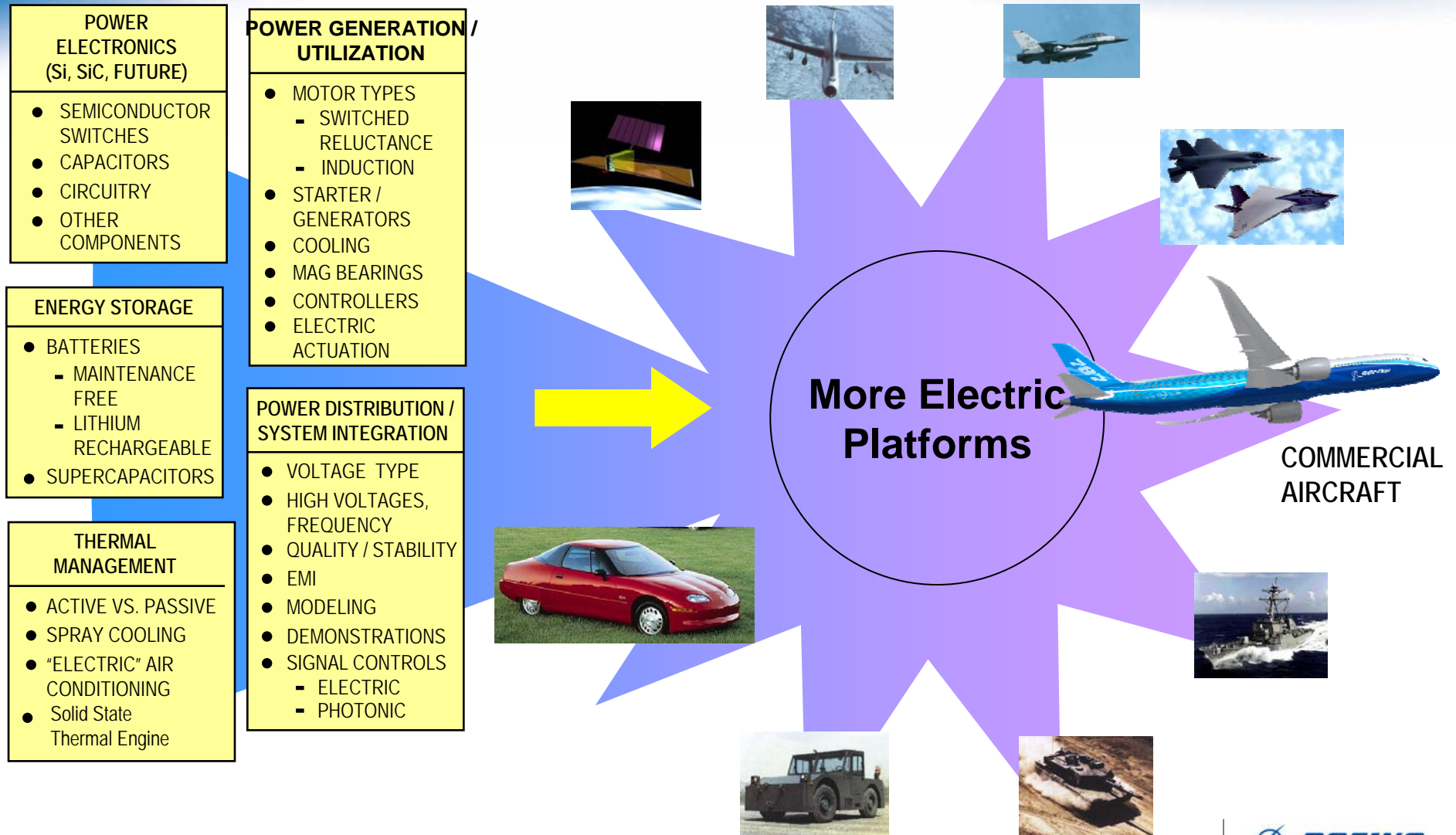
- **Power Sources:**
 - Two - 120 kVA, 115Vac, 400Hz engine driven generators
 - One 120 kVA, 115Vac, 400Hz Auxiliary Power Unit (APU) driven generator
 - Four 950 W Permanent Magnet Generators (PMG) integrated into the two backup generators
 - One 7.5kVA Ram Air Turbine (RAT)
 - Main, APU, and flight controls batteries
- **Conversion Equipment:**
 - Four 120 Amp DC Transformer Rectifier Units (115Vac to 28Vdc)
 - Battery chargers and inverters
- **Distribution System:**
 - Centralized distribution panels
 - Thermal circuit breakers and electro-mechanical relays
 - Contactors with built-in current sensing and control electronics

