INTEGRATION OF MSC.FLIGHTLOADS AND DYNAMICS AT LOCKHEED MARTIN AERONAUTICS COMPANY*

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Abstract

MSC.Flight Loads and Dynamics (MSC.FLD) is becoming an integral part of the flight loads analysis process at Lockheed Martin Aeronautics Company (LM Aero). The MSC.Nastran Toolkit Application Programming Interface (API) is being used to integrate the core strengths of MSC.FLD and the LM Aero flight loads analysis processes and tools. This paper discusses the implementation of these technologies.

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Introduction

External loads development is an essential building block in aircraft structural design and analysis. The design external loads package is a cornerstone that supports many design and analysis tasks. Stress analysts and designers need “design-to” loads to establish structural arrangement and sizing of structural members (e.g. skin thickness, substructure requirements, fittings for concentrated loads, fastener sizing and spacing, actuator sizing, etc.). The significance of timely, accurate external loads cannot be overstressed. Missed critical design load cases can result in structural damage or failure and often necessitate extensive reanalysis and associated operational flight limitations or costly structural redesigns. Alternatively, development and introduction of high-fidelity external loads early in the design process can improve the design, shorten design cycle time and reduce operational life-cycle costs.

Lockheed Martin Aeronautics Company (LM Aero) understands the crucial role that external loads analysis plays in an aircraft program. External loads analysis is a multidisciplinary activity that requires knowledge and integration of aerodynamics, structural analysis, mass properties, aeroelasticity, and flight dynamics (Figure 1). LM Aero has a long history of developing and using in-house external loads analysis processes and tools to integrate these diverse analysis tasks. In recent years, LM Aero has been transitioning to an increased reliance on commercial off-the-shelf (COTS) software for structural analysis. However, continued development and maintenance of in-house external loads analysis software tools is often a necessity since no commercial software exists to do the entire job.

![Figure 1 – External Loads Analysis is a Multidisciplinary Activity](image)

The MSC.Software Corporation (MSC) has recognized the need for commercial external loads analysis software. In response to customer requests, MSC has developed an integrated, process-driven external loads and dynamics system called MSC.FlightLoads and Dynamics (MSC.FLD). MSC.FLD was developed to enhance the aeroelastic and design capabilities included as part of MSC.Nastran and MSC.Patran. MSC.FLD is an integrated flight loads development tool consisting of MSC.Nastran and MSC.Patran; MSC.Nastran serves as the computational engine, while MSC.Patran provides the graphical user interface.

MSC.FLD addresses many common requirements for flight loads analysis software across the aerospace industry. MSC continues to enhance MSC.FLD to expand its functionality. However, a commercial tool typically cannot adequately address all the unique requirements, processes and procedures at each
individual company. Some level of integration must occur at each company to utilize the software to achieve the required functionality.

LM Aero saw the potential of using MSC.FLD as a central part of the LM Aero flight loads analysis process, but had concerns about duplicating all the functionality of the existing legacy toolset. In particular, LM Aero recognized the MSC.FLD strength of aeroelastic model development and data generation, but also required certain unique capabilities of the LM Aero in-house processes and tools that use the aeroelastic data. The solution was for LM Aero and MSC to work together to identify and integrate the core strengths of MSC.FLD and the LM Aero flight loads analysis processes and tools.

LM Aero and MSC evaluated the capabilities of the MSC.FLD product and the LM Aero flight loads analysis process to determine the level of integration required. This evaluation resulted in recommended actions to be performed by both MSC and LM Aero to allow MSC.FLD to be a central part of the LM Aero flight loads analysis process. Some of these actions required enhancements to the MSC.FLD product suite at a level below that accessible to the customer. These enhancements were performed by MSC and are contained in new releases of the commercial product. Other actions involved high level tailoring of the MSC.FLD product suite by both MSC and LM Aero to allow integration of LM Aero specific functionality.

