MSC/Flight Loads and Dynamics
Version 1

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Abstract For the past year, the MacNeal-Schwendler Corporation (MSC) has been actively developing solutions to the challenges faced by our customers in the area of external loads and aerodynamic response. Through strategic partnerships with the world's leading civilian and military air vehicle manufactures, MSC has developed an in-depth understanding of our customers' needs. These efforts have lead to the development of an integrated, process-driven external loads and dynamics system called MSC/FlightLoads and Dynamics.

MSC Americas User's Conference
October 5-8, 1998
Universal City, California

Introduction

Aerospace companies that develop and market commercial and military air vehicles are subject to performance regulations specified by government agencies such as the Federal Aviation Administration, Joint Airworthiness Administration, U.S. Military, etc. A subset of these regulations govern not only the external loading environment for air vehicles but also the dynamic response. Each of these regulatory agencies specify a number of vehicle maneuvers that must be performed within an appropriate margin of safety before the vehicle will be certified "air-worthy" and allowed to enter into revenue service. Prior to manufacturing and flight testing, aerospace companies spend tremendous amounts of money attempting to accurately predict external loads and the inherent dynamic response of the structure.

The importance of accurately predicting external loads on a structure and its dynamic response cannot be overemphasized. If the external loads on a structure or its predicted flutter speed are incorrect, the structural design is likely to be inadequate. Typically these inadequacies are revealed in the testing phase, necessitating costly redesigns. In a more dramatic case, the inadequate design could result in catastrophic in-service failure, resulting in costly warranty claims.

Cost efficient structural designs are imperative in today's competitive market. "Better, Cheaper, Faster" and "Do More With Less" are not just slogans but reflect the prevailing attitudes across the aerospace industry. Engineering teams are required to meet FAA, JAA, etc., regulations in the face of head count reductions and pressure from upper management to reduce product time to market.

A typical aerospace program can have 10's to 100's of stress engineers that rely on accurate and timely external loads. A team typically consisting of 5 to 10 engineers is responsible for computing the external loads. For each day the downstream communication of external loads is delayed, a tremendous cost can be incurred to an aerospace program. Timely communication of more accurate external loads data with a high degree of confidence will allow aerospace companies to reduce the loads cycle time while supporting more accurate structural designs.

For the past year, MSC has been actively developing solutions to the challenges faced by our customers in the area of external loads and aerodynamic response. Through strategic partnerships with the world's leading civilian and military air vehicle manufactures, MSC has developed an in-depth understanding of our customers' needs. These efforts have lead to the development of an integrated, process-driven external load and dynamics system called MSC/FlightLoads and Dynamics. Version 1 of this system will be available in late 1998 and will include support for the calculation of flight loads. MSC/FlightLoads and Dynamics will facilitate the use of MSC/NASTRAN structural model data in the early assimilation of the

aeroelastic characteristics into the conceptual, preliminary and detailed design processes.

Maturation of engineering models and data from conceptual to detailed design was a key consideration during design of MSC/FlightLoads and Dynamics. Evolution of structural models from beam-stick representations to full 3-dimensional finite element models is easy. Multiple aerodynamic meshes are supported.

Aerospace companies are striving eliminate redundant structural representations. Tremendous improvements in MSC/NASTRAN solver efficiency and a robust modeling user interface offer the prospect of sharing a single structural model between the external and internal load teams. Time lost on structural model correlation and data mapping can be turned into time spent developing more cost efficient structural designs through more extensive evaluation of the flight envelope and alternative structural designs.

Stress engineers "downstream" of the external loads team in the design-to-certification process will benefit from the timely receipt of information essential to completing their certification process tasks. Improved confidence and accuracy in loads data will support reductions in loads design cycle times. MSC/FlightLoads and Dynamics provides an integrated external-internal loads process, which allows engineers to better focus on the engineering tasks required for vehicle certification.

