DATCOM Predicted Aerodynamic Model

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1.0 Introduction

The fundamental purpose of the USAF Stability and Control **DATCOM** is to provide a systematic summary of methods for estimating stability and control characteristics in preliminary design applications. DATCOM is contained in a series of notebooks with over 3100 pages. The Air Force Digital DATCOM program incorporates the methods contained in the DATCOM notebooks into a computer program.

2.0 DATCOM and DATCOM+ Programs

Okay, so what IS this DATCOM stuff? Well, a long time, back before the advent of a computer on everyone's desk, engineering was done through calculations done by hand. Aircraft designers would spend years deriving predicted aircraft performance parameters before an aircraft's design was finalized and an actual airplane was built. Much of their work was compiled into a series of notebooks, a compendium of the data they knew. This series of notebooks, which filled a 6-foot bookshelf, made the design process easier.

With the advent of digital computers, a program was written to make this data compendium more user-friendly. Rather than poring over volumes of paper copies, the user could specify to the computer the defining physical characteristics of the design aircraft, and very quickly obtain design coefficients of the design aircraft. Iterations for design changes could be made much more quickly.

So, why do we care? Well, if the design is frozen, as we find with an aircraft in production, we can use the DATCOM program to derive the defining characteristic coefficients. Those can be applied to a generic flight simulation program, thus yielding a representative simulation of the aircraft.

The original DATCOM program is written is some rather messy FORTRAN IV, but the predictive capabilities are very impressive. The original program probably was loaded with punch cards (Look up punch cards at a museum if you don't know what I'm talking about). The output generated is quite extensive, but rather burdensome to work with.

DATCOM+ is an attempt to make DATCOM a little more user-friendly. The original code has been ported to a PC, minor execution errors have been corrected, and a new front-end and new output formats have been added. The original code remains intact as much as possible, to maintain it's capabilities without the introduction of new errors.

3.0 The Front-End

The input format of DATCOM is a series of NAMELIST statements, listing input variables which describe the aircraft under consideration and variables which control the execution and output of DATCOM. For example:

```
DIM FT
$FLTCON NALPHA=20.0$
$FLTCON ALSCHD(1)= -16.0, -8.0, -6.0, -4.0, -2.0, 0.0, 2.0,  4.0,  8.0,9.0, 10.0, 12.0, 14.0, 16.0, 18.0, 19.0, 20.0, 21.0,
22.0, 24.0$
$FLTCON WT=7000.0$
$OPTINS SREF=320.8$
$OPTINS CBARR=6.75$
$OPTINS BLREF=51.7$
$SYNTHS XCG=21.9$
$SYNTHS ZCG=3.125$
```

Now, by looking at these variables, you can probably figure out what they are, but the third variable, ALSCHD isn't readily apparent. It is the list of angles of attack that you want to investigate for your aircraft. In order to know that, you'd have to have the 300 page DATCOM Users Manual available, and you'd have to pour through it looking for all the right terms. Over the years, you'll eventually learn what each of the parameters mean, and how best to use it, and you'll have a collection of previous aircraft to review if you want to refer back to you previous work.

The new front end to DATCOM contained in DATCOM+ does all of this for you. Let's look at one term, BLREF, from the new version of the input file:

```
*   BLREF   Lateral reference length value of wing span used by program
#T-34 $OPTINS BLREF=33.396$
 $OPTINS BLREF=51.7$
```

Okay, here we have a comment with an asterick in front of it, and the comment describes the term. In this case, the description is simple, but for other terms, the description might be quite extensive. As you play with DATCOM+, you might realize something about a term, which you can add to the comment. If you share your file with someone else, they gain from your experience.

4.0 The Back-End

DATCOM does a wonderful job of generating output. With a simple 125 line input file, you can easily generate 26,000 lines of output. Making sense of it all, and putting it to good use is a whole other matter.

A couple of subroutines have been added to the original DATCOM program to output data tables in more useful formats that the original tabular format. The tabular format has been cleaned up a little and some format errors fixed, in case you look at that. There have also been some hooks placed into the code where necessary to extract data that is significant to the simulation process, since some of the data has to be extracted midstream. Unfortunately, the original DATCOM program used overlays for its common blocks, depending on which subroutines it has to run, so the data midstream may not be the same as at the end. Keep this in mind if you are modifying the code.

Allow me to expand on that last point a little bit. The DATCOM Users Manual, pg 47 states:

> “In general, the eight flap types defined using SYMFLP (variable FTYPE) are assumed to be located on the most aft lifting surface, either horizontal tail or wing if a horizontal tail is not defined."