Simplified 777 Electrical System

One Line Diagram



“More Electric” is Industry Trend



Current More Electric Aircraft



Boeing 787

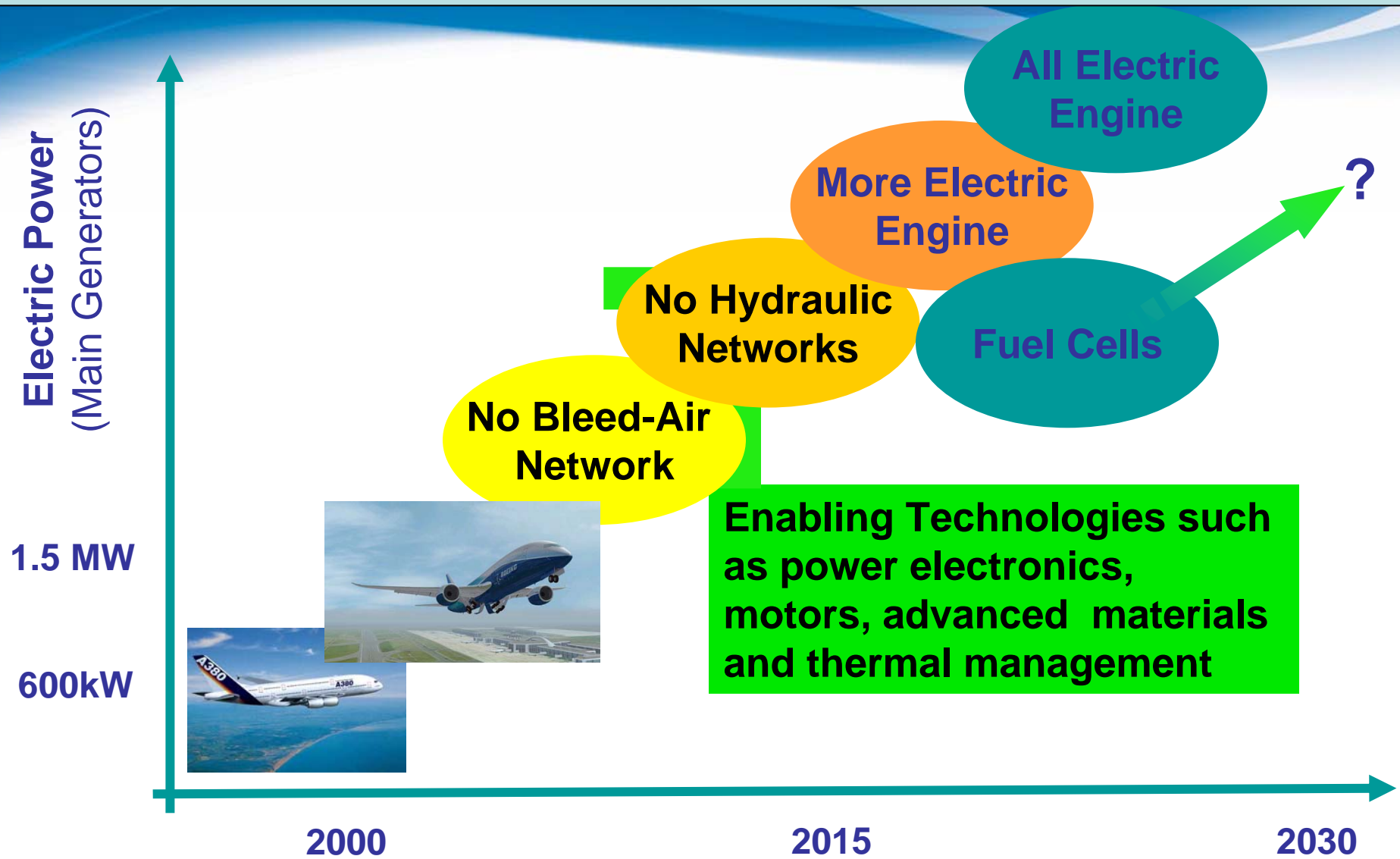


Airbus A380

F-35 Fighter



More Electric Aircraft is an Evolutionary Application of Electrical power



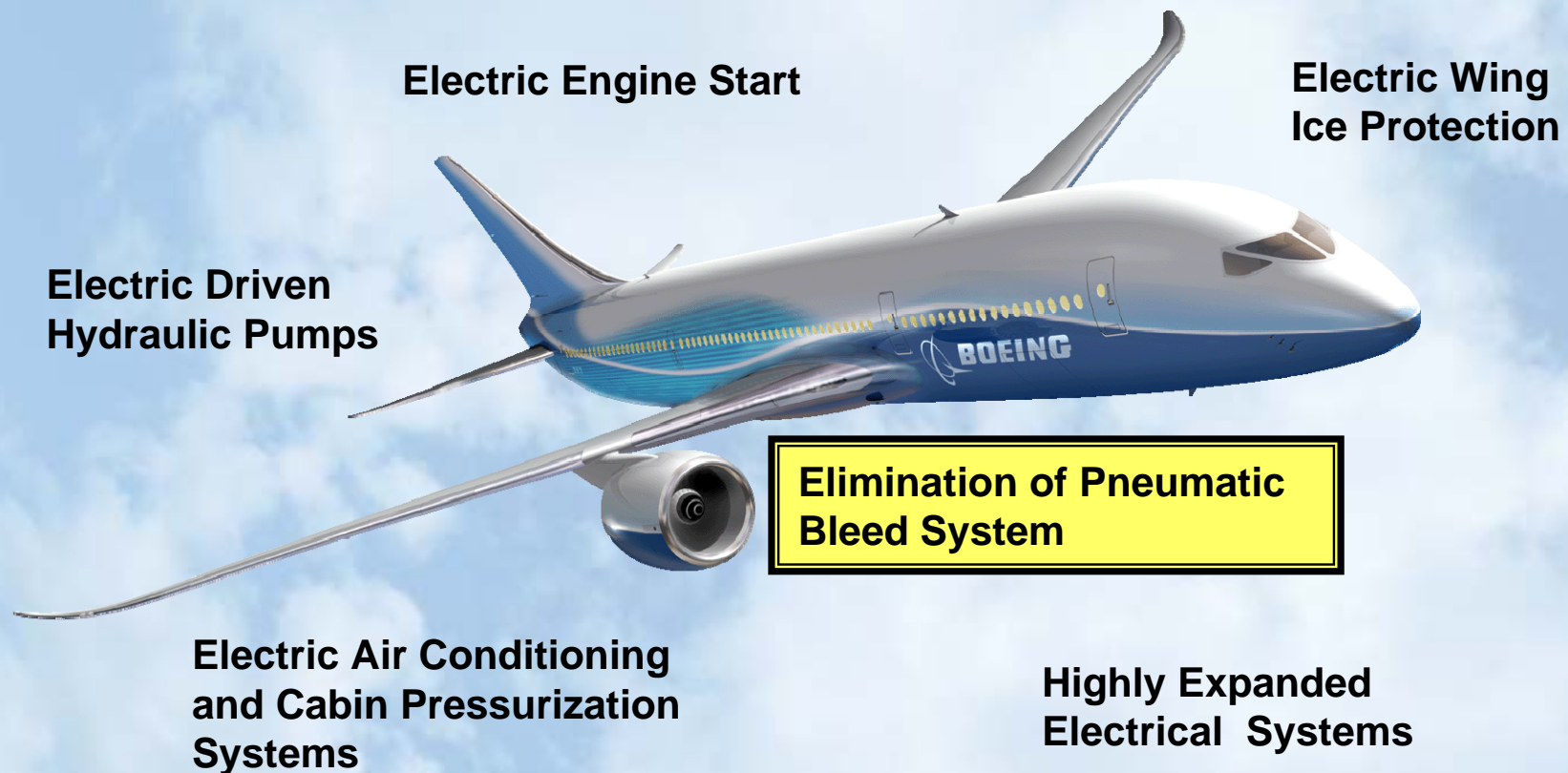
The 787 More Electric Airplane



787 No-Bleed Systems

787 MEA Architecture

Generate, Distribute, and Consume energy in an effective and efficient manner



Advanced Electric Architecture



- The Boeing 787 “Dreamliner”
 - The first commercial airplane to have a 230 Vac Variable frequency distribution system.
 - The first commercial airplane to have an electrically powered air conditioning system
 - The first to utilize electro-mechanical flight control actuators.
 - Unrivalled airplane efficiency.
 - Extensive use of solid state power electronics.



787 Electrical Systems Summary

Hybrid AC and DC Primary
Distribution Systems
(235Vac, 115Vac, \pm 270Vdc, 28Vdc)