Benefits

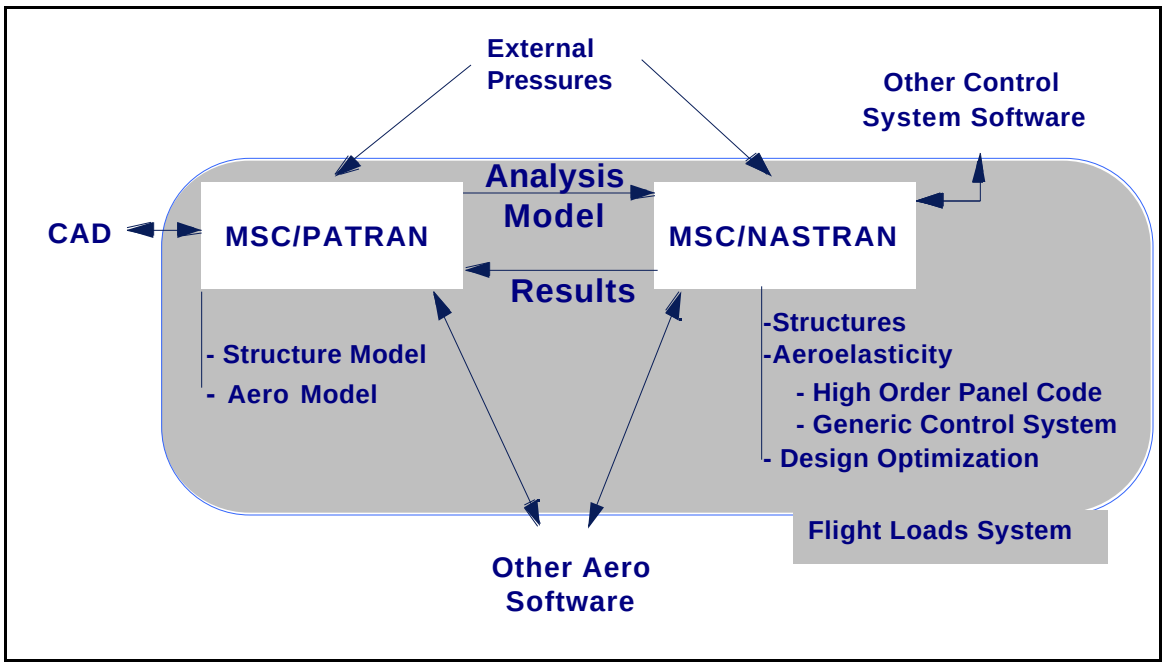
MSC/FlightLoads and Dynamics provides a tool which allows engineers to more accurately, efficiently and confidently predict external air vehicle loads. MSC/FlightLoads and Dynamics will dramatically impact customers' loads cycle processes.

- **Reduced Likelihood of Costly Redesigns**
  - More Accurate External Loads and Dynamics Analyses
  - Improved Confidence in Analysis Data
  - Can Simulate More of the Operating Environment
- **Timely Communication of Loads Data**
  - Stress Group Obtains Quality Loads Earlier in Design Cycle
- **Improved Engineering Efficiency**
  - Common Structural Model
  - Data Reuse
- **Engineers Can Focus On Engineering**