We are going to assume that this means that we will have to perform a wing-body-vertical tail analysis in order to get the flap effects, then add the horizontal tail in order to get its effects and trim points.

DATCOM handles 8 different types of symmetrical and 5 types of asymmetrical flap deflections. However, it has difficulties in running multiple sets of these in the same file. DATCOM+ overcomes these limitations and allows you to define multiple types of flaps without problems.

Ground and flight spoilers are handled as symmetrical flap deflections, with coefficients for the left and right sides. This allows proper handling of differential deflection, yielding lift, drag, roll and yaw moments. It also gives the added benefit of modeling malfunctions such as one flap surface not deflecting properly.

5.0 More on DATCOM

The Digital DATCOM program uses aircraft-unique configuration and geometry parameters to predict aircraft performance by utilizing classical aerodynamic equations. The Digital DATCOM program calculates static stability, high lift and control, and dynamic derivative characteristics, and is applicable to subsonic, transonic, supersonic, and hypersonic vehicles, for traditional body-wing-tail or canard-equipped vehicles. Coefficient data output by DATCOM is presented as a function of angle of attack at up to 20 user-defined values of angle of attack, and up to 9 user-defined values of surface deflection for flaps, ailerons, and elevator. Although DATCOM is capable of transonic, supersonic, and hypersonic regimes, these are not used in the DATCOM+ input, as general aviation needs are within the subsonic range. For general aviation-type aircraft, a DATCOM Predicted Aerodynamic Model can be used as a basis for an FAA Flight Training Device or Airplane Flight simulator, with proper tuning to match flight test data. Verification of transonic and supersonic coefficients has not been attempted, so the user is cautioned to do extensive testing before placing any faith in the generated output.

For those speed regimes and configurations where DATCOM methods are available, the Digital DATCOM output provides the longitudinal coefficients C_L, C_d, C_m, C_N, and C_A (body axis), and the derivatives $dC_L/d\alpha$, $dC_m/d\alpha$, $dC_Y/d\beta$, $dC_n/d\beta$, and $dC_l/d\beta$. Output for configurations with a wing and horizontal tail also includes downwash and the local dynamic-pressure ratio in the region of the tail. The pitch, roll, yaw and angle-of-attack rate derivatives dC_L/dq, dC_m/dq, $dC_L/d(\alpha\text{-dot})$, $dC_m/d(\alpha\text{-dot})$, dC_l/dp, dC_Y/dp, dC_n/dp, dC_n/dr, and dC_l/dr are also computed for most configurations. Divided into degree of freedom, the parameters output by the DATCOM program may include:

- Lift Coefficient due to:
    - Basic geometry (CL_{α})
    - Flap deflection ($CL_{\delta f}$)
    - Elevator Deflection ($CL_{\delta e}$)
    - Pitch Rate derivative (CL_q)
    - Angle of Attack Rate derivative ($CL_{\alpha dot}$)

- Drag Coefficient due to:
    - Basic geometry (Cd_{α})
    - Flap deflection ($Cd_{\delta f}$)
    - Elevator deflection ($Cd_{\delta e}$)

- Side Force Coefficient due to:
    - Sideslip (Cn_{β})
    - Roll Rate derivative (Cn_p)
    - Yaw Rate derivative (Cn_r)

- Pitching Moment Coefficient due to:
    - Basic Geometry (Cm_{α})
    - Flap Deflection ($Cm_{\delta f}$)
    - Elevator Deflection ($Cm_{\delta e}$)
    - Pitch Rate derivative (Cm_q)
    - Angle of Attack Rate derivative ($Cm_{\alpha dot}$)

- Rolling Moment Coefficient due to:

- Aileron Deflection ($Cl_{\delta a}$)
- Sideslip (Cl_{β})
- Roll Rate derivative (Cl_p)
- Yaw Rate derivative (Cl_r)

- Yawing Moment Coefficient
  - Aileron Deflection ($Cy_{\delta a}$)
  - Sideslip (Cy_{β})
  - Roll Rate derivative (Cy_p)
  - Yaw Rate derivative (Cy_r)

- Misc
  - Horizontal Tail Downwash Angle (ε)
  - Derivative of Downwash Angle ($\delta\varepsilon/\delta\alpha$)
  - Elevator-surface hinge-moment derivative with respect to alpha (Ch_{α})
  - Elevator-surface hinge-moment derivative due to elevator deflection (Ch_{δ})
  - Normal force coefficient (body axis) (C_N)
  - Axial force coefficient (body axis) (C_A)

Notes :
1. All tables are in stability axis system unless otherwise noted.
2. DATCOM provides predicted data only up to stall for some tables. Beyond stall, if DATCOM did not provide data, the table is clamped at the last valid value.
3. Dynamic derivatives from DATCOM are presented for clean configuration only.