Power Conversion from
235Vac to \pm 270Vdc

Variable Frequency
Generation at 235Vac

- 2 x 250 kVA per Engine
- 2 x 225 kVA on APU

Remote Power
Distribution System

Forward
E/E Bay

Aft E/E Bay

Electric Engine Start

Current Return Network

Three 115Vac Ground
Sources

Electric Brakes

APU Starter /
Generator System

Adjustable Speed Motors
and Motor Controllers

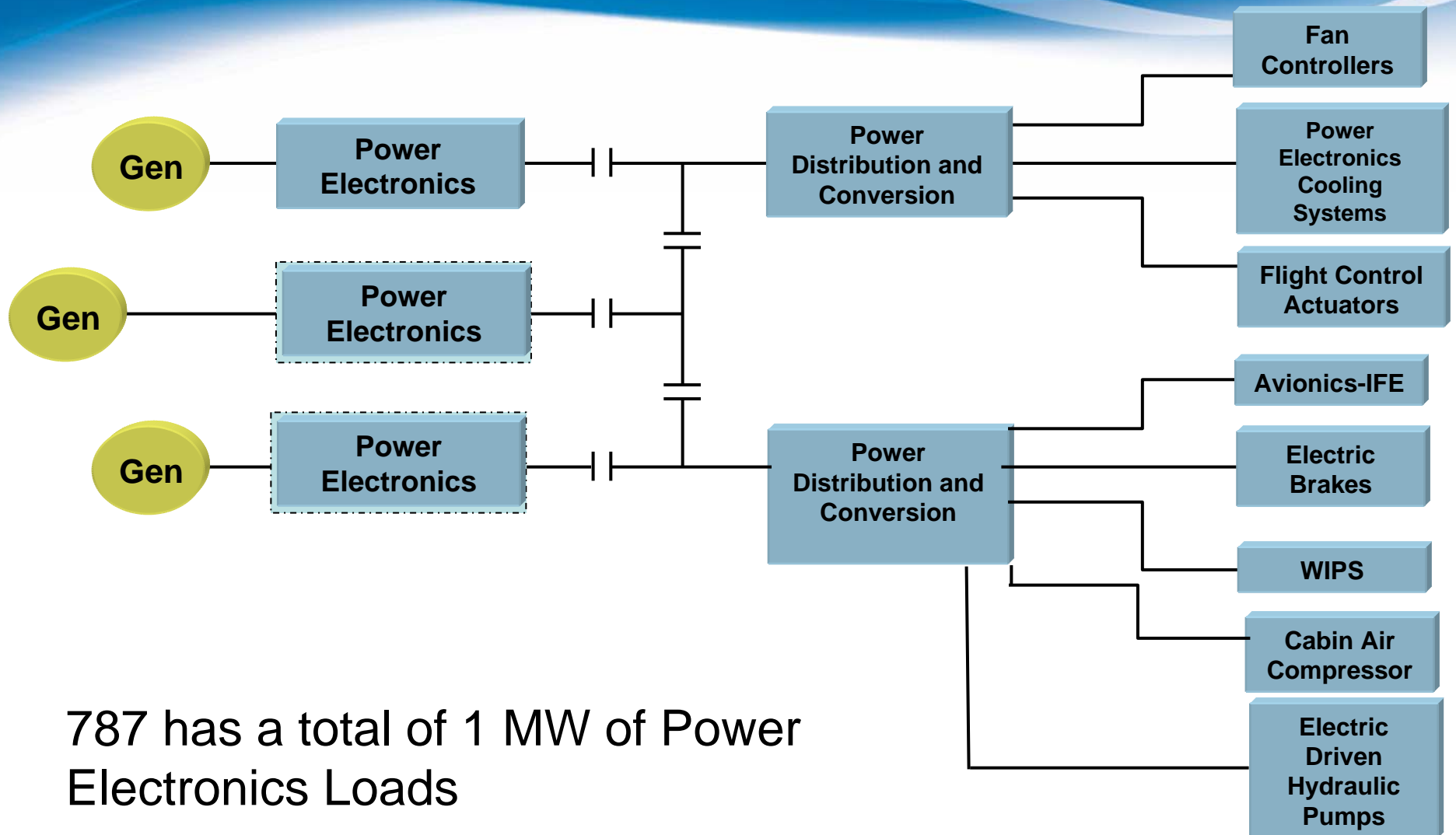
Liquid cooling of \pm
270Vdc Conversion and
Motor Controllers

Reference: Aviation Week, "Massive 787 Electrical System Pressurizes Cabin" 3/27/05

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Power Electronics is a Pervasive Technology in the MEA



MEA is Applicable to Multiple Platforms



SSBJ



Quiet GA



Honda Jet



Global Hawk



PAV



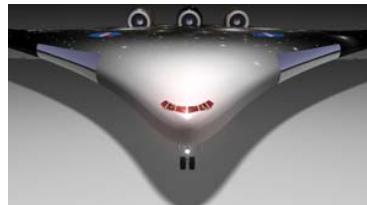
Raven



Eclipse



X-45



Future Airliner



Present Airliner



BR&TE Technology Demonstrator



General Aviation



Darkstar



J-UCAS



HALE

MEA is applicable to UAVs, Commercial and Military airplanes, supersonic and subsonic, pressurized and unpressurized, high and low altitude.

More-Electric-Airplane

Vision:

The More-Electric-Airplane has the potential to take advantage of emerging technologies in power generation and distribution, power electronics, and energy storage.

