MSC/Flight Loads and Dynamics
Version 1

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ABSTRACT

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/FlightLoads and Dynamics Version 1 supports static aeroelasticity (steady state external loads). This paper will present the current state of the technology within MSC/FlightLoads and Dynamics Version 1.

INTRODUCTION

Every aerospace company considers the accurate prediction of external loads one of the most critical parts of product development. A typical aerospace program can have 10's to 100's of stress engineers that rely on accurate and timely external loads. A smaller team of 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.

"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.

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THE VALUE OF MSC/FLIGHTLOADS AND DYNAMICS

MSC/FlightLoads and Dynamics is a tool that allows engineers to more accurately, efficiently, and confidently predict external air vehicle loads and dynamic response.

- **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 upon MSC's two flagship products, MSC/NASTRAN and MSC/PATRAN. Extensive enhancements to both products as well as restructuring of aeroelastic data provide a tool useful for aeroelastic analysis. The following chart describes the general architecture.

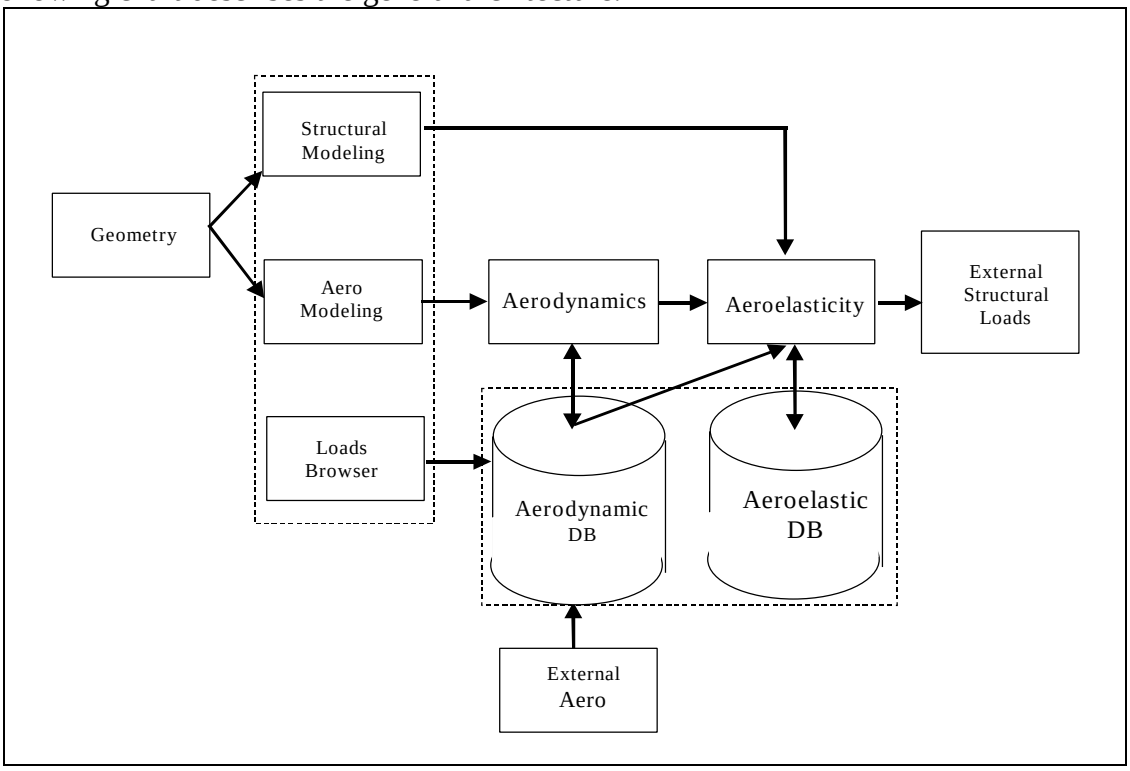

Figure 1: MSC/FlightLoads and Dynamics General Architecture

FlightLoads provides the ability to start with native geometry, (from a number of sources including CAD, STEP AP203/AP209, and IGES), and to subsequently define an aeroelastic environment with coupled structural and aerodynamic models or to define a rigid aircraft as a point mass coupled to an aerodynamic model. This system facilitates the definition and evaluation of the appropriate rigid aerodynamic pressure distributions and aeroelastic influence coefficients to generate the external loads on the structure and/or the aerodynamic model. All of these steps are driven from a graphical user interface. The following illustration presents the conceptual product integration for this system.