The recent availability of the MSC.Nastran Toolkit Application Programming Interface (API) provided a unique capability to integrate functionality of MSC.Nastran into the existing LM Aero flight loads analysis process. The integration effort involved using the MSC.Nastran Toolkit API to modify LM Aero in-house flight loads analysis tools to directly access and alter data produced by MSC.FLD. The premise of this approach is to develop the aeroelastic model and data using MSC.FLD and then reuse that data in the modified LM Aero in-house flight loads analysis tools.

**Background**

External loads include all external forces acting on the structure. Figure 2 illustrates some of these loads. The term “external loads” can be confusing because external loads also include internally applied inertia loads, power plant loads and internal pressurization loads in addition to externally applied aerodynamic and ground loads. However, the “external” designation serves to distinguish these loads from the “internal” loads within the structure that are derived from external loads and used for stress analysis.

![Figure 2 – External Loads Come From Many Sources](image-url)
**LM Aero External Loads Development Process**

The LM Aero external loads development process is centered on the creation of a set of elastically corrected aerodynamic loads, structural loads (e.g., inertia loads and ground loads) and miscellaneous loads (e.g., store loads and thrust loads) that can be linear or nonlinear functions of vehicle parameters. These loads are used in quasi-static maneuver trim solutions to generate balanced aircraft loads for arbitrary maneuver response conditions. The outputs of the quasi-static maneuver trim solutions are then used to establish a set of critical “design-to” loads that comprise the strength requirement for the vehicle.

The collection of loads, or loads database, are assembled from a variety of sources including aerodynamic analyses using Doublet-Lattice method (DLM), other linear methods, nonlinear aerodynamics (Euler/Navier-Stokes), wind tunnel and other measured or analytically computed data. The rigid forces are “elasticized” using a linear aeroelastic correction matrix that is derived from one or more of the analytical methods for aerodynamics (typically DLM) and from the structural finite element method. Note that “non-aerodynamic” forces (that is, those not derived from theoretical or measured aerodynamic pressures) may still require an elastic increment due to aerodynamic forces arising from the induced elastic response.

A key attribute of the LM Aero external loads development process is the ability to adapt to the level of analysis being performed. The analysis models are seen to evolve during the design process as illustrated in Figure 3. Initially, simple models may be adequate, but very soon, more sophisticated analyses are needed to accurately perform the design tasks. For example, initial aerodynamic distributions for conceptual and preliminary design are derived from linear methods such as DLM. This linear aerodynamic data is often “corrected” to correlate integrated loads results to wind tunnel force model data. As the design progresses, higher fidelity aerodynamic data from computational fluid dynamics (CFD) analyses and wind tunnel testing become available. Finally, flight test data provides the ultimate source of “truth” loads data.

**Figure 3 – External Loads Analysis Models Evolve During the Design Process**
A critical feature in the LM Aero loads analysis toolset is the ability to overlay these dissimilar aerodynamic data sets. For example, CFD or wind tunnel data for various angles-of-attack and control surface deflections may replace existing data from a linear, low-order panel method. This capability allows incremental improvement of the loads analysis as more accurate data become available. Some aerodynamic data, such as rotary rate damping, are usually only available from theoretical methods. Other aerodynamic data, such as external store aerodynamic data, may exist only as integrated loads at a point. The ability to use multiple dissimilar aerodynamic data sets allows a full description of aircraft aerodynamics.

In addition to aircraft aerodynamics, inertial characteristics of the aircraft must be included in the external loads development process. The mass configuration of the aircraft not only contributes inertial loads, but also produces incremental elastic aerodynamic loads arising from deformations caused by inertial loads. It is sometimes convenient to reuse aeroelastic loads due to a baseline mass configuration in analyses with perturbations of that baseline mass configuration. The combination of aerodynamic, inertial and other distributed loads form the loads database for the aircraft configuration under consideration.

