Agile Wing Integration (AWI)

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| **Title** | Agile Wing Integration (AWI) |
| **Current Version** | V 0.1 |
| **Owner** | University of Bristol (UoB) & Airbus Future Project Office (FPO) |
| **Created On** | 07/2018 |
| **Created By** | Mr Christopher Szczyglowski (UoB)  Dr Dario Calderon (UoB)  Dr Robert Cook (UoB)  Dr Christopher Howcroft (UoB)  Mr Philip Rottier (Mathworks Consulting Services) |
| **Administrator[[1]](#footnote-1)** | Mr Christopher Szczyglowski [christopher.szczyglowski@bristol.ac.uk](mailto:christopher.szczyglowski@bristol.ac.uk) |
| **Software Compatibility** | Windows Operating System  MATLAB version 2015b or later |
| **Files** | <insert link to iShare here> |

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# Release Statement (Version 0.1)

This software is in the pre-alpha development stage meaning that perfect performance is not guaranteed. It is highly likely that there are many bugs remaining in the code and it is probable that the framework may not be compatible with all MATLAB versions and Airbus FAME models. In the event of an unexplained error the user is requested to inform the developers of the framework, providing sufficient detail (barring commercially sensitive information) such that the error can be replicated and solved. The main AWI developer and point of contact for all AWI-related software issues is Mr Christopher Szczyglowski.

# Introduction

Agile Wing Integration (AWI) is an interactive environment for nonlinear aeroelastic analysis and preliminary sizing of conventional and unconventional aircraft configurations. The software is written entirely in object-orientated MATLAB code and requires a valid installation of MATLAB (version 2015b or later) to be executed.

The framework comprises of several modules which are broadly split into three functional areas:

* **Importing Data** – The AWI framework supports the import of data from various file types. Information about the model and/or results data can be provided in Excel format (.xlsx), Comma-Separated-Variable (.csv), Extensible Markup Language (.xml) as well as MATLAB’s proprietary file format (.mat). AWI also supports the import of Airbus aircraft models and aeroelastic/sizing data from a FAME file (.fm4) as well as models designed using the CPACS parameterisation scheme. Further information on the data import process can be found in Section...
* **Analysing Models** – The AWI framework supports various types of aeroelastic analysis, including:
  + **Static Aeroelastic Trim –** Including automatic calculation of the optimum control surface deflection for a given trim case.
  + **Dynamic Aeroelasticity** – Including ‘1-minus cosine’ and continuous turbulence analysis.
  + **Aeroelastic Stability Analysis** – Including classical flutter analysis and nonlinear continuation analysis.
  + **Additional Analyses** – Further analysis types are available within AWI, including the calculation of mass and inertia properties, automated generation of finite element models and …
* **Visualising and Exporting Data** – The AWI framework can also be used as a means of viewing and/or exporting results and model data. Various methods are available for viewing results quantities, including: line plots, quiver plots, deformations and animations. Furthermore, the data in an AWI session can be exported to several formats:
  + **Comma-Separated-Variable (.csv)** – Returns a table of results for a specified quantity. Results are grouped by results set and one file is generated per results quantity.
  + **Excel (.xlsx) –** Returns an Excel workbook for a specified quantity. Results are grouped by results and quantity type and one workbook is generated per quantity type.
  + **AWI Session File (.awi)** – Returns a persistent data model of an AWI session, allowing the user to continue their work and move a session between machines.
  + **AWI Results File (.awi\_r)** – Returns the AWI results objects in a thinly masked MATLAB (.mat) file. These results can then be passed into the AWI framework for further post-processing and viewing.

AWI has been developed as a research tool by staff from the Aerospace Engineering Department at the University of Bristol (UK) in collaboration with Mr Philip Rottier of MathWorks Consulting Services. There are two intended user groups for the AWI framework:

* **University researchers** – This group are predominantly interested in…
* **Aerospace engineers** -

# Getting Started

# Importing Data

# Analysing Models

# Viewing Results

# Exporting Data

# Method Description

# Code Description

# Quick Start Guide (Airbus)

This guide is intended as a brief introduction to the AWI framework. This guide will explain how to:

* Obtain the AWI framework files
* Start the AWI framework
* Import a FAME aircraft model into the AWI framework
* Make changes to the model
* Run an aeroelastic analysis
* View results
* Export results

This document is a step-by-step guide of how to interact AWI via the GUI. It will not discuss how to run AWI programmatically although this is arguably the more powerful use of the framework.