Goals

- **Improve power system efficiency**
- **Improve Weight/Volume**
- **Reduce Total Cost**
- **Enhance Safety**
- **Improve Thermal Efficiency**
- **Improve Reliability**
- **Improve Maintainability**
- **Increase Functionality**
- **Cost Effective Rapid Technological Insertion**
- **Green Systems**

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The 787 Dreamliner is cleaner, quieter and more efficient

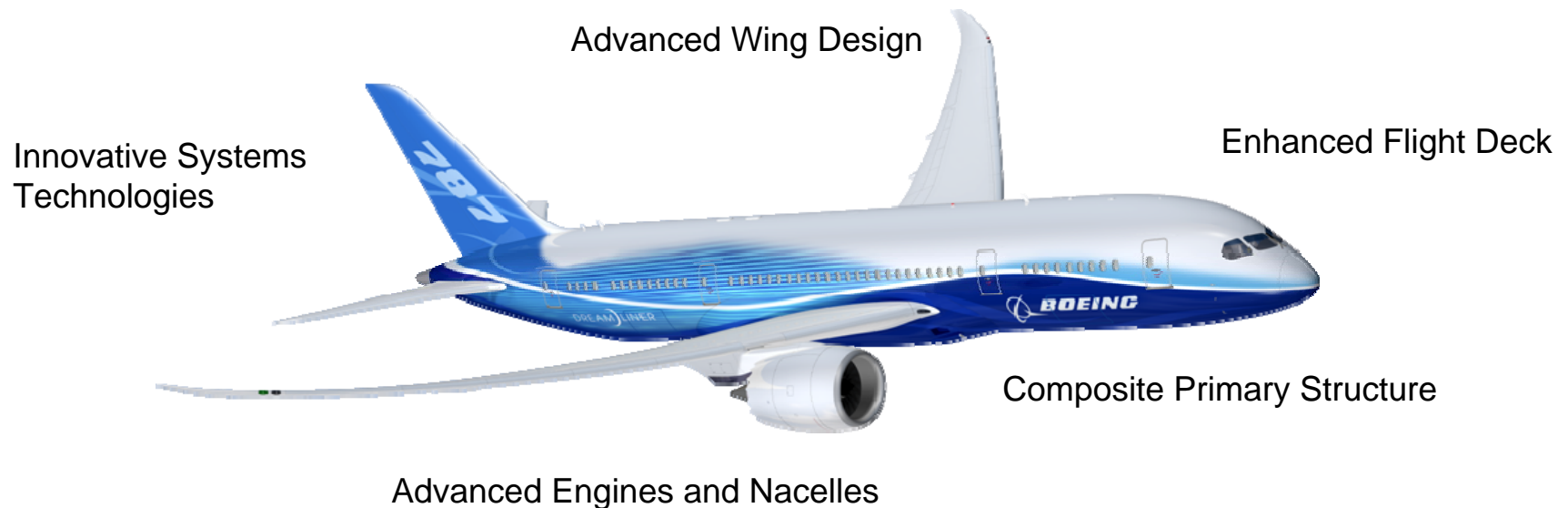
The 787 Dreamliner delivers:

*Relative to the 767

20%* reduction in fuel and CO₂

28% below 2008 industry limits for NO_x

60%* smaller noise foot print



The Challenge

How can we most effectively minimize aviation's impact on the environment – specifically CO₂ emissions?

Priority technology research for fuel efficiency, emissions and noise



Researching next generation materials

Next generation composites

Result: Reduces weight, which reduces fuel use and emissions

Researching less energy-intensive electric systems

Reducing pneumatic systems

Result: Improving electrical efficiency improves fuel efficiency



Demonstrating fuel cell technology

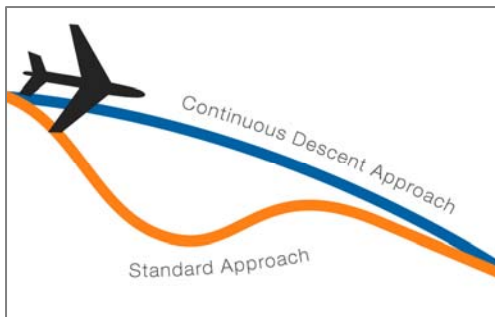
Fuel Cell Demonstrator

Result: Reduces fuel consumption, NOx and noise

Advancing more efficient operations and air traffic management

Continuous Descent Approach (CDA)