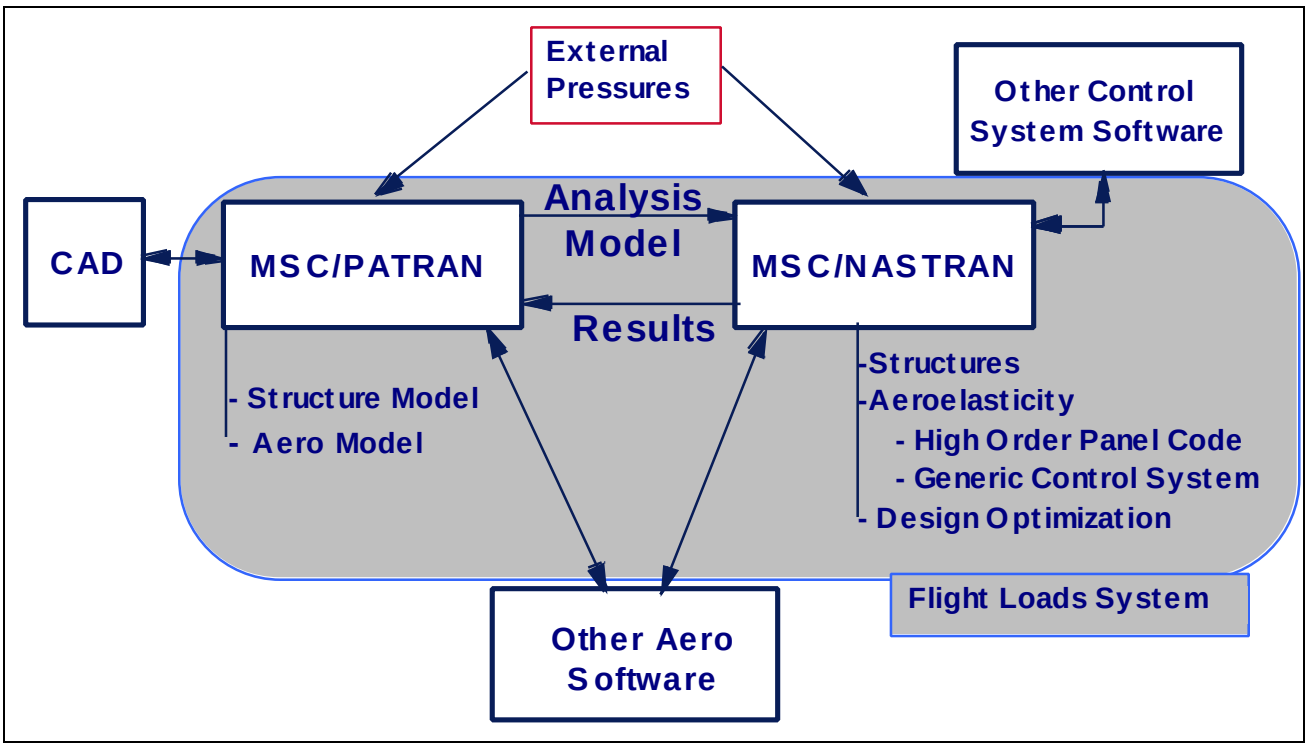

Figure 2: MSC/FlightLoads and Dynamics Integration

GRAPHICAL USER INTERFACE

MSC/FlightLoads and Dynamics provides comprehensive pre- and postprocessing support from MSC/PATRAN. This graphical support includes model integrity checking to facilitate the development of aerodynamic and aeroelastic models. The arduous task of aero-structure coupling is now very simple through a comprehensive user interface. Prior to analysis, users can now verify the integrity of this coupling through the spline verification tool within the user interface. Extensive visualization tools allow users to understand the external loads, both total and each of the contributing load components (rigid, elastic, inertia and trimmed). Unit load increments due to perturbations in the trim variables are available for display on the model. The migration from course beam-stick structural model to a detailed 3-D model is supported as well.

The graphical user interface is separated into a number of modules:

- Aerodynamic Modeling
- Aeroelasticity
- Loads Browser
- Import/Export
- Postprocessing (via MSC/PATRAN Results application)

Each of these modules is summarized below.

Aerodynamic Modeling

- Doublet Lattice Method surfaces and bodies
- Control Surfaces, including position and hinge moment limits
- Automated modeling error detection and correction methods
- Extensive model visualization and query capabilities
- Support of multiple aerodynamic mesh representations

Aeroelasticity: Aero-Structural Coupling

- Interactively define spline relationships
- Optional separation of spline definitions into force and displacement components
- Interactively verify spline relationships using existing structural displacements (static deformations or dynamic modes). Results of aero-structural coupling are automatically displayed and animated.