Quasi-static maneuver trim analysis must be sufficiently robust to navigate the loads database and accurately predict aeroelastic criteria for control effectiveness and aerodynamic performance throughout the design envelope. Highly maneuverable aircraft often have more control surfaces available than necessary for trim and require sophisticated flight control systems that command the control surfaces. Trim algorithms require definition of relations between independent and dependent surfaces that are enforced throughout the trim solution. Control surfaces that are used to trim the aircraft are assigned specific contributions to roll, pitch, and yaw control using control surface blend (or gearing) ratios. Additionally, control surface position may be scheduled as a function of flight condition and aircraft attitude. Sophisticated users have the option of scheduling control surface blend ratios, as well. In addition to commanding the position of control surfaces, limits may be placed on their travel and hinge moment. Limits on aircraft angle-of-attack may also be specified.

Maneuver response data used in quasi-static trim analyses are derived from dynamic maneuver simulations that produce time histories of aircraft response parameters. Rather than perform a loads analysis on each instant of a time history containing potentially thousands of points, several snapshots of the maneuver time history are selected based on criterion developed to capture instances producing extreme loads. This filtering process selects maneuver loads analysis points and produces maneuver response data suitable for subsequent input to quasi-static maneuver trim analyses.

The output of quasi-static maneuver trim analyses are balanced distributed loads for trimmed maneuver conditions. Distributed loads are integrated over defined regions, or components, of the airframe to produce component loads. Component loads results drive the critical load condition selection process. In an aircraft design cycle, thousands of maneuver trim conditions are produced. A means of reducing the number of load conditions to a manageable set that comprise the “design-to” load set is required. A filtering process called “enveloping” is used to define critical load conditions. Critical load conditions define the limit, or envelope, of loads the aircraft is designed to experience. Distributed loads for the critical conditions are mapped to the structural finite element model (FEM) for structural analysis and sizing.

**MSC.FlightLoads and Dynamics**

MSC.FlightLoads and Dynamics (MSC.FLD) is a commercial off-the-shelf (COTS) product developed by the MSC.Software Corporation (MSC) to enhance the aeroelastic and design capabilities included as part of MSC.Nastran and MSC.Patran. MSC.FLD is an integrated flight loads development tool.
consisting of MSC.Nastran and MSC.Patran, as shown in Figure 4. MSC.Nastran serves as the computational engine, while MSC.Patran provides the graphical user interface.

![Figure 4 - MSC.FLD is an Integrated Flight Loads Development Tool](image)

The MSC.Patran component of MSC.FLD provides access to the user’s CAD system for basic geometry information and then supports creation of the aerodynamic and structural models used in calculating loads. The MSC.Nastran system handles the computationally intense calculations that produce basic loads information. This information can be passed back to the graphics package for visualization of the results, including the components used in building up the final solution. For loads determination, the end result is the creation of loads in MSC.Nastran bulk data format that can be applied to the structural model to provide detailed stress information.

The MSC.FLD software package is best viewed as a bridge between MSC.Patran and MSC.Nastran in support of aeroelastic analysis. The complete suite of modeling and visualization tools in MSC.Patran is available as well as the entirety of linear analysis capabilities of MSC.Nastran. In version 1.0, MSC.FLD focused on model creation and on the analysis of static aeroelastic trim. In particular, MSC.FLD V1.0 directly supports the creation of aerodynamic and aeroelastic databases and the definition of trim conditions for which the trim state and total loads are to be computed. The trim solutions rely on the components of the aeroelastic database to determine the trimmed state.

The aerodynamic database of MSC.FLD V1.0 is a “linear” database in the sense that the forces can be represented as a “baseline” force field (denoted the ‘intercept’ in MSC.FLD V1.0) and a sequence of incremental forces due to unit perturbations of the trim parameters. MSC.FLD V2001 supports a nonlinear aerodynamic data model. The generation of a nonlinear aeroelastic loads database entails the creation of a set of data that allows the rigid (and, by natural extension, the elasticized) force data to be associated with a parameter set rather than a single parameter’s perturbation with respect to an “intercept.” In addition to the data restructuring, the trim solution algorithm was modified to make the adjustment from “load increments” to “loads at a given parameter set.” To trim the vehicle, the local elasticized load increments are computed relative to an identified baseline reference state. MSC.FLD was augmented to allow the reference state to be user defined, rather than assumed to be the freestream.