There are two guides in this document:

1. A written guide that provides the bare minimum of detail and should be used as a prompt for users who are familiar with AWI.
2. An annotated guide that uses screenshots to explain each step of the process. User’s who are unfamiliar with AWI should use this guide to help them get started.

Some assumptions are made about the user and the machine that they are working on. These assumptions are:

* The user is an employee of Airbus and has a working knowledge of the FAME-W analysis tool
* The user’s machine is running on a Windows operating system
* The user has already downloaded and installed a valid installation of MATLAB which is version 2015b or later.
* The user understands how to open MATLAB and run a file.

## Accessing the AWI files

The source files for AWI are stored on the Airbus iShare portal. Mr Sylvain Boye[[2]](#footnote-2) is the owner of the iShare and should be contacted if access is required. The files are stored at <INSERT FOLDER PATH HERE> Simply download the .zip and extract the files to a folder location of your choice.

At this point it is important that the user understands that the copy of the AWI framework that is held by Airbus is not version controlled. This has two main implications:

1. If any changes are made to the source files on the user’s machine they will be localised to the user’s machine, i.e. changes will not be propagated back to the iShare. The Airbus iShare is not a version-control system and the code available on the iShare is to be considered constant between any updates from the developers at the University of Bristol.
2. Any changes that the user makes to the source files will cause a divergence in the codebase away from the version-controlled (original) code held by the University of Bristol. Therefore, it is not recommended that the user make any changes to the AWI source code as this will cause the software to become unreliable and will make debugging any issues very difficult. In future releases the source code may be obfuscated (p-coded) and released as a MATLAB package to protect the integrity of the AWI framework.