6.0 Aerodynamic Equations

Component build-up for the 3 force and 3 moment coefficients is shown below, for most terms for a normal configuration general aviation aircraft. The terms that may be supplied by DATCOM are identified.

6.1 Lift Coefficient

CL_Total =

CL_Basic	DATCOM
+ CL_Flaps	DATCOM
+ CL_Power	
+ CL_Elevator	DATCOM
+ CL_Speedbrake	
+ CL_Thrust	
+ CL_PitchRate	DATCOM
+ CL_AlphaDot	DATCOM
+ CL_IGE	

6.2 Drag Coefficient

Cd_Total =

Cd_Basic	DATCOM

+ Cd_Flaps	DATCOM
+ Cd_Power	
+ Cd_Elevator	DATCOM
+ Cd_Speedbrake	
+ Cd_PitchRate	
+ Cd_Gear	
+ Cd_AlphaDot	
+ Cd_IGE	
+ Cd_Beta	
+ Cd_Rudder	

6.3 Side Force Coefficient

Cy_Total =

Cy_Rudder	
+ Cy_Aileron	
+ Cy_Beta	DATCOM
+ Cy_RollRate	DATCOM
+ Cy_YawRate	
+ Cy_BetaDot	

6.4 Pitching Moment Coefficient

Cm_Total =

Cm_Basic	DATCOM
+ Cm_Flaps	DATCOM
+ Cm_Gear	
+ Cm_Power	
+ Cm_Elevator	DATCOM
+ Cm_Speedbrake	
+ Cm_PitchRate	DATCOM
+ Cm_Thrust	
+ Cm_AlphaDot	DATCOM
+ Cm_IGE	
+ Cm_Beta	
+ Cm_Rudder	

6.5 Rolling Moment Coefficient

Cl_Total =

Cl_Aileron	DATCOM
+ Cl_Rudder	
+ Cl_Beta	DATCOM
+ Cl_RollRate	DATCOM
+ Cl_YawRate	DATCOM
+ Cl_BetaDot	

6.6 Yawing Moment Coefficient

Cn_Total =

Cn_Aileron	DATCOM
+ Cn_Rudder	
+ Cn_Beta	DATCOM
+ Cn_RollRate	DATCOM
+ Cn_YawRate	DATCOM
+ Cn_BetaDot	

From the equations above, it is evident that there are terms that DATCOM does not provide. Chief among these missing terms are the effects of the rudder to yawing and rolling moments. The determination of these terms, and others, is covered extensively in standard airplane design textbooks such as Roskam[1]. Some of these terms are insignificant or may be approximated, dependent on the application.

Power effects for propeller and jet engines may be included in DATCOM, but require many parameters (blade or efflux angle, velocity, pressure) for various mach numbers and coefficient of thrust values. These effects are not currently included in the Predicted Aerodynamic Model.

7.0 Two Examples

Predicted Aerodynamic Models were produced with DATCOM+ for two general aviation-type aircraft, a single engine aircraft and a twin-engine aircraft. The Predicted Aerodynamic Model coefficients are compared to manufacturer's models, and are presented in Appendix A and Appendix B. For the second example aircraft, the Predicted Aerodynamics Model produced by DATCOM+ was incorporated into a flight simulation model that would allow execution of the aerodynamics model with the remaining flight model and Automatic Fidelity Test system. Once incorporated, the new DATCOM simulation model was run through several representative flight tests. To judge the quality of the model produced by DATCOM+, no attempt was made to provide inputs for the terms not defined by DATCOM+. A selection of the test results is presented in Appendix B.

8.0 Using DATCOM+

The first step towards running DATCOM+ is to build your input file. Starting with the supplied aircraft files, modify this file to include the parameters that define your target aircraft. The values for a lot of these parameters can be obtained from Jane's All the World's Aircraft, a good pilot's manual, measured off a good three-view drawing of the aircraft, or measured off the actual aircraft if you are lucky. If you are measuring off a three-view drawing, keep in mind that a photocopy/enlargement may stretch the image slightly. It is generally a good idea to measure a known value such as wingspan or length

[1] "Airplane Flight Dynamics and Automatic Flight Controls", Jan Roskam, 1979.

in each direction, and set up scale factors for each axis for each view, to convert from measured units (inches, centimeters) to actual distances (feet). Some of the values you might not have values for, and will have to make educated guesses at. That is where the previous values from other aircraft come into play. Some of them may be valid for your aircraft, some may not be. It is up to the user to make those judgments, as there is no cross-checking of the data file.