In the MSC system, the trim parameters can be rigid body accelerations, angles and rates as well as any number of user-defined control surfaces. However, the aerodynamic database structure is not restricted to these parameters. If data were introduced into the system that represents other parameters (e.g., thrust), MSC.FLD would be able to perform trim analyses and compute the elastic increments due to the unit perturbation. In V1.0, such introductions were only possible using MSC.Nastran Direct Matrix Abstraction Program (DMAP) Alters, ISHELL sub-processes or other means. With MSC.FLD V2001,
direct support is provided for static applied loads and other distributed loads that are representative of parameters not included in the standard parameter set; notably, vectored thrust gimbal angles and store air loads. That is, there may exist rigid applied (structural) loads that are functions of the trim parameters.

MSC.FLD can compute distributed load conditions that are in equilibrium (trim). These loads can include static applied loads on the structural mesh (e.g., thermal distributions and thrust), rigid aerodynamic loads, elastic increments caused by the external loads (aerodynamic, applied and inertial), and inertial loads. These data are computed on both the aerodynamic mesh and the structural mesh with the exception of the static applied and inertial forces. These two components are defined only on the structural mesh. The means of computing the trimmed loading is to define a trim maneuver in terms of fixed parameters and free parameters. The free parameters are then found that trim the forces arising from the fixed parameters. The trim algorithms in MSC.Nastran include a linear trim (in which the number of rigid body modes exactly equal the number of free parameters) or an iterative trim (in which the number of free parameters can exceed the number of axes to be trimmed). There is also a generic control law that uses some heuristics to blend the “excess” free parameters to again reach a linear trim.

Distributed loads can be integrated over a portion of the vehicle about the origin of some arbitrary coordinate system to produce component loads. Version 1 of the MSC.FLD graphical user interface supports the evaluation of component loads as an interactive post-processing step on the results of an aeroelastic analysis. This includes the elasticized load increments and the trimmed loads. With Version 2001, MSC.Nastran was given the ability to calculate these component loads in a batch manner. The concept of a “Monitor point” was introduced. This monitor point is the location about which the loads from a defined region are integrated. MSC.FLD V2001 provides default monitor points for the complete aircraft and any defined control surfaces. In V1.0, control surface hinge moment calculations included only the rigid and elastic increment air loads. This restriction came about because the control surface is defined by pointing to a set of aerodynamic boxes and the inertia loads are associated with structural grids. In V2001, the control surface definition was expanded to include structural node sets that can be used to compute the control surface inertia loads about the hinge line.

MSC.FLD V2001 now supports the display of pressure data. This enhancement makes the evaluation of aerodynamic data using the graphical displays easier. The pressure calculations are trivial for the DLM theory that is supported. Additionally, MSC.Nastran V2001 offers the capability to reuse an aeroelastic database with an updated mass state. Previously, any updates to the structural mass were ignored in the static aeroelastic trim process when reusing an aeroelastic database via the DBLOCATE technique. Now, the aeroelastic database archive can be reused and new masses (like stores and payload variations) can be examined without causing resource intensive recalculation of the aeroelastic corrections.

**MSC.Nastran Toolkit API**

MSC.FLD supports a variety of methods to extract and insert data into its data stream. Both the graphical interface and computation system support programmatic high-level process flow and data access methods (Patran Command Language (PCL) and DMAP, respectively) that are very general. In addition, both support the concept of process spawning (uil_process_spawn and ISHELL, respectively) to invoke one or more subprocess to retrieve, augment and return data in a seamless execution flow. Such interfaces can be tailored for particular needs on a site-by-site basis.

A particularly powerful method to interact with the MSC.FLD data stream is provided by a very general client-server interface known as the MSC.Nastran Toolkit Application Programming Interface (API). The MSC.Nastran Toolkit API is an emerging product that provides the necessary tools (Application Programming Interfaces) to write general client applications that invoke MSC.Nastran functionality to compute and retrieve data directly into the process space of the client (Figure 5). These APIs provide an
extremely powerful set of tools to tailor existing systems (and future updates) to the particular in-house augmentation that may be desirable.

