Formulation and Implementation of a Methodology for Aircraft Subsystem Architecture Selection

Turab Zaidi
2008-2009 Grand Challenge Team
Aerospace Systems Design Laboratory
Georgia Institute of Technology
Atlanta, GA, USA

In collaboration with:

EPE 2009 8 - 10 September, Barcelona, Spain
13th European Conference on Power Electronics and Applications
Outline

The Installation Problem

Architecture Selection Methodology

The Proof of Concept

Concluding Remarks
Outline

- The Installation
- Problem
- Architecture
- Selection
- Methodology
- The Proof
- of Concept
- Concluding
- Remarks

Not to be copied or reproduced without permission from the author. 3rd TEOS forum, Barcelona, 10 September 2009
Motivation

- Current efforts emphasize developing more electric technologies
  - Components optimized individually by vendors
- Majority of issues arise during system integration
  - New technologies often physically swapped in
  - Organization of Aircraft Equipment Systems (AES) affects overall subsystem efficiency
- Interactions and constraints between components must be captured
  - Information should be leveraged to develop strategic AES installation
  - No environment exists to evaluate these types of tradeoffs during conceptual design
The Focused Problem: Installation

- Full potential of new components may not be achieved in future aircraft
- Current configurations may benefit from holistic re-integration/evaluation
- Potential gains:
  - Minimizing system weight - Adding/removing cabling or hydraulic lines
  - Minimizing exergy loss - Maximum amount of available work
  - Managing energy flows - Efficiency fluctuation due to thermal effects

Investigation of new installation architectures is necessary
What is an Installation Architecture?

Architecture 1

Architecture 2

Same components
Different placement
Previous Grand Challenge teams have studied aspects of the functional architecture design process.

Lack of a modeling environment has caused a discontinuity in the design process which is needed to select an optimal architecture.
Program Objectives

1. Formulate a generic methodology that allows designers to optimally install Aircraft Equipment Systems into an aircraft
   - Methodology facilitates installation of any subsystem or component

2. Demonstrate methodology through a Proof Of Concept (POC)
   - POC makes enabling assumptions to facilitate project scope
   - POC shows how the methodology can be used to improve component placement and realize aircraft level gains

Methodology

Proof of Concept

Program Results

Not to be copied or reproduced without permission from the author. 3rd TEOS forum, Barcelona, 10 September 2009
Modeling & Simulation Environment

- M&S environment was created in Pacelab Aircraft Preliminary Design (Pacelab APD)
- Displays a 3D representation of the model
- Unique software platform focused on Knowledge Based Engineering
- Allows mathematical definition of an aircraft and its internal structure
- Acquisition of Pacelab APD was a key breakthrough for our design environment
Outline

The Installation Problem

Architecture Selection Methodology

The Proof of Concept

Concluding Remarks

Not to be copied or reproduced without permission from the author. 3rd TEOS forum, Barcelona, 10 September 2009
The Architecture Selection Methodology

Step 1: Component Library Creation

Step 2: Sizing/Synthesis & Aircraft Zoning

Step 3: Component Placement Requirements Flow-down

Step 4: Initial Architecture Generation

Step 5: Measures of Merit Identification

Step 6: Investigate Competing Architectures
Step 1 – Component Library Creation

Methodology

- Method of library creation leveraged from previous Grand Challenge Teams
- 1.1 Select a primary function
- 1.2 Identify induced functions
- 1.3 Create matrix of alternatives of components
- 1.4 Define basic connections between components
- 1.5 Verify specific functions are met

Primary Function
Generate light

Component List

Induced Functions
Provide electricity or ignite light source

Component List

Output of Step 1
A fixed list of components and basic connections to be installed

Proof-of-Concept

- Only one primary function was demonstrated to limit the scope
  - Deliver electrical power to loads in the avionics bay
- Function further limits the scope by reducing the number of components modeled
- The component list was created from the Maintenance Facility Planning (MFP) document and information from Airbus component suppliers
- Schematics in the MFP were used to define basic connections
Step 2 – Sizing/Synthesis & Aircraft Zoning

Methodology

2.1 Select an aircraft geometry

2.2 Acquire sizing and synthesis information

2.3 Zone the aircraft
   - Assists with capturing component placement constraints

2.4 Specify possible connection routes

Output of Step 2

A fully defined and zoned aircraft geometry

Proof-of-Concept

- A320 chosen as the aircraft geometry for POC
- Flight deck, passenger cabin, & cargo holds modeled in simulation environment
- Feasible aircraft areas divided into five zones
  - Zones based on possible locations for components in library
  - Includes knowledge gained from Delta 737 overhaul
- Feasible wiring route pathways generated for potential component connections
Step 3 – Placement Requirements Flow-down