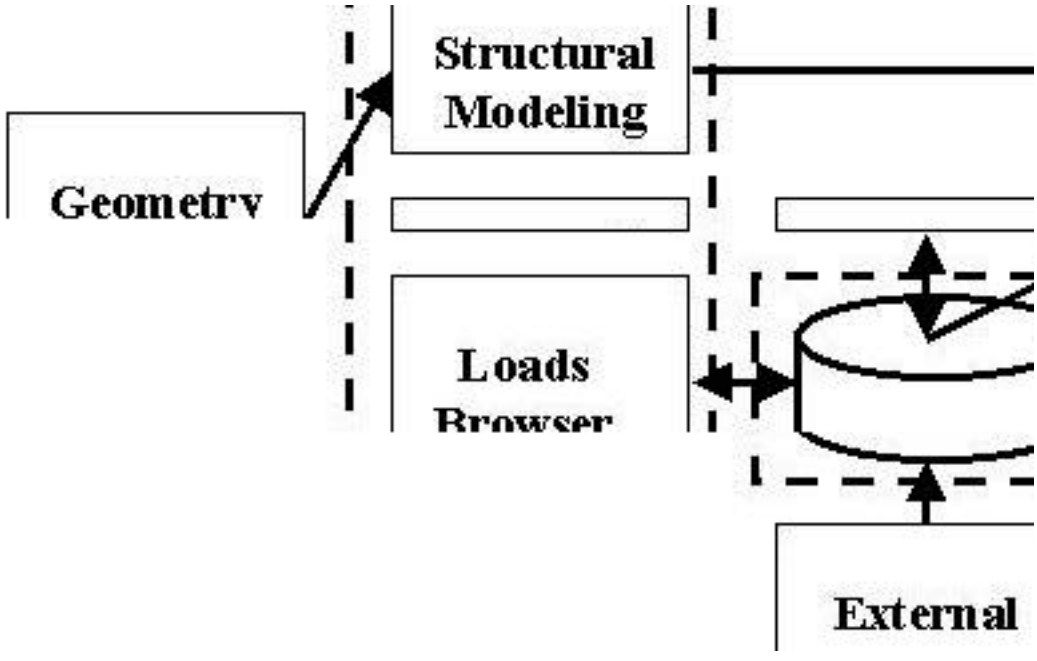
Architecture

MSC/FlightLoads and Dynamics is built on top of MSC/NASTRAN and MSC/PATRAN. Using these industry standard tools as the foundation, FlightLoads delivers powerful capabilities to the engineer, including large problem solution efficiency, integration with the world's leading CAD systems and extensive CAE modeling tools. Tight integration between MSC/NASTRAN and MSC/PATRAN, using client-server technology, provides

users the capability to interactively verify their aeroelastic models prior to analysis. The tedious process of aero-structural coupling is now simple. The system, as shown below, is designed with the recognition that most aerospace companies already have proprietary tools for the creation of aerodynamics and controls models.



In basic terms, MSC/FlightLoads and Dynamics provides the ability to start with native CAD geometry and define an aeroelastic environment with coupled structural and aerodynamic models. This facilitates the definition and evaluation of the appropriate rigid aerodynamic pressure distributions and aeroelastic influence coefficients to generate the external loads on the vehicle. All of these steps are driven from a graphical system.



MSC/FlightLoads and Dynamics User Interface

The MSC/FlightLoads and Dynamics user interface is organized based on typical customer workflow. Each major step in aeroelastic modeling and analysis is supported through unique modules. For Version 1, these modules include:

- Aero Modeling
- Aeroelasticity
- Loads Browser

Aero Modeling Module

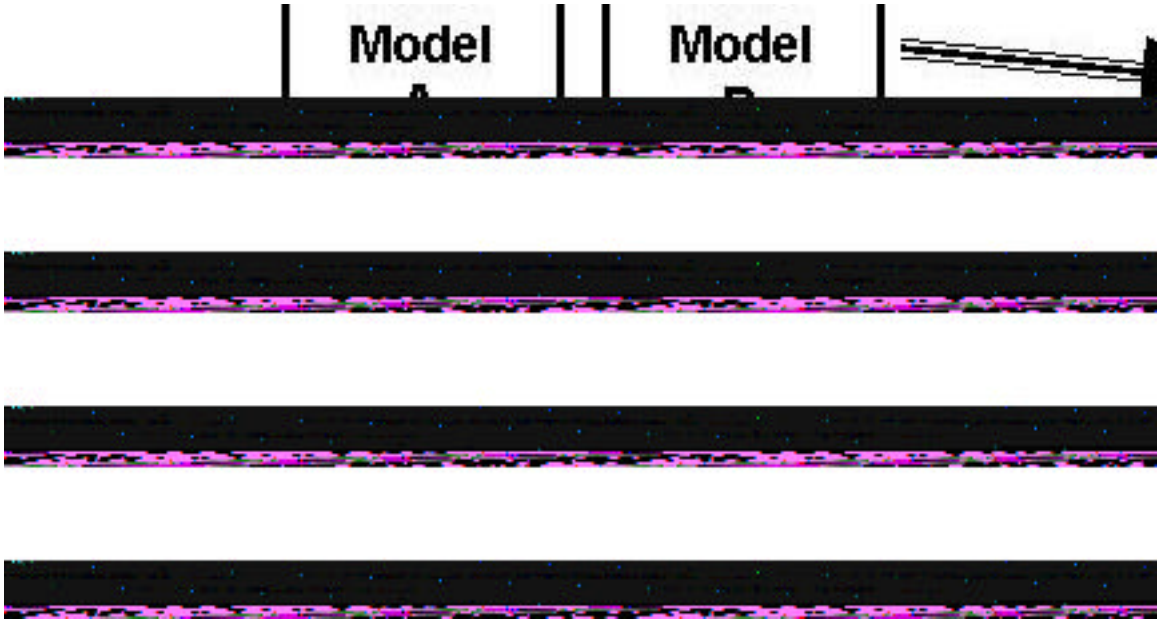
Aerodynamic Modeling in Version 1 will support "legacy" MSC/NASTRAN aeroelastic capabilities (Doublet Lattice Method lifting surfaces, slender and interference bodies). The basic aerodynamic modeling capabilities include the easy definition of aerodynamic lifting surfaces, bodies, components (collections of surfaces and bodies) and control surfaces. Modeling error detection is implemented to provide on-the-fly corrections so aerodynamic models adhere to MSC/NASTRAN rules.

Multiple aerodynamic mesh representations are described through the use of SuperGroups. Each SuperGroup represents a complete aerodynamic model. For aeroelastic analysis, a SuperGroup must be selected and coupled to a structural model. Extensive tools are provided to manage the individual aerodynamic groups (surfaces and bodies) and the SuperGroups; these are located under Model Management in the Aero Modeling module.

Aerodynamic Database

MSC/FlightLoads and Dynamics supports the archival and reuse of aerodynamic rigid pressure data through an aerodynamic database. This database can contain pressure data computed by MSC/NASTRAN or supplied from an external source. External data must be mapped onto the aerodynamic mesh.

The aerodynamic database will be used to store baseline plus increment data and will be hierarchical in nature. The following illustrates the aerodynamic database.



As shown above, the aerodynamic database contains reference states (Mach, angle of attack, side slip angle, pitch rate, roll rate, yaw rate, controls settings) as well their associated aerodynamic influence coefficient matrices.

Aeroelastic Analysis

The aeroelastic features of MSC/FlightLoads and Dynamics couples the aerodynamic and structural data to perform aeroelastic response analyses. The Aeroelasticity user interface module in Version 1 supports static aeroelastic analyses for flexible trim, rigid trim and the computation of flexible increments. Flexible trim is the technology currently supported in MSC/NASTRAN static aeroelasticity (SOL 144). Rigid trim is equivalent to flexible trim excluding flexibility effects; inertia characteristics will be determined from the structural model identified as part of the aeroelastic model. Flexible increments describe contributions to the flexible load due to unit increments in each of the model's trim parameters; these increments can be stored on the aerodynamic database for subsequent reuse.

Graphical tools facilitate the aeroelastic model development. Splining (coupling the structural model to the aerodynamic model) is one of the most error prone modeling activities in aeroelasticity. FlightLoads includes a number of tools to allow the user to graphically define the spline(s) and to evaluate their accuracy based on displacement transfer.