DATCOM+ is run from a command-line window (a.k.a DOS window) on a Windows machine, or under CygWin. Other implementations will follow. The following files should be placed in your local directory:

process.bat and process
datcom.exe
Your data file, named with a .dcm extension. (e.g. citation.dcm, T-34C.dcm)
lfiplot.exe

Now, to start the processing, just type:

```
process citation
```

Note that we left off the ".dcm" from the file name.

DATCOM+ will execute, and generate data into a file called datcom.xml. This data is formatted to be in the XML format for the JSBSim flight model. The output file is not all-inclusive of all the parameters that need to be defined, but is a pretty good start. There are several sections where the user will have to fill in modeling information. Keep the file names in mind, as if you modify this output file without renaming it, it will be overwritten the next time that you run DATCOM+.

Where you had to make assumptions for aircraft values, you may want to revisit those assumptions later and rerun DATCOM+, to refine your predicted model.

DATCOM+ also generates a file called DATCOM.OUT, which is the original output format of DATCOM. In our little example, the output file is 21,000 lines long. It contains all the coefficient data, if you are interested in seeing it.

However, DATCOM+ also output the coefficient data in a little nicer format, one that can be visualized, with:

```
lfiplot  citation.lfi  scn  {table}                    (scn means screen)
```

If you don't know which table number that you would like, leave it blank and LFIPLOT will list all of the available tables. Select the one of interest to you, or 0 to see them all. The plot should be displayed on your screen.

For example, specify:

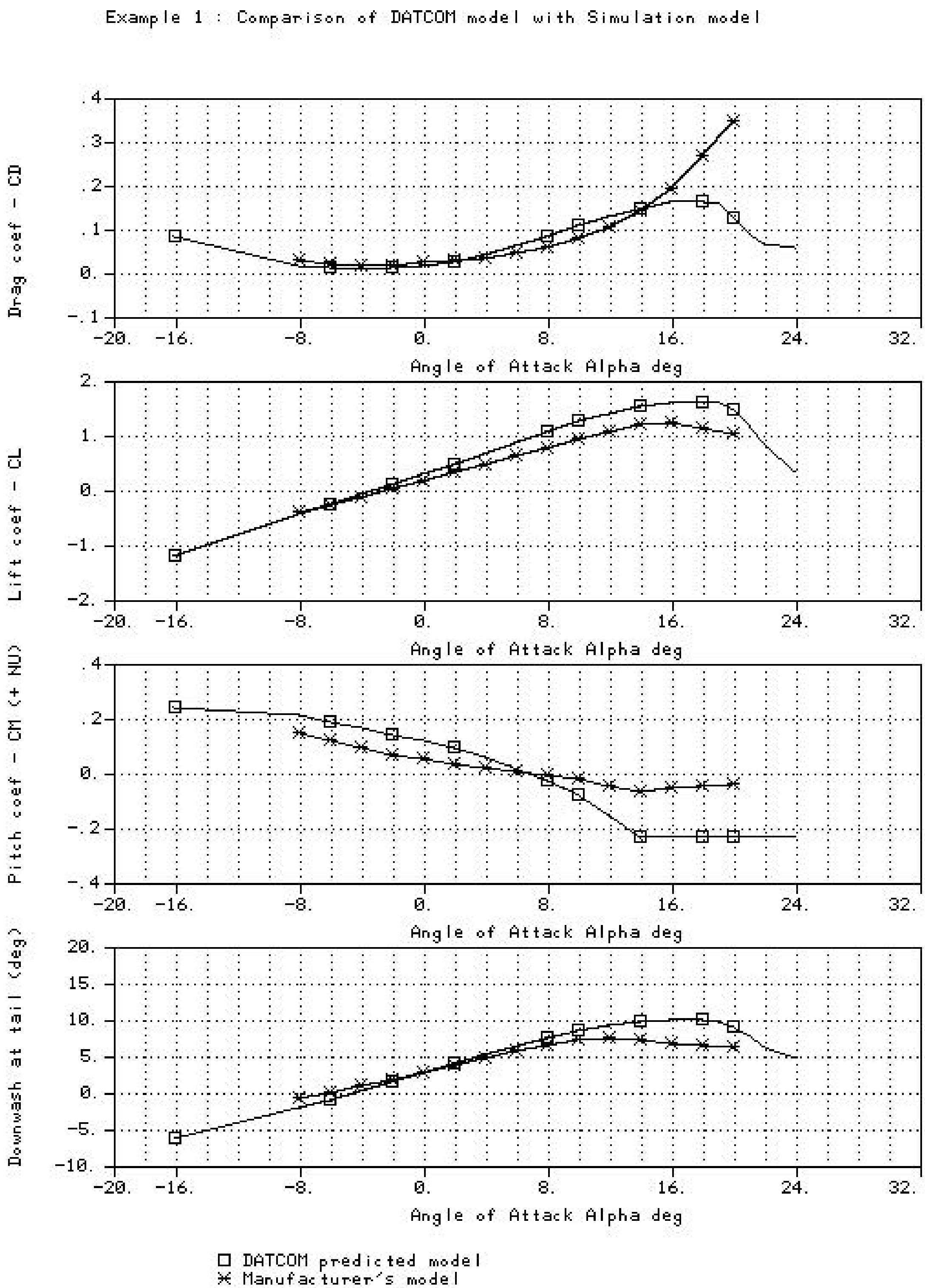
```
lfiplot  citation.lfi  scn  7
```

to see the basic lift coefficient plot.

Appendix A

Example 1 Aircraft

Selected Coefficient Comparisons



Example 1 : Comparison of DATCOM model with Simulation model
Drag coef - CD
Lift coef - CL
Pitch coef - CM (+ NU)
Downwash at tail (deg)
Angle of Attack Alpha deg
-20. -16. -8. 0. 8. 16. 24. 32.
DATCOM predicted model
Manufacturer's model