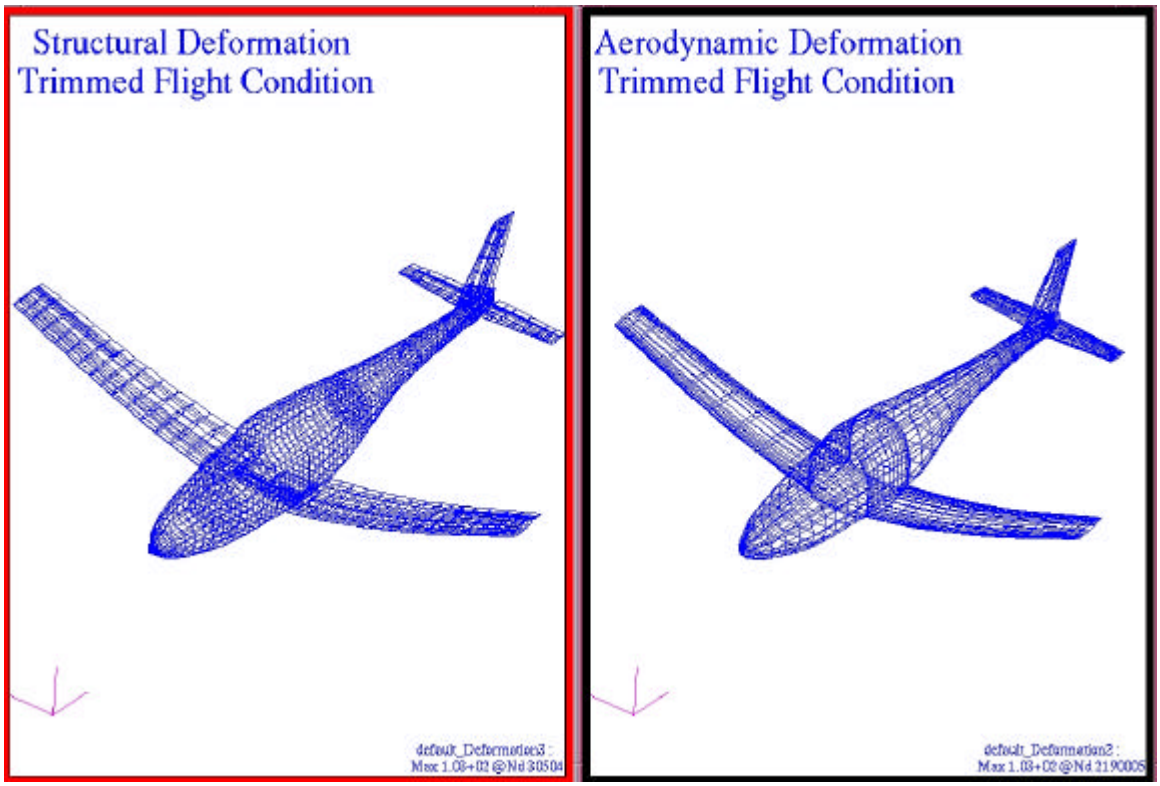

Figure 3: Structural Deformations Mapped to Aerodynamic Model

Aeroelasticity: Static Aeroelasticity

- Subsonic and supersonic aerodynamics
- Simultaneous symmetric and antisymmetric boundary conditions
- 3 analysis methods: flexible trim, flexible increments, rigid trim
- Automatic trim parameter determination based on aerodynamic model
- Trim parameter linking