## Written Step-by-Step Guide

1. **Start MATLAB**
   1. Launch MATLAB via the Windows start-menu or using a desktop shortcut.
2. **Navigate to the AWI file location**
   1. Use the folder browser on the left-hand side of the MATLAB window to navigate to the folder where the AWI files are located.
3. **Start AWI** 
   1. Type “AWI” in the MATLAB Command Window and press “Enter” to start AWI.
4. **Import a FAME model** 
   1. Using the menu-strip at the top of the GUI select File>Import. (N.B. Previously imported models can be imported using File>Reimport)
   2. Using the file selection window, navigate to the location of the FAME model that you wish to import, select the .fm4 file and click “Open”. (N.B. Make sure the file specification is set to “FAME Input files (\*.fm4)” using the drop-down menu above the “Open” button)
   3. If the import is successfully initialised a progress window will open which provides details of the actions being performed. These messages can be reviewed later by viewing the AWI ‘Audit Trail’. This can be done by selecting Audit trail>Show in the menu strip at the top of the GUI.
   4. Once the import process is complete the progress window will close, and a drawing of the model will be shown in the GUI. At this point, the user is free to view different aspects of the model, interrogate the model properties and make any necessary changes. Further details are provided in the Annotated Step-by-Step Guide.
5. **Make changes to the model**
   1. Changes to the model are made using the “Property View” which is accessible in two ways:
      1. Through the object context menu
         * Using the ‘Tree View’ on the left-hand side of the AWI GUI, select the object you wish to edit, right-click to bring up the context menu and then navigate to Edit>Properties>This.
         * This version of the Property View is not dynamic, therefore the user is required to select “Apply” to propagate changes to the model which will then trigger a rebuild.
      2. Through the GUI context menu
         * Right-click on any of the top-level tabs in the GUI and select Add View>Properties.
         * This version of the Property View is dynamic, meaning that any changes are automatically propagated to the model which is then rebuilt in real-time.
   2. The user should exercise caution when making changes as it is possible to drastically modify the model and cause a disparity between the geometry and the underlying structural properties of the model which has serious implications for the aeroelastic analysis and aircraft sizing modules.
6. **Run an aeroelastic analysis**
   1. To run an aeroelastic analysis the AWI session must contain a valid aircraft model and at least one valid load case. Furthermore, when analysing FAME models, the user must have imported the FAME results data containing the aircraft mass and stiffness distribution.
   2. **Running an aeroelastic trim analysis**
      1. To initiate an aeroelastic trim analysis select Analyse>Aeroelastic>Trim using the menu strip at the top of the GUI.
      2. Selecting this option will automatically open a new view in the GUI called “TrimAnalysis”.
      3. Using the drop-down menu on the right-hand side of the new view, select the load case and beam model for analysis by the trim solver.[[3]](#footnote-3)
         * N.B. The user is automatically given the option of all available “manoeuvre” load cases in the AWI session. If, for some reason, there are no load cases of type “manoeuvre” then the user will be unable to run a trim analysis.
      4. Select “Trim…” to run the trim solver. N.B. By default the trim solver will use the aircraft pitch angle and the elevator to balance the aircraft weight and pitching moment.
      5. Whilst the trim solver is running the user can monitor the progress of the solution and view the state of the model, including: the residual norm, the aircraft deflections and the control surface deflections.
      6. Once the trim solver has achieved convergence the TrimAnalysis view will be populated by some preliminary results and a new result set will be added to the AWI session. This can be viewed in the tree view by expanding the “Results Sets” node and looking under the relevant beam model.
   3. **Running a 1-minus cosine gust analysis**
      1. To initiate a 1-minus cosine analysis select Analyse>Aeroelastic>Gust using the menu strip at the top of the GUI.
      2. Selecting this option will automatically open a new view in the GUI called “GustAnalysis”.
      3. Using the drop-down menu on the right-hand side of the new view, select the load case, beam model and the trim result for analysis by the gust solver.
         * N.B. The user is automatically given the option of all available “one-minus-cosine” load cases in the AWI session. If, for some reason, there are no load cases of type “one-minus-cosine” then the user will be unable to run a gust analysis.
         * A trim result is required to allow the gust solver to start the model from its deformed/trimmed shape. This represents an important difference from traditional linear tools as the for the case where nonlinearities are included the gust response is dependent on the initial conditions of the system, i.e. the initial trimmed shape.
         * The trim condition will be calculated automatically if no trim result is present that matches the specified flight-point.
         * If there are no “one-minus-cosine” load cases in the AWI session the user can create their own. For further details see the Annotated Step-by-Step Guide.
      4. Select “Analyse…” to run the gust solver.
      5. Once the gust solver has finished the *GustAnalysis* view will be populated by some preliminary results and a new result set will be added to the AWI session. This can be viewed in the tree view by expanding the “Results Sets” node and looking under the relevant beam model.