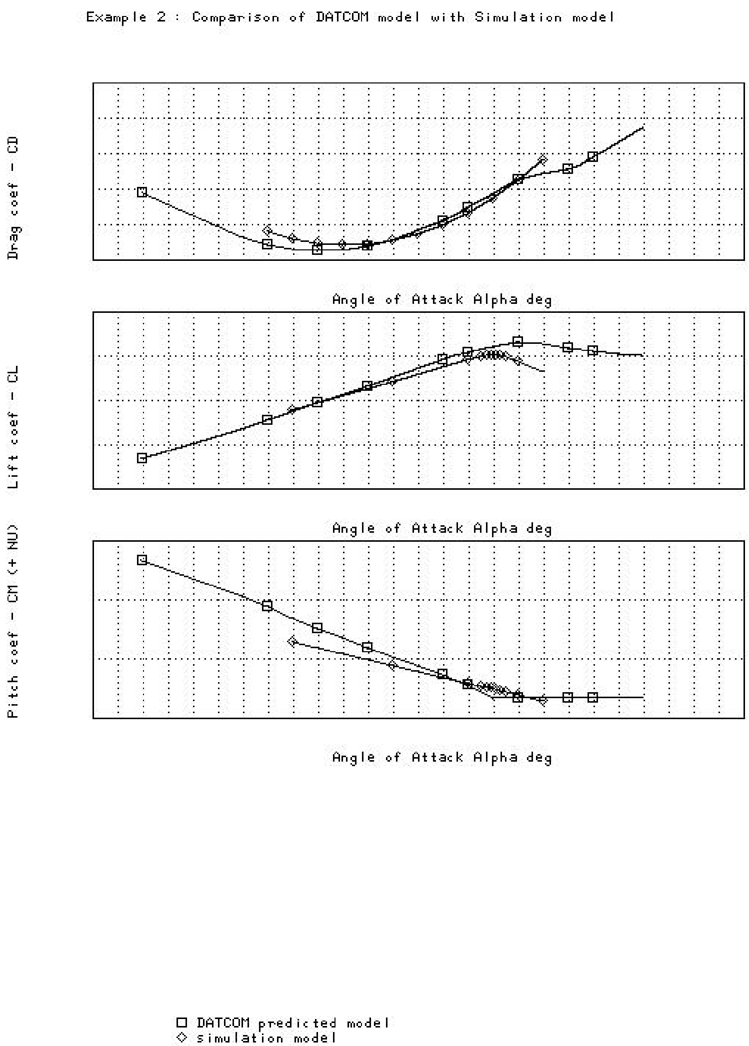
Appendix B

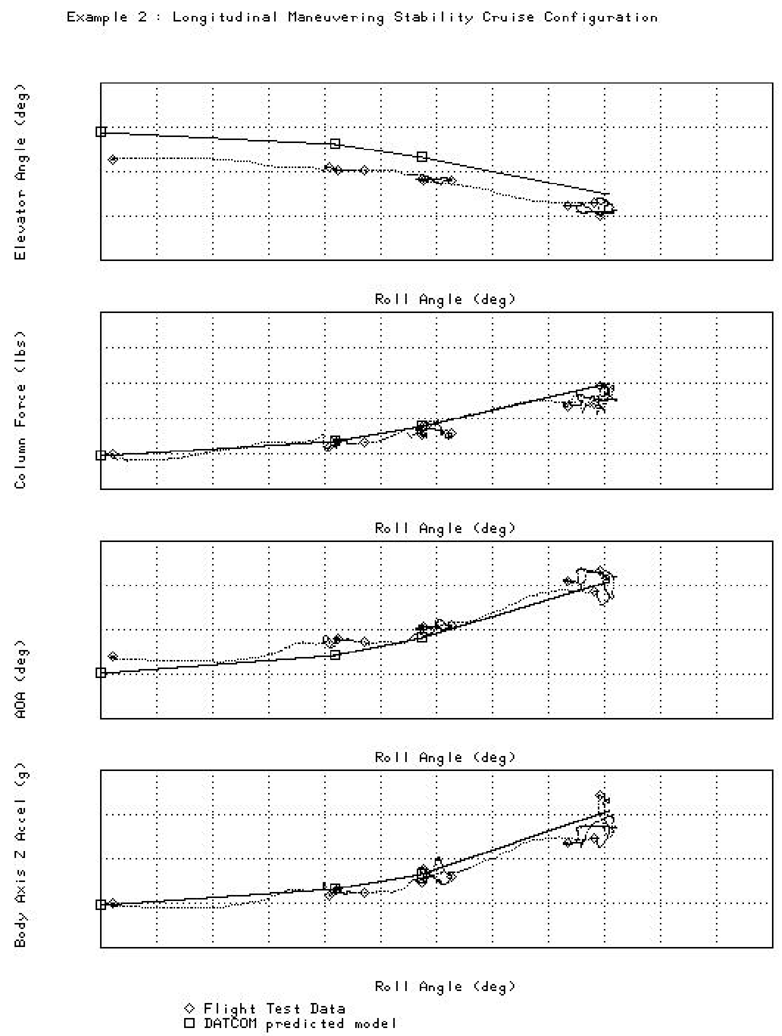
Example 2 Aircraft

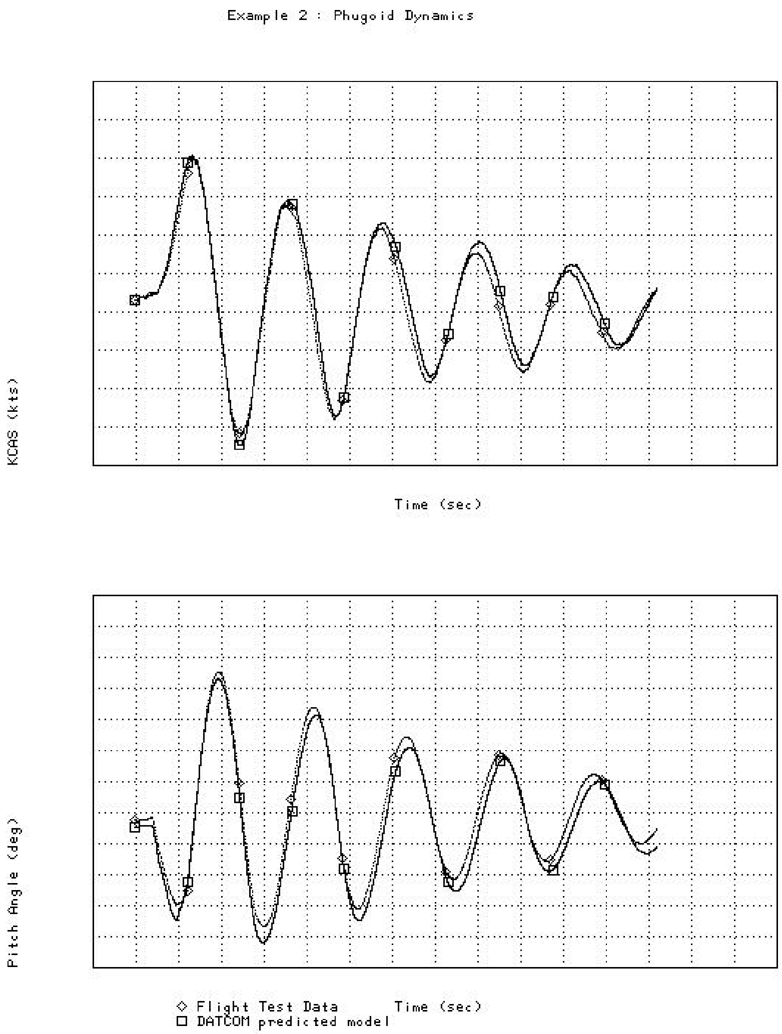
Selected Coefficient and

Flight Test Results Comparisons

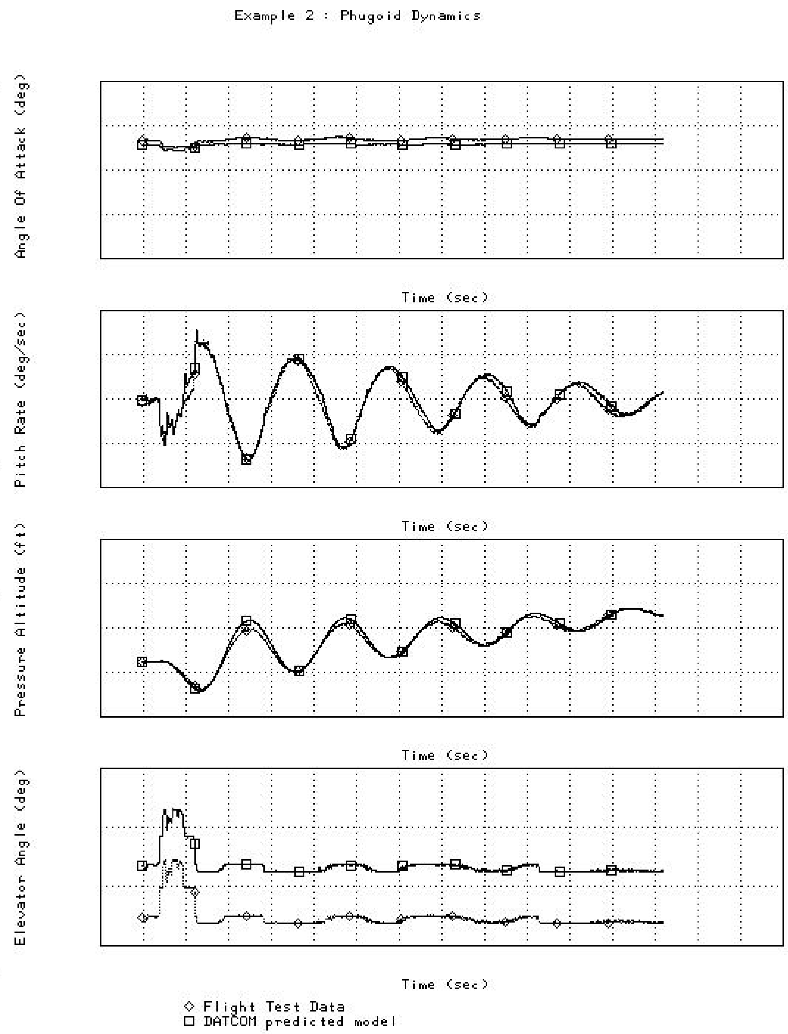
(units on axes intentionally omitted)


Example 2 : Comparison of DATCOM model with Simulation model
Drag coef - CD
Angle of Attack Alpha deg
Lift coef - CL
Angle of Attack Alpha deg
Pitch coef - CM (+ NU)
Angle of Attack Alpha deg
DATCOM predicted model
simulation model