Methodology

3.1 Find applicable system level constraints
   - FAA Federal Aviation Regulations (FAR)
   - Stability Limits
   - Volume Limits
   - Ease of maintenance

3.2 Define applicable component level requirements
   - Temperature ranges, Electrical power and ratings, EMI control, System grounding, etc.²

3.3 Formulate zonal placement requirements

Output of Step 3

Constraints and requirements on component placement

Proof-of-Concept

Operating Temperature

Required Power

Center of Gravity

Volume

Zones

Wire Routes

Fire Zone

Cabin/ Cargo Compartments

General Wire Paths
Step 4 – Initial Architecture Generation

Methodology

4.1 Select location of components within feasible zones
   - Use historical data when available

4.2 Verify all requirements are met
   - Change component location when needed

Proof-of-Concept

- Initial configuration used for comparison to all other architectures
- Initial placements and connections determined from Airbus documentation
- Initial architecture input into Pacelab APD using Excel file

Output of Step 4

Baseline aircraft with components placed to meet requirements
Step 5 – Measures of Merit Identification

**Methodology**

5.1 Identify relevant system level metrics
   - Metrics should be related to costs and benefits

5.2 Relate system level metrics to applicable installation metrics
   - Metrics have to be quantifiable

5.3 Benchmark the initial architecture

**Output of Step 5**

Metrics for comparison of different architectures

**Proof-of-Concept**

**Method of Calculation**

- Wire Weight
- Power Extraction from engines
- Locations of Components

**Related System Level Metric**

- Payload Capacity
- Fuel Weight
- Fuel Cost
- C.G.
- Stability

**POC Evaluator**

- $/RPM
Step 6 – Investigating Competing Architectures

Methodology

6.1 Choose method to explore design space

6.2 Implement exploration method
   - Requires development of modeling and simulation environment

6.3 Perform architecture trades
   - Based on weighting preferences on measures of merit

Output of Step 6

An optimized architecture based on customer preferences

Proof-of-Concept

- Many methods to identify competing architectures
  - Optimization methods
  - Design Space Exploration methods
- Selected a Monte Carlo simulation combined with data post-processing
- Investigation consists of three phases:
  - Pre-processing: Generating architectures
  - Processing: Running the modeling and simulation environment
  - Post-Processing: Analysis of the saved measures of merit
Pacelab APD Front-End
Pacelab APD Avionics Bay
Pacelab APD Results

[Image of a software interface showing a grid of scatter plots and tables with data.]

Not to be copied or reproduced without permission from the author. 3rd TEOS forum, Barcelona, 10 September 2009
Conclusions

- POC tool applies generic methodology to focused problem
  - Provides capability to dynamically and visually trade architectures
  - ‘Best’ design demonstrates fuel savings and increase in payload capacity for small fraction of the AES

- POC enables not only study of fixed aircraft and components:
  - Ability to create architectures with entirely new and varying component lists
  - New technologies can be input and explored early in design
  - With appropriate information and knowledge base, entire AES can be studied

This study serves as a stepping stone for future integration of Energy Optimized Aircraft
Future Work

- Modeling of more components and systems to realize a more complete perspective of the installation design space
  - Replacing hydraulic and pneumatic systems

- Incorporate Pacelab APD’s sizing and synthesis
  - If aircraft could be scaled geometrically as in sizing and synthesis, benefits would be magnified

- Requirements added to include different flight modes and failure modes

- Expand knowledge base with more accurate industry information
  - Requirements and experience utilized for installation must be captured as rules and input
  - More comprehensive set of evaluators can be considered
Acknowledgements

2008-2009 EOASys Grand Challenge Team

- Neal Patel
- Turab Zaidi
- José Bernardo
- Peng Chen
- David Jackson
- Sehwan Oh
- Edward Tsai

ASDL
- Dr. Dimitri Mavris
- Dr. Elena Garcia
- Dr. Neil Weston
- Michael Armstrong
- Latessa Bortner
- Bjorn Cole
- Cyril de Tenorio
- Andrew Dunbeck
- Kelly Griendling
- Eric Hendricks
- Hernando Jimenez
- Leon Phan

Delta Airlines
- Livia Carneiro
- Brian Duff
- Charles Harkey

PACE
- Mathias Emeneth
- Glenn Reis
- Alexander Schneegans

Not to be copied or reproduced without permission from the author. 3rd TEOS forum, Barcelona, 10 September 2009
Questions?