         * As the gust analysis is a *transient* analysis there is a significant amount of data that is generated. These results are split into two categories:
           1. **Static Results** – For every gust length considered, the maximum and minimum loads with respect to time are calculated for every spanwise position along each beam in the analysis model. These results are added to the “Static Results” collector in the tree view.
           2. **Transient Results** – For every gust length considered, the raw time domain data is retained and added to the “Transient Results” collector in the tree view.
7. **View Results**
   1. **Add a “Statics Results” view –** In order to view the results, the appropriate view must be added to the GUI. Right click on any of the top-level GUI tab pages to bring up the AWI View Manager context menu and select Add View>Beam Results Viewer.
      1. **N.B.** The ‘Static Results View’ shows results data which is independent of time. These results are either associated with manoeuvre load cases or are the maximum and minimum envelope loads from a gust analysis. The results viewer allows the user to view the distribution of a results quantity over the span of a beam, however, it will not show the user any time history data.
   2. **Select the results –** Using the list-menus in the right-hand pane, the user can select the following quantities to plot:
      1. **Results Sets (Multi-Select)–** A results set represents the output from a single analysis. The Beam Results Viewer allows quantities from multiple results sets to be viewed at once.
      2. **Beam Elements (Single-Select) –** After selecting a result set the user is offered a selection of all the common beam elements for which a results quantity has been defined. When considering results from a FAME model this will typically be just the starboard wing, however, if the user runs an aeroelastic analysis using the AWI framework then there will be results for other ‘beams’ in the model such as the VTP, HTP, etc.
      3. **Results Types (Single-Select) –** After selecting a result set and a beam element to view the results over, the user will be offered a choice of all results types in the chosen result set. A results type defines a group of results and is dependent on what type of result set has been selected. For instance, an aeroelastic result set will have various aerodynamic and structural results quantities defined, however a sizing result will contain information about the box thicknesses etc.
      4. **Results Quantities (Multi-Select)** – After selecting the results type the user will be offered a selection of all results quantities in this results type. The user can select any number of results quantities for viewing, however, the appropriate number of axes must be requested using the edit box titled “No. of axes”.
   3. **Customise the display –** The “Static Results View” allows a high degree of customisation for each of the plots. Right-clicking on an axes will open up a context menu which allows additional quantities to be plotted on the left or right y-axis which can then be cleared by selecting the option “Clear additional data”.
   4. **Calculate the loads envelope –** When displaying results of type “Internal Loads” it is possible to view the loads envelope of all the selected results sets. Simply click the push button “Show Loads Envelope” and a colour-coded loads envelope will be plotted for each axis in the view.
8. **Export Results**
   1. **Add a “Static Results” view –** An instance of the “Static Results View” is required to initiate the export process.
   2. **Select “Export Results…” –** Click the “Export Results…” push button to open up the “AWI Export Manager”.
   3. **Configure export specification –** The following options must be set before the results can be exported:
      1. **Results Selection (Multi-Select) -** The export manager will honour the current selection of results sets, however, this is easily changed by the user if a different selection is required. Simply highlight the results in the list-box or click “Select All” to select all results sets.
      2. **Beam Elements (Multi-Select) –** The user must select the beams over which the results data is defined.
      3. **Results Types (Multi-Select) –** The user must select the results types to be exported. Every results quantity from the selected results types will be exported.
      4. **Export Directory –** The use must select a folder location for the results to be saved to. The full directory path can be pasted into the edit box or the user can click the ‘open’ button to select a directory using the Windows Explorer.
      5. **Export File Format –** The user must select the format for exporting the results. The number of files that are generated is dictated by this option.
         * **CSV (.csv) -** This option is much quicker but generates more files. One file is generated per results quantity (for each beam) and each file contains the data for that results quantity across all selected results sets.
         * **Excel (.xlsx)** – This option is slower and generates fewer files. One file is generated per results type and each results quantity is defined on a separate (named) sheet in the excel workbook.
           1. The slower speed is attributed to using MATLAB’s inbuilt *‘xlswrite’* function as opposed to a vectorised call to *‘fprintf’* which is what the csv-exporter uses.
         * **N.B.** - The output files are automatically named based on the beam name and results type/quantity. If a file of the same name (and file extension) already exists in the export directory, then the new results will be appended to that file.
   4. **Export the data –** Hit “Export” to initiate the export process. A progress dialogue box will open during the export process and will close once the last file has been written.