![Diagram of MSC.Nastran Toolkit APIs](image)

**Figure 5 – MSC.Nastran Toolkit APIs Provide Client/Server Access to MSC.Nastran**

The Toolkit provides the client program full access to the MSC.Nastran database. Table and matrix data may be queried, created, read from and written to the database. Client applications interface with the MSC.Nastran server using programmatic interfaces (C, Fortran, or Java) and DMAP sequences. The DMAP interface allows any MSC.Nastran module to be executed from the client using standard DMAP and/or MSC.Nastran Solution Sequence capabilities.

**The Case for Integration / The Integration Problem**

The first release of the MSC.FLD product contained several features well suited for the LM Aero external loads development process. The user interface provided through MSC.Patran offered excellent modeling capabilities for developing two-dimensional (2D) aerodynamic panel models and the aero-structural splines that couple the aerodynamic model to a structural model. Additionally, the aeroelastic data visualization features provided exceptional tools for checking out aeroelastic models and gaining insight into the aeroelastic database. The high-quality aeroelastic data generation capabilities offered by MSC.Nastran were already appreciated within LM Aero following the expanded usage of MSC.Nastran for generation of linear 2D aeroelastic data used primarily in conceptual and preliminary design. The aeroelastic data was imported into the LM Aero legacy process using a system of DMAP alters and translator programs. Using MSC.FLD as the central external loads analysis (trimmed loads generation) tool would circumvent this translation step and streamline the process.

The prospect of using a commercial flight loads development tool consisting of MSC.Patran and MSC.Nastran was attractive to LM Aero. MSC.Nastran and MSC.Patran are used extensively at LM Aero, particularly for stress analysis. External loads data are provided to stress analysts in MSC.Nastran static load input format (e.g., FORCE cards). The legacy external loads process includes mapping loads from a loads integration model to a stress structural model and conversion to MSC.Nastran input format. A common analysis model and tool set would provide a seamless transfer of information to the stress group. Furthermore, the level of documentation and technical support provided by MSC was superior to that available for some of the older legacy tools.

However, there were several essential capabilities of the LM Aero external loads analysis processes and tools that could not be duplicated by the initial MSC.FLD product. Some of these capabilities involved the upstream and downstream processing of data flowing through the MSC.FLD tool. In particular, the LM Aero process requires efficient mechanisms to bring large quantities of maneuver response data into the system as quasi-static trim cases and to output the extensive component loads data suitable for the critical loads evaluation process. Other process integration issues included the use of legacy theoretical aerodynamics correction methods centered on modification of pressures and the import of three-dimensional (3D) aerodynamic data into a 2D aeroelastic analyses. These types of process integration
issues were resolved with a high-level tailoring of the MSC.FLD product suite using MSC.Nastran Toolkit API, PCL, DMAP, and similar tools.

However, the LM Aero process also required other capabilities involving more fundamental aspects of the MSC.FLD feature set. These fundamental capabilities included a nonlinear aeroelastic database, an associated quasi-static trim algorithm with robust handling of redundant control surfaces, generation of component loads in the computational engine (MSC.Nastran), use of multiple mass configurations in combination with aeroelastic data reuse, and visualization of aerodynamic pressure data in the user interface (MSC.Patran). These fundamental aspects are best addressed by enhancing the MSC.FLD product suite at a level below that accessible to the customer and required software development by MSC.

The Integration Solution

LM Aero and MSC decided to work together to integrate the key strengths of the MSC.FLD product and the LM Aero external loads development processes and tools. The key strengths of the MSC.FLD product are the aeroelastic model development capabilities of the MSC.Patran interface and the aeroelastic data generation capabilities of the MSC.Nastran computational engine. The key strengths of the LM Aero external loads development processes and tools are the handling of upstream maneuver simulation data, the robust quasi-static maneuver trim algorithms, and the generation and processing of component loads data for the downstream critical loads evaluation process.

Significant commercial MSC.FLD development efforts by MSC supported the LM Aero integration project. Specifically, these efforts included the development of a nonlinear aeroelastic database and component loads generation in the MSC.Nastran computational engine and the addition of pressure visualization capabilities to the MSC.Patran user interface. These developments provided the MSC.FLD product with the fundamental technical features required for the LM Aero external loads analysis process and significantly enhanced the aeroelastic analysis capabilities of the commercial MSC.FLD software.