Result: Reduces noise and saves up to 500 pounds of fuel on each flight

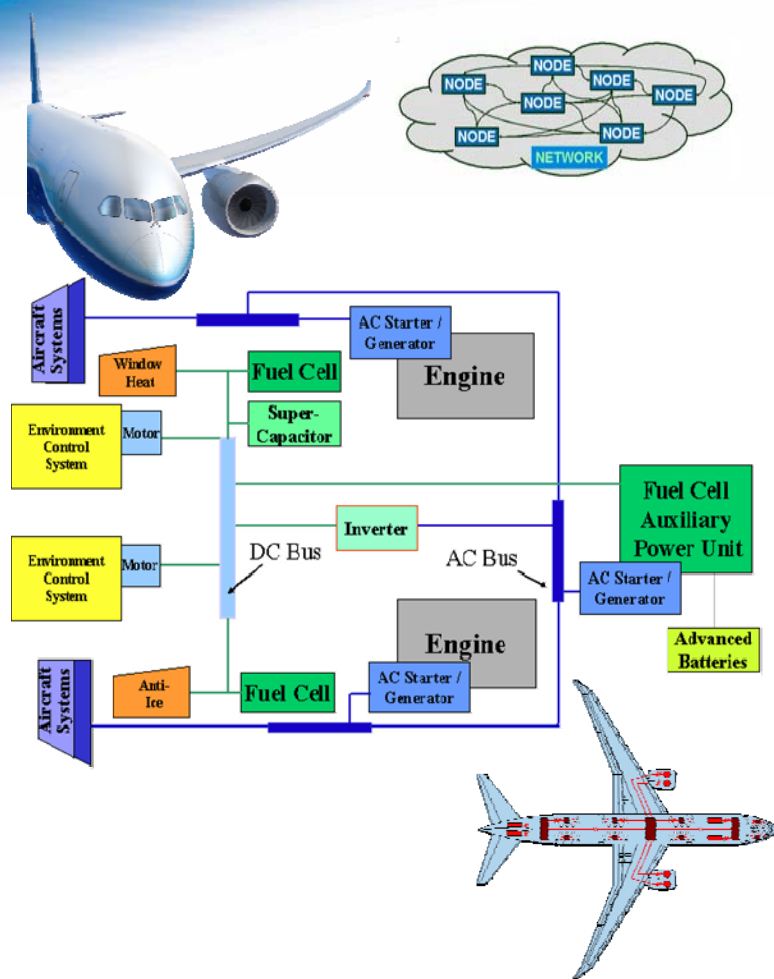


Designing aerodynamic improvements

Advanced wing design - raked wing tip

Result: Reduces drag which reduces fuel use and emissions

Fuel cells Support Grid-like Power Systems



- Power system flexibility & utility
- Graceful, graduated failure modes
- Reduced power extraction
- Lower wire weight
- Improved efficiency
- Greater dispatch availability
- Reduced Power Extraction
- Reduced Operational (Life Cycle) Cost
- Environment (less emissions and noise)