Static aeroelastic response treats the maneuvers as quasi-static in that the unsteady nature of the aerodynamics is ignored while the dynamics of the structural model is accounted for. These analyses rely on the nonlinear rigid data and an aerodynamic influence coefficient (AIC) matrix to assemble the applied aerodynamic forces. In the basic, embedded analysis capabilities, the control effectors are modeled using an improved control system model that allows for blending, scheduling and limiting the control surfaces. In

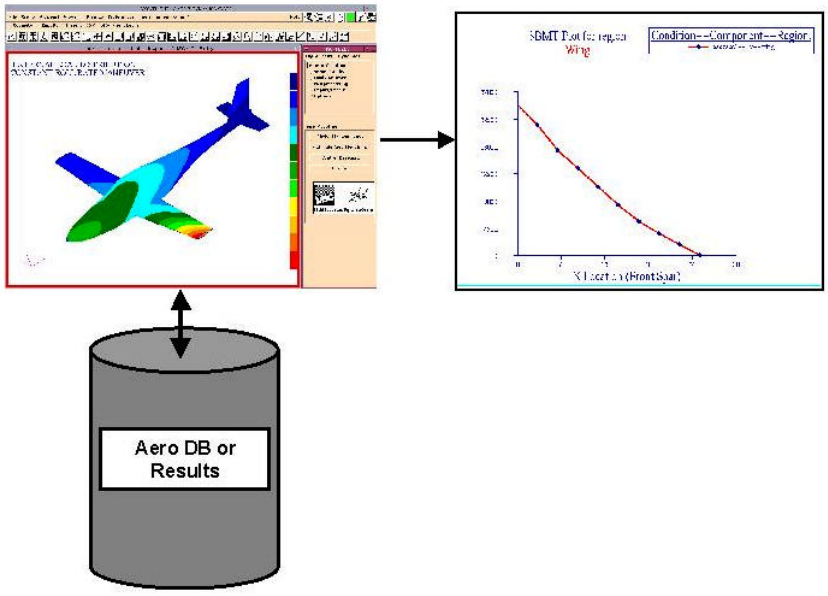
particular, FlightLoads contains an implementation of the Generic Control System (Refs. 2 and 3). This tool is useful for conceptual and preliminary design, while the actual control system software is in development.

The results of an aeroelastic analysis is a set of external loads applied to the vehicle. A number of tools are available for reviewing and manipulating this data, including standard MSC/PATRAN postprocessing and the Loads Browser in MSC/FlightLoads and Dynamics.

Loads Browser Module

The Loads Browser is the looking glass into an aerodynamic or aeroelastic database or an aeroelastic analysis results file. This module provides a number of important aerodynamic and aeroelastic model validation features. These include:

- Running Load Plots: bending moment, shear and torque (BMST) plots
- Load Summation: summation of loads about a specific point on either the aerodynamic or structural model
- Loads Export: creation of a text file containing MSC/NASTRAN FORCE/MOMENT cards for the selected loads on the structural model
- Loads Import: creation of Load Sets in MSC/PATRAN from selected results, which represent structural external loads as calculated by an aeroelastic analysis.
- Graphical views of aerodynamic loads data



Conclusion

In response to customer input, MSC has undertaken a major project to create a solution to address the concerns of external loads and aeroelastic response. MSC/FlightLoads and Dynamics Version 1 is useful for the prediction of external loads on air vehicles. This system is completely graphically driven and easy to use. Typical modeling and analysis processes are supported, which emulate the workflow commonly found across the aerospace engineering community in the discipline of aeroelasticity (coupling of aerodynamics and structural response).

MSC's flagship products MSC/NASTRAN and MSC/PATRAN are tightly integrated to deliver unprecedented capabilities in the field of aeroelasticity. Using these industry standard tools as the foundation, FLDS delivers powerful capabilities to the engineer, including large problem solution efficiency, integration with the world's leading CAD systems and extensive CAE modeling tools. Tight integration between MSC/NASTRAN and MSC/PATRAN, using client-server technology, provides FlightLoads users unparalleled capabilities in the arena of aeroelastic modeling and analysis.

References

1. Rodden, William P. and Johnson, E.H., *MSC/NASTRAN Aeroelastic Analysis User`s Guide, V68,* The MacNeal-Schwendler Corporation, 1994.

2. Volk, J.A and Ausman, J.D., *Integration of a Generic Control System into ASTROS*, AIAA-96-1335, April 1996.

3. Ausman, J.D and Volk, J.A, *Integration of a Control Surface Load Limiting into ASTROS*, AIAA-97-1115, April 1997.