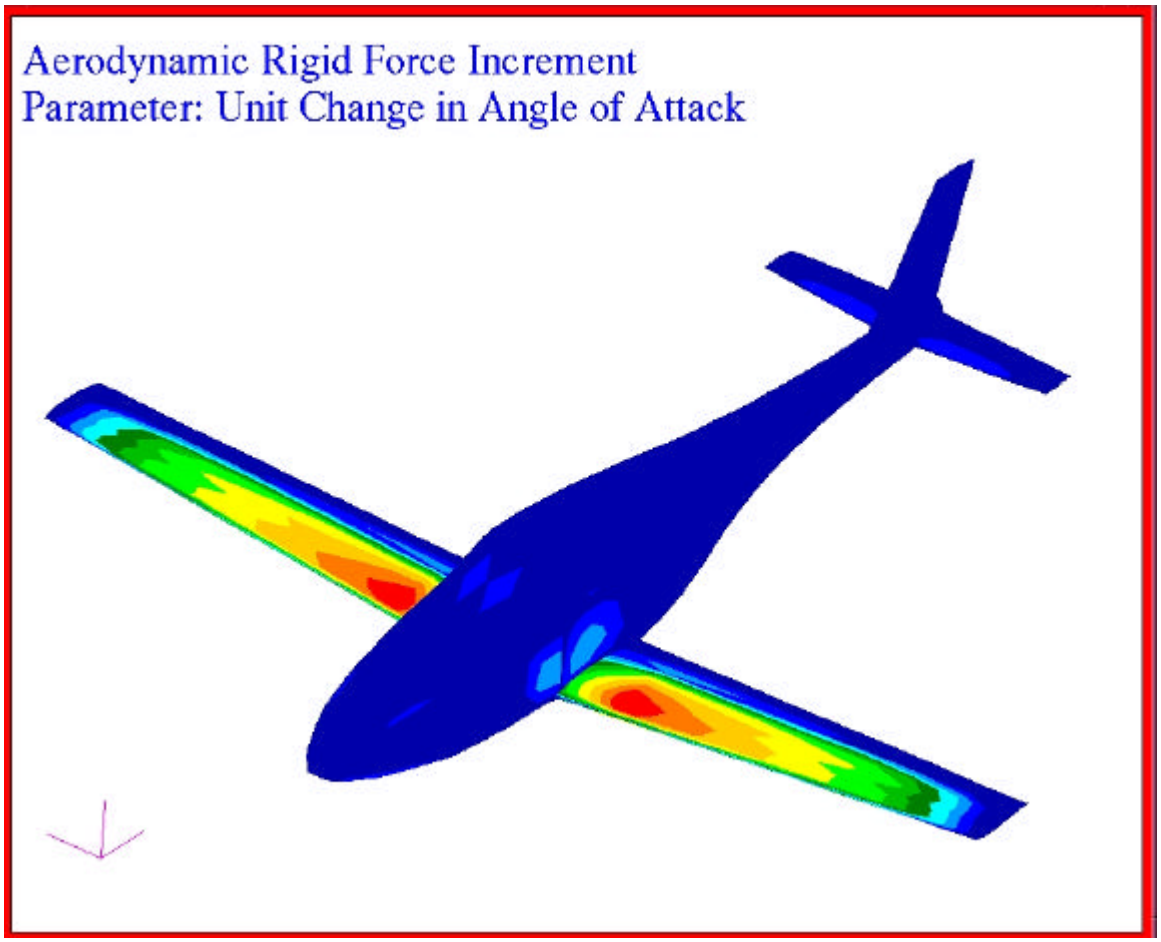

Figure 4: Aeroelastic Unit Solutions Analysis: Angle of Attack

Loads Browser

- Running Loads Plots and Load Summations, including automatic report generation
- Browse loads on either aerodynamic or structural models
- Sources of loads information: aerodynamic or aeroelastic database, analysis results, loads/boundary conditions applied to structural model in MSC/PATRAN database
- Import loads into MSC/PATRAN and apply to structural model
- Export MSC/NASTRAN FORCE cards for selected loads