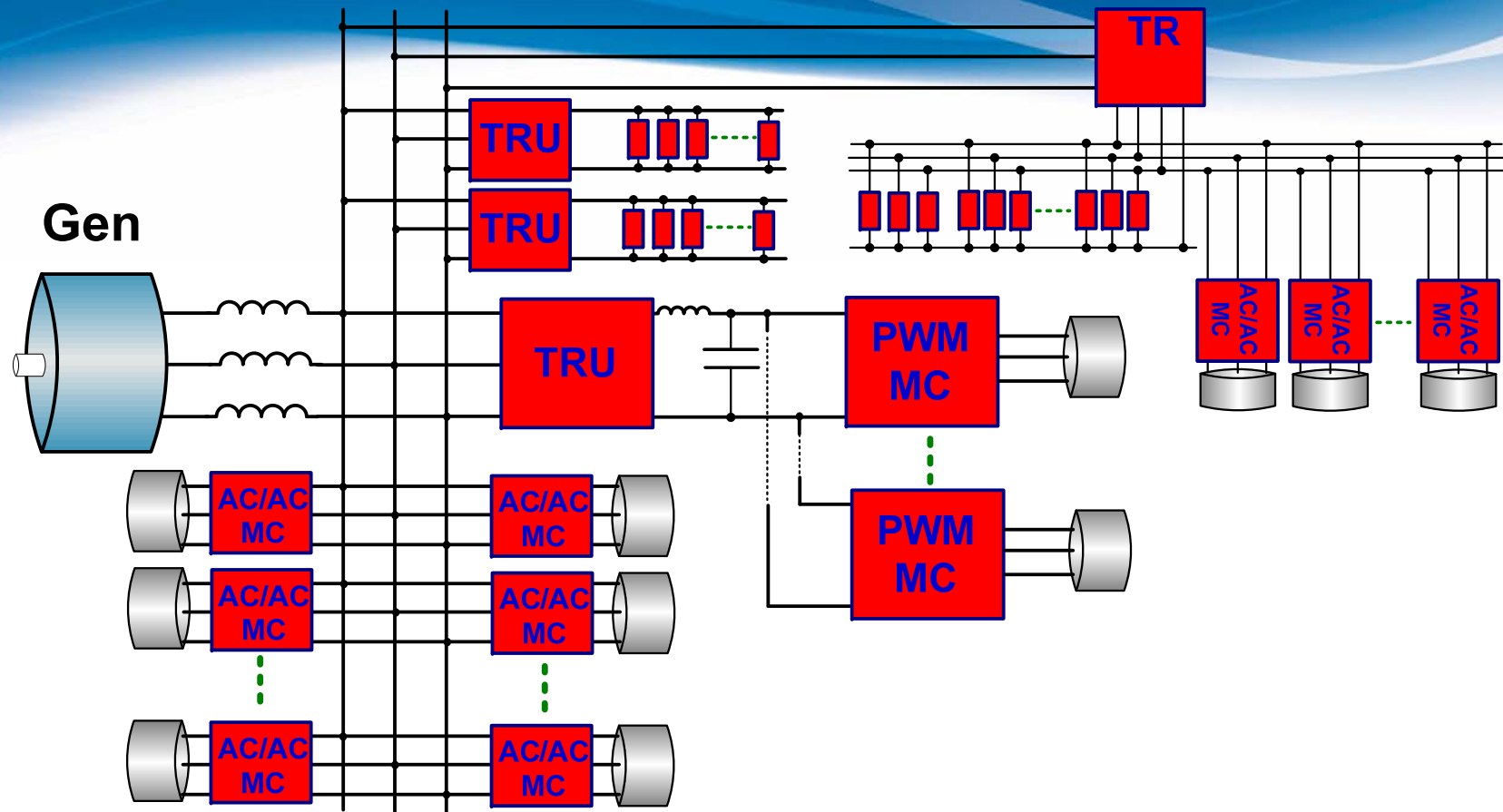
Future Aircraft Power Systems

- Advance Architectures
- Higher Voltage Systems
- High Temperature Power Electronics
- Adaptive and Intelligent power systems
- Power Electronics Integration
- Fuel Cell Integration

More-Electric-Airplane Challenges

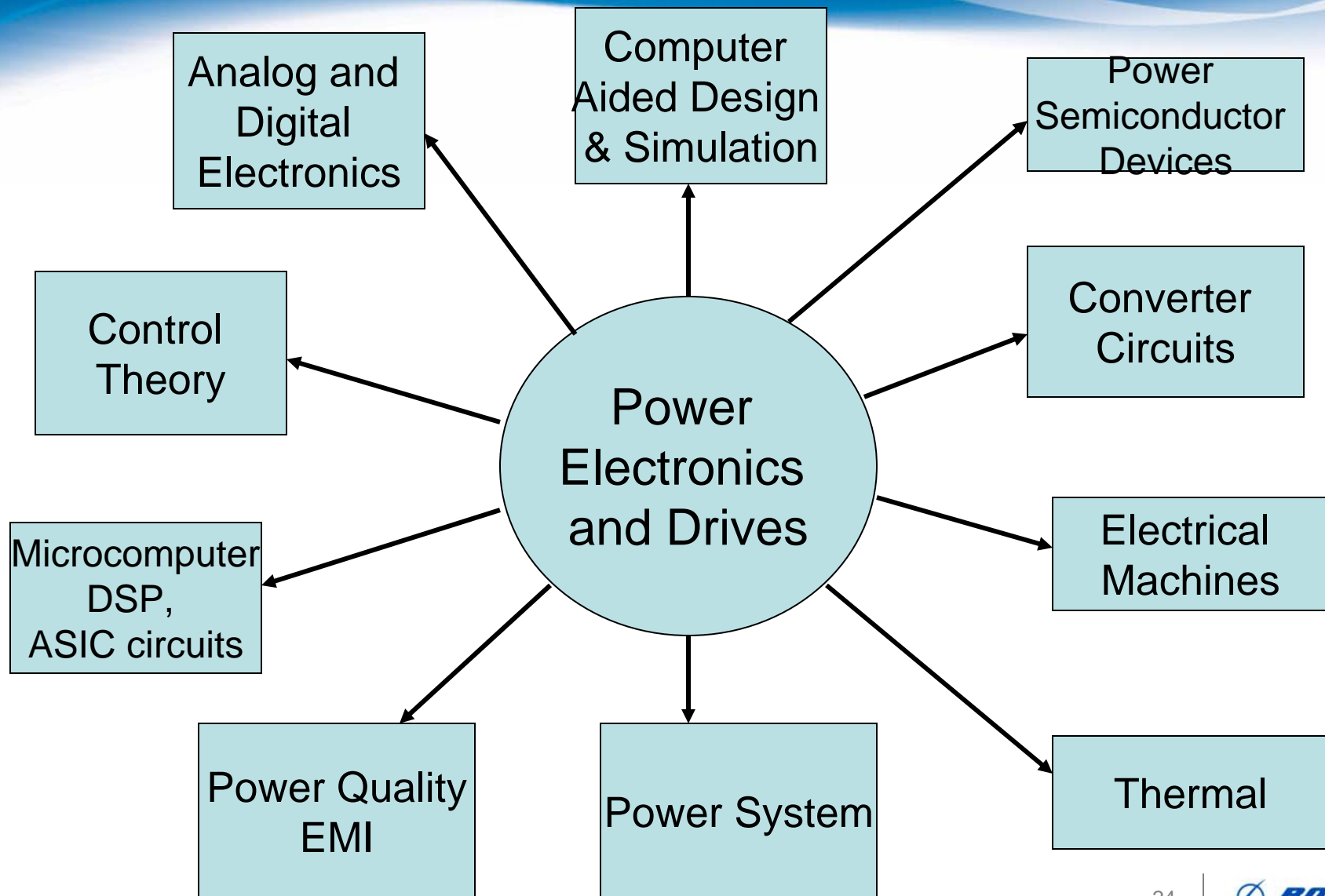
- Integration of New Power Electronics Loads
 - System Power Quality
 - All electrical loads are prone to failures when exposed to one or more electrical power quality problems.
 - Electrical equipment is only guaranteed/qualified to operate properly if its input power quality is per specification
 - Examples:
 - Interactions between power electronics loads and sources (stability and resonance)
 - Harmonic distortion
 - Start-up
 - Testing and Simulation is extensively used to develop requirements, validate requirements, and verify design