Addressing the process integration issues that are the focus of this paper involved cooperative software development performed by LM Aero and MSC. This effort centered on using MSC.Nastran Toolkit APIs to modify a LM Aero legacy flight loads analysis tool to directly access the MSC.Nastran nonlinear aeroelastic database. Other software development efforts included implementation of LM Aero methods of aerodynamic data correction and 3D-to-2D aerodynamic data mapping to alter and augment aerodynamic data contained in the MSC.Nastran nonlinear database. The premise of this integration approach is to develop the aeroelastic model and data using MSC.FLD and then reuse that data in the modified LM Aero in-house flight loads analysis tools.

The integrated LM Aero external loads development process is illustrated in Figure 6. The MSC.Patran interface of MSC.FLD is used to develop the aeroelastic model and pass it along to MSC.Nastran for solution and generation of the aerodynamic and aeroelastic databases. The aerodynamic database (ADB) may be augmented or modified using the 3D-to-2D mapping or rigid aero correction tools, respectively, as the appropriate source data is available. If the rigid aerodynamic data is changed, MSC.Nastran is invoked to reuse the new aerodynamic database and produce a corresponding aeroelastic database (AEDB). The resulting ADB and AEDB are accessed within the balanced maneuver loads analysis tool using MSC.Nastran Toolkit APIs. The component loads output drives the critical loads survey that selects design external load conditions. These critical load cases are provided to the stress group in MSC.Nastran bulk data format (i.e., FORCE cards).
The joint LM Aero and MSC integration effort involved the LM Aero external loads analysis processes and tools centered around the NLDS balanced maneuver loads analysis software tool. The NLDS-based external loads process fulfills and defines the attributes of the LM Aero external loads development process described previously. NLDS is currently used as the primary flight loads tool on several new aircraft development programs at LM Aero.

**Balanced Maneuver Loads Analysis**

The LM Aero NLDS software is a general-purpose flight loads prediction tool capable of using linear and/or nonlinear aerodynamic data. The software relies on user-supplied descriptions of the aircraft's inertial and aerodynamic properties to calculate balanced aircraft loads for arbitrary maneuver response conditions. The user directs the trim algorithms to balance the aircraft in up to 6 degrees-of-freedom using aircraft attitude, response and control surface position parameters. The aerodynamic and inertial forces resulting from the trim condition are summed at user defined loads reference points to produce component loads data. The loads data are output in various forms for documentation and post-processing. The component load output of NLDS is used to drive the critical load condition selection process.

As the central component of the integration effort, NLDS was given the ability to access data directly from an MSC.Nastran Version 2001 aerodynamic/aeroelastic database (ADB/AEDB) (Figure 7). The MSC.Nastran Toolkit provided the mechanism that enables a client/server connection between the client program (NLDS) and the server program (MSC.Nastran). Once the client/server connection is opened, the NLDS process has direct access to the database of the MSC.Nastran process. The NLDS modifications concentrated on providing read access to data previously obtained through translator programs and multiple flat file interfaces. These data included aerodynamic model geometry, coordinate systems, aerodynamic reference dimensions, control surface definitions, aerodynamic control vector settings, rigid aerodynamic loads, and flexible aerodynamic load increments. Data obtained from a
MSC.Nastran ADB/AEDB can supersede data obtained from traditional NLDS input and are stored in the same manner as the replaced data.

MSC.Nastran Toolkit

Flight Loads Toolkit

NLDS

**Figure 7 – NLDS Accesses MSC.Nastran Data Through the MSC.Nastran Toolkit**

The aerodynamic loads data may be nonlinear. The MSC.Nastran aerodynamic loads data exists as organized collections of independent aerodynamic load sets. Each set represents a load condition on the aerodynamic model and is identified by a control vector state containing the corresponding set of control parameter settings. An interpolator developed for MSC.Nastran Version 2001 to calculate loads at arbitrary control parameter settings was made available to NLDS by means of a statically-linkable object library. This interpolator supports the existing NLDS iterative quasi-static trim algorithms.