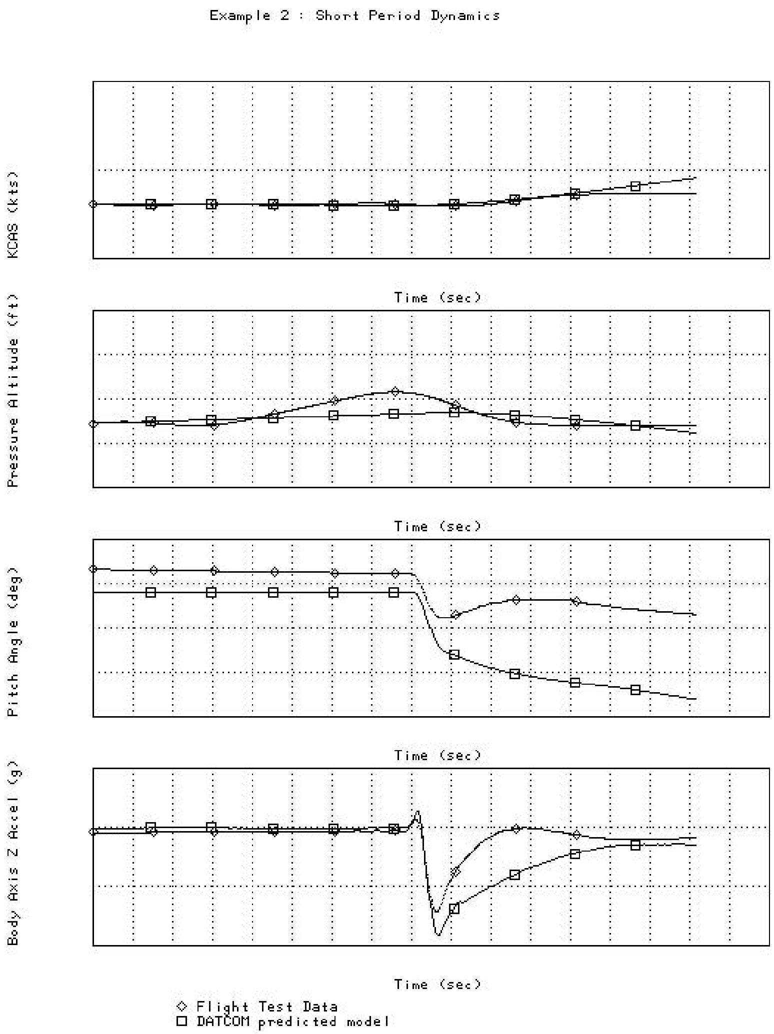

Example 2 : Longitudinal Maneuvering Stability Cruise Configuration
Elevator Angle (deg)
Roll Angle (deg)
Column Force (lbs)
Roll Angle (deg)
AOA (deg)
Roll Angle (deg)
Body Axis Z Accel (g)
Roll Angle (deg)
Flight Test Data
DATCOM predicted model

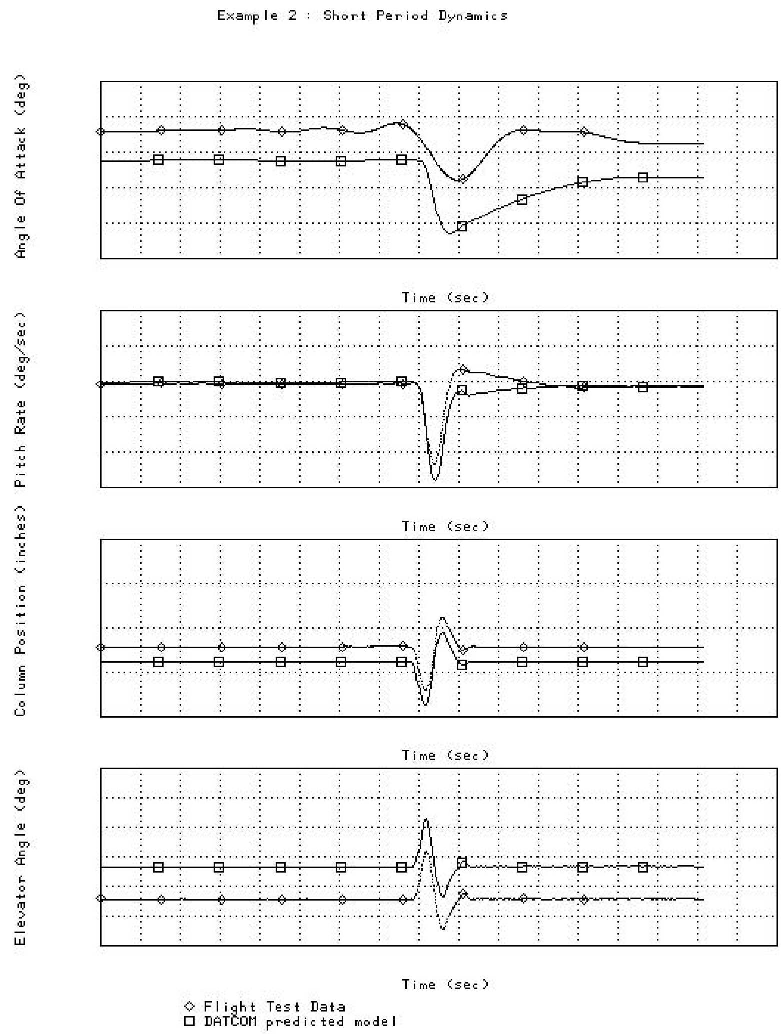