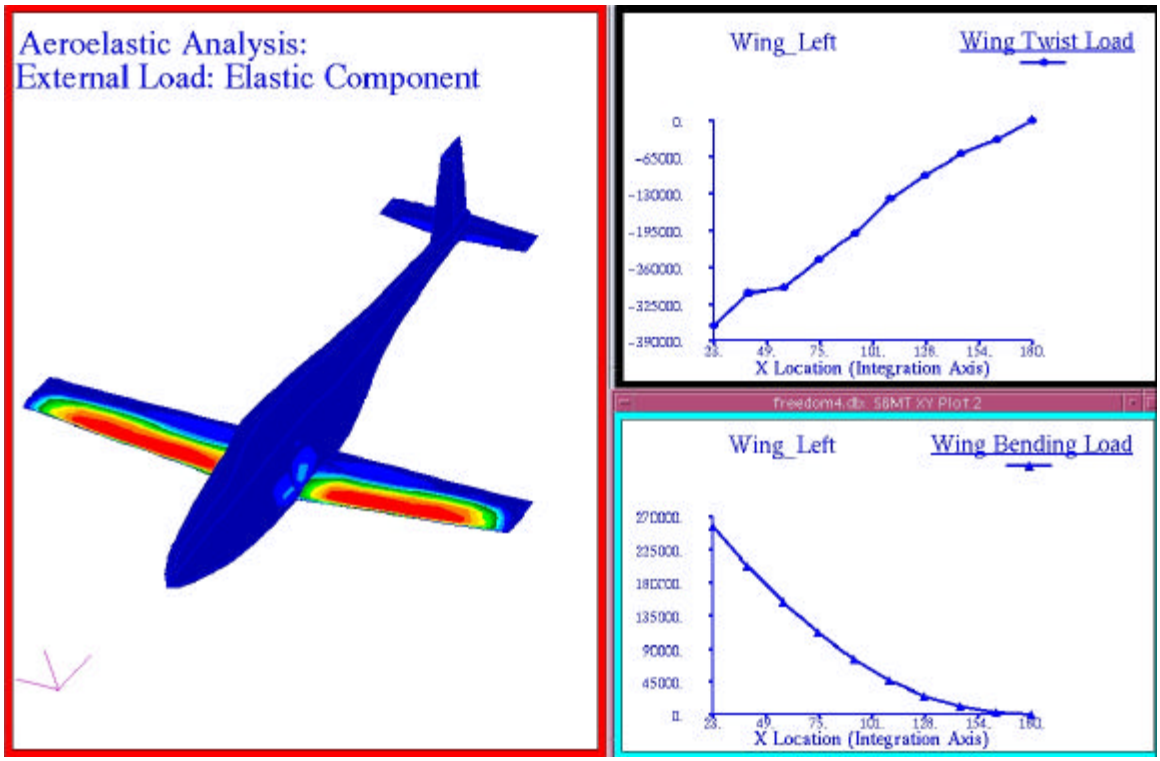

Figure 5: Aeroelastic Loads & Corresponding Running Load Plots

Import-Export Aeroelastic Model

- Import MSC/NASTRAN aerodynamic model input file (lifting surfaces, bodies, control surfaces)

Postprocessing

- Running Loads Plots and Load Summations, including automatic report generation
- Improved results availability: External loads separated into components (rigid, flexible, inertial, trim, flexible increments)
- Standard MSC/PATRAN Results tools available. Different plot types include fringe, vector, and deformation.

HTML Help Pages

- Immediate access to topic-specific help
- Easily customized at user or site level

AEROELASTIC ANALYSIS

MSC/FlightLoads and Dynamics is built on the industry standard analysis program MSC/NASTRAN. Recent improvements provide significant support of the aeroelastic loads and dynamics requirements of the aerospace industry. Improved data management and numerical algorithms now provide the ability for the use of a common structural model between the external and internal loads teams. MSC/FlightLoads and Dynamics

Version 1 supports the static aeroelastic capability of MSC/NASTRAN (steady state external loads).

Capabilities added to MSC/NASTRAN and supported through MSC/FlightLoads and Dynamics include:

- Rigid and Flexible Trim, Flexible Increments
- Nonlinear Trimmed Maneuvers
- Aerodynamic Database
- Aeroelastic Database

Rigid and Flexible Trim, Flexible Increments

MSC/FlightLoads and Dynamics supports flexible trim, rigid trim and the calculation and subsequent storage of flexible increments. Rigid trim is equivalent to flexible trim, excluding flexibility effects. Flexible increments describe contributions to the flexible load due to unit increments in each of the model's trim parameters; these increments are optionally stored on the aerodynamic database for subsequent reuse.