## Annotated Step-by-Step Guide

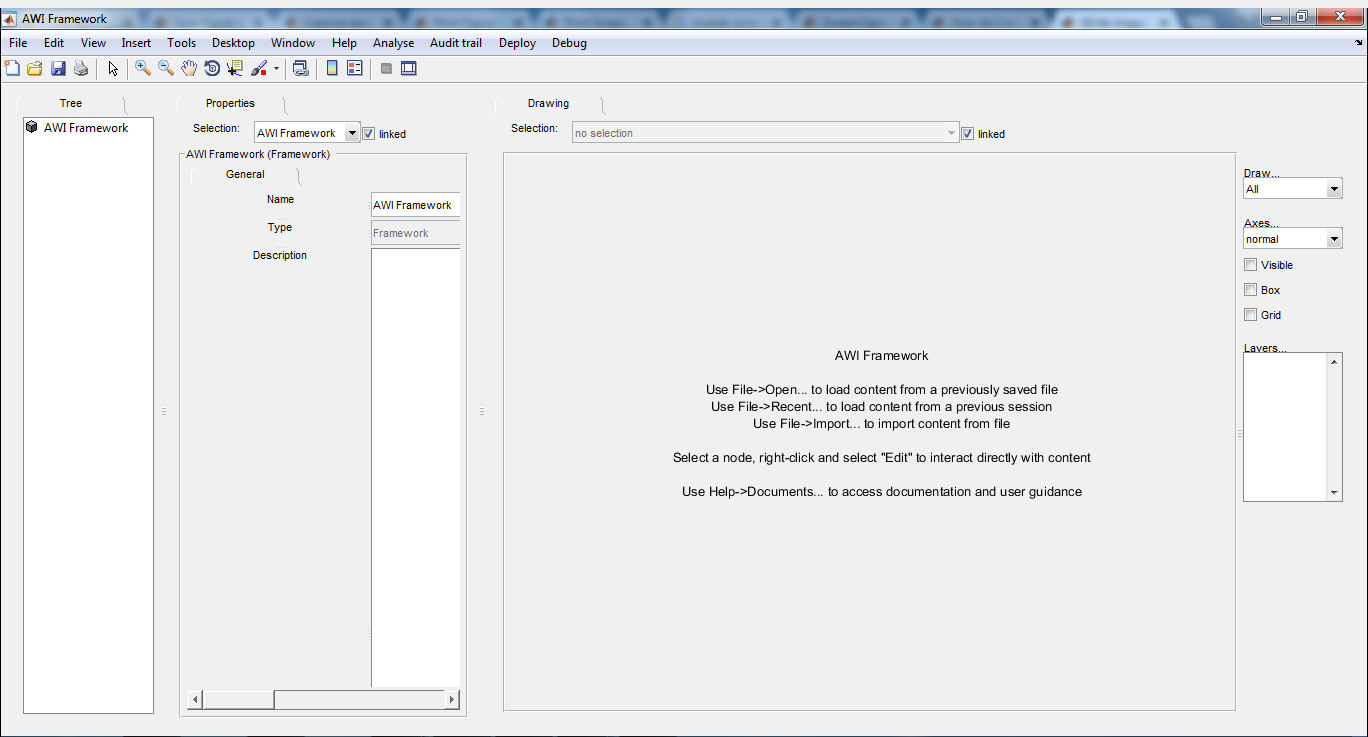
### Navigate to the AWI files and start AWI

### The AWI GUI

**Menu Strip** – Context menus for interacting with the GUI and with the wider MATLAB environment.

This is the AWI opening screen.

**Icon Strip** – Shortcuts for creating a new session, selecting elements of the GUI and interacting with MATLAB figures.

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**Drawing View** – Displays the model and allows the user to toggle ‘layers’ of the model as visible or invisible.

**Property View** – Shows the ‘observable’ properties of a given object. These are properties that can be dynamically changed by the user.

**Tree View** – Displays the contents of the AWI session in a hierarchical fashion.

### Import a FAME model

Using the menu strip, select File>Import to launch the file browser window. Navigate the FAME model that you wish to import and select the .fm4 file.

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Select the .fm4 file and click “Open” to launch the import process. **Make sure the file specification is set to “FAME Input Files (\*.fm4)”**

Note the folder structure of the FAME files…

Use File>Import to launch the file browser.

# Quick Start Guide (University of Bristol)

1. Change this to an Airbus employee or one of the academic staff at UoB for continuity [↑](#footnote-ref-1)
2. Sylvain Boye is a member of Airbus FPO, Filton, UK. Contactable at [sylvain.boye@airbus.com](mailto:sylvain.boye@airbus.com) [↑](#footnote-ref-2)
3. A beam model defines the various mass and stiffness properties of the aircraft. Multiple beam models may be present in the AWI session if the user has run a sizing analysis or has imported multiple FAME models. [↑](#footnote-ref-3)