The MSC.Nastran dynamic memory manager was also made available to NLDS by means of a statically-linkable object library. This memory manager was used extensively in the NLDS/database interface routines to minimize model size limitations.

**Aerodynamic Pressure Data Correction**

The LM Aero Correct_ADB software is a tool that allows the user to modify aerodynamic pressure data on an existing MSC.Nastran Version 2001 aerodynamic database (ADB) to conform with test or higher-order theoretical data. It is a client program using MSC.Nastran Toolkit APIs to facilitate communication with the MSC.Nastran server. Existing LM Aero correction techniques were implemented in this new tool developed for the integration effort.

During the correction process, individual aerodynamic load sets in an MSC.Nastran aerodynamic database are selected for correction by specifying their associated aerodynamic parameter settings, or control vector state. Additive or multiplicative corrections for each load set may be specified for individual boxes or groups of boxes on the aerodynamic panel model. If a target integrated load coefficient is provided, these corrections are scaled such that the resulting integrated load coefficient matches the target value.
The Correct_ADB process is executed in two phases. First, the correction factors are calculated, and then the aerodynamic loads are corrected. The first phase is handled completely within the client process. Aerodynamic data obtained from the ADB is processed and the resulting correction factors are written to the database. The second phase is performed by the MSC.Nastran server as directed by a DMAP procedure provided by the client. The MSC.Nastran Toolkit allows DMAP instructions to be submitted from the client program to the server program for execution. For Correct_ADB, the DMAP process applies the correction factors to the existing aerodynamic loads data sets. Figure 8 illustrates this two-phase process.

Figure 8 – Correct_ADB Uses the Toolkit To Access and Modify MSC.Nastran Data

3D-to-2D Aerodynamic Pressure Mapping

The LM Aero Map3D_2ADB software is used to map aerodynamic pressure data from a three-dimensional (3D) aerodynamic model to a two-dimensional (2D) aerodynamic model (Figure 9). The 3D data typically comes from wind tunnel tests or computational fluid dynamics (CFD) analyses. The 2D aerodynamic model is created in MSC.FlightLoads and Dynamics for analysis within MSC.Nastran. The resultant mapped aerodynamic data is used to supplant the theoretical aerodynamic data generated by MSC.Nastran and contained in a MSC.Nastran aerodynamic database (ADB). This procedure allows higher fidelity rigid aerodynamics to be used in the aeroelastic analyses.

The Map3D_2ADB tool provides a mechanism to bring 3D aerodynamic data into a 2D aeroelastic analysis within MSC.Nastran. Map3D_2ADB was developed using the Patran Command Language (PCL) of MSC.Patran and runs within an MSC.Patran session. The fields capability of MSC.Patran is used to perform the mapping. MSC.Patran fields are sets of three-dimensional spatial information.

The 3D aerodynamic model is divided into upper, lower, left and right regions, and the 2D aerodynamic model is divided into horizontal and vertical regions. During the mapping process, pressure data from the upper and lower 3D regions are mapped to the horizontal 2D region, while pressure data from the left and right 3D regions are mapped to the vertical 2D region. Delta pressure values are calculated on the 2D aerodynamic model regions and merged to form the final 2D mapped delta pressure data set. The 2D delta pressures are output in various forms, including MSC.Nastran bulk data format for subsequent use in an aeroelastic analysis.
Conclusions

This paper has described the integration of the MSC.FlightLoads and Dynamics software tool into the external loads development process at Lockheed Martin Aeronautics Company. The MSC.Nastran Toolkit API was used to access and modify the MSC.Nastran nonlinear aerodynamic and aeroelastic databases (ADB and AEDB). These technologies were implemented in existing external loads analysis processes and tools to develop client programs of an MSC.Nastran server application. LM Aero and MSC worked together to produce an integrated external loads analysis tool suite that combines the core strengths of the MSC.FLD product and the LM Aero external loads analysis processes and tools.

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