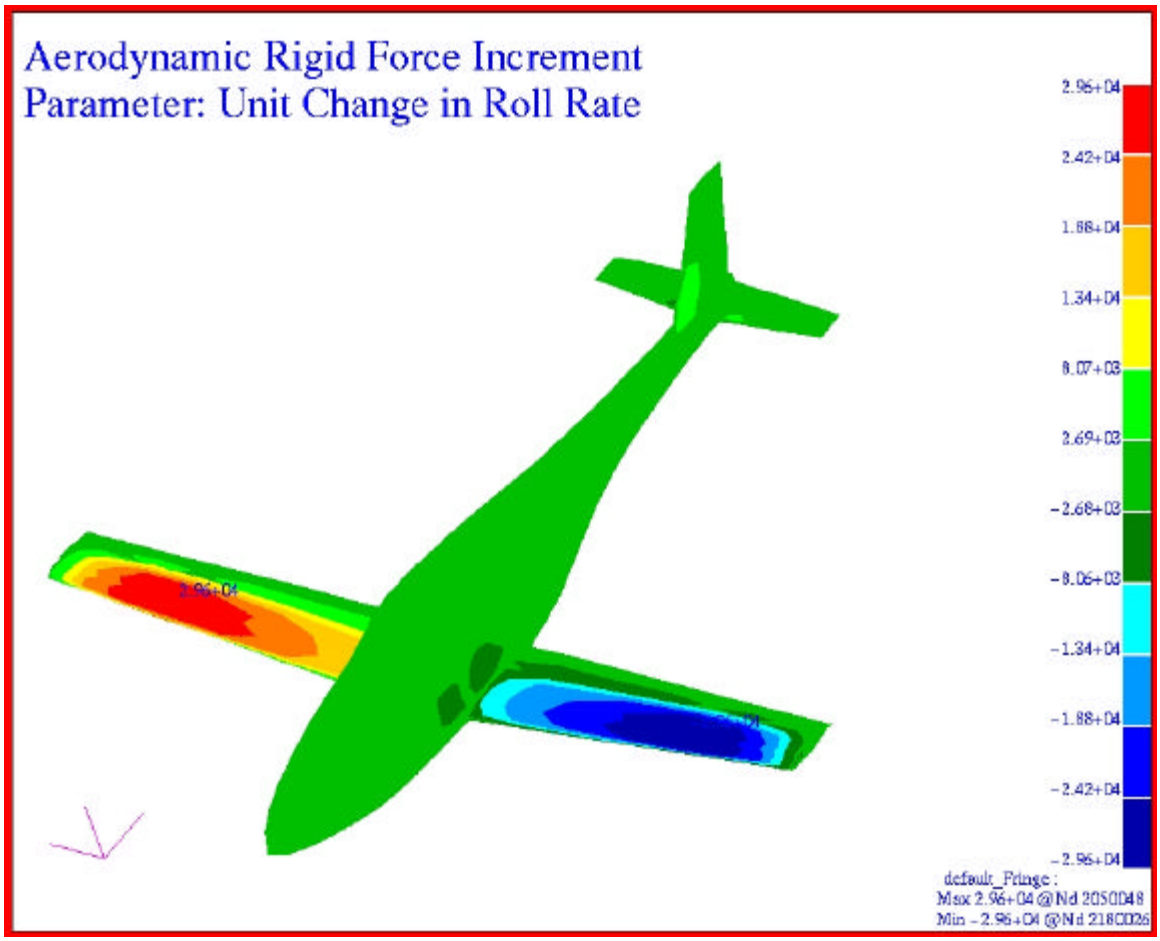

Figure 6: Aeroelastic Unit Solutions Analysis: Roll Rate

Nonlinear Trimmed Maneuvers
The aeroelastic analysis of MSC/NASTRAN is enhanced to more accurately simulate trimmed. It has incorporated a Generic Control System (GCS) which allows for rapid generation of reasonable preliminary maneuver loads without the need to fully define a set of flight control laws. The GCS uses a minimum control energy heuristic that accounts for control saturation to simulate the control system.

Aerodynamic Database
The aerodynamic database allows customers to archive rigid aerodynamics data for subsequent reuse. This data is baseline plus increment data and is hierarchical in nature. The aerodynamics database uses the MSC/NASTRAN database technology, thus improving analysis efficiency in reuse. Version 1 supports reuse of aerodynamic data computed by MSC/NASTRAN. This capability that presumes that the pressures arise from an AIC operating on a geometric downwash perturbation, hence a linear force-displacement relationship for the aerodynamic parameters (α, β and control surface deflections).

Future development of an integration toolkit will support incorporation of aerodynamics data from multiple sources: CFD codes, wind tunnel, flight test, MSC/NASTRAN, other commercial software, in-house software.

Aeroelastic Database
The aeroelastic database is a superset of the aerodynamics database and structural flexibility information. This database is larger than the aerodynamics database. However, the benefit in its creation is realized in solution efficiencies. In Version 1, archived flexible increments provide for extremely rapid trim solutions for static aeroelasticity. As with the aerodynamics database, users are not required to keep an aeroelastic database; data will be re-computed as required.

CONCLUSION
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).

Every aerospace company considers the accurate prediction of external loads one of the most critical parts of product development. 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. “Better, Cheaper, Faster” and “Do More with Less”

are not just slogans but reflect the prevailing attitudes across the aerospace industry. MSC/FlightLoads and Dynamics delivers the ability to do more with less and provide more accurate, external loads data in a more timely manner.