Aircraft Power System



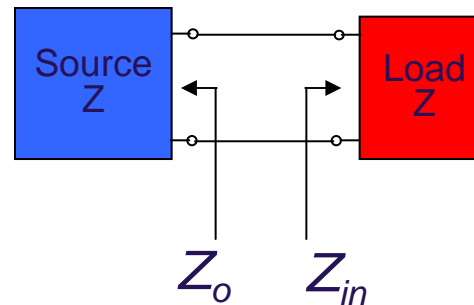
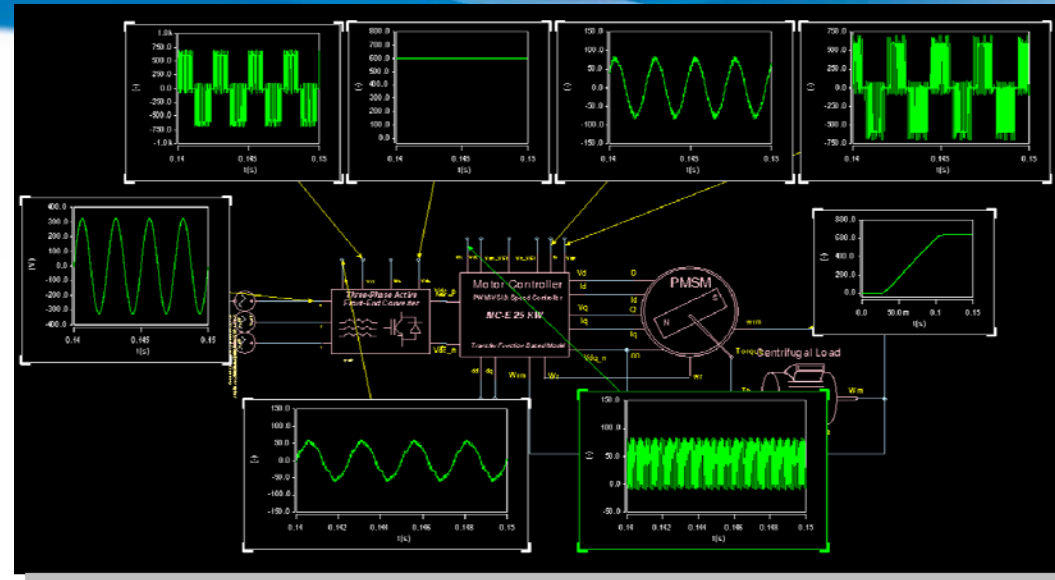
How to analyze and evaluate the power system?

Interdisciplinary Technology

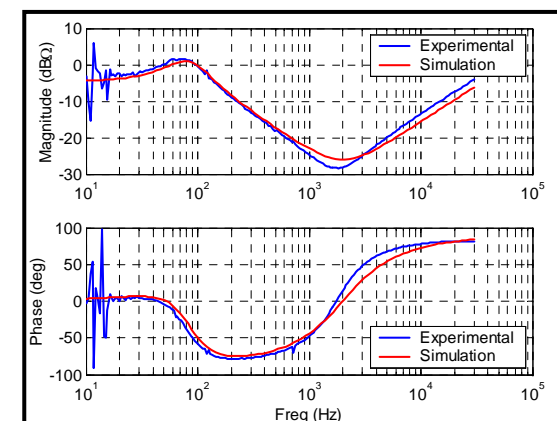


Simulation

- Power Quality
 - In-rush
 - Harmonic Distortion
 - Modulation
 - Power Factor
- System Stability
 - Linear and Non-linear
- System Protection
- Power Quality/Thermal/EMI/Lightning/



$$\frac{Z_o}{Z_{in}} \ll 1$$



Simulation

- Models are developed using Multiple Tools
- Challenges:
 - Number of components
 - Multiple Time Scales
 - Different types of analysis (stability, power quality, protection coordination, faults/failures, load management)
 - Model Validation

Conclusions

- More-Electric-Airplanes are the industry trend
- MEA is an enabler for advances in future airplane system design, operation and performance
- MEA is a technology enabler for energy generation, storage and conversion systems and technologies
- MEA contributes to lower operating costs and reduces fuel use, emissions and noise.
- Power Electronics, Intelligent Power Systems, and alternative sources play a significant role for future More-Electric-Airplanes
- There remains challenges with efficient large-scale simulation of more-electric-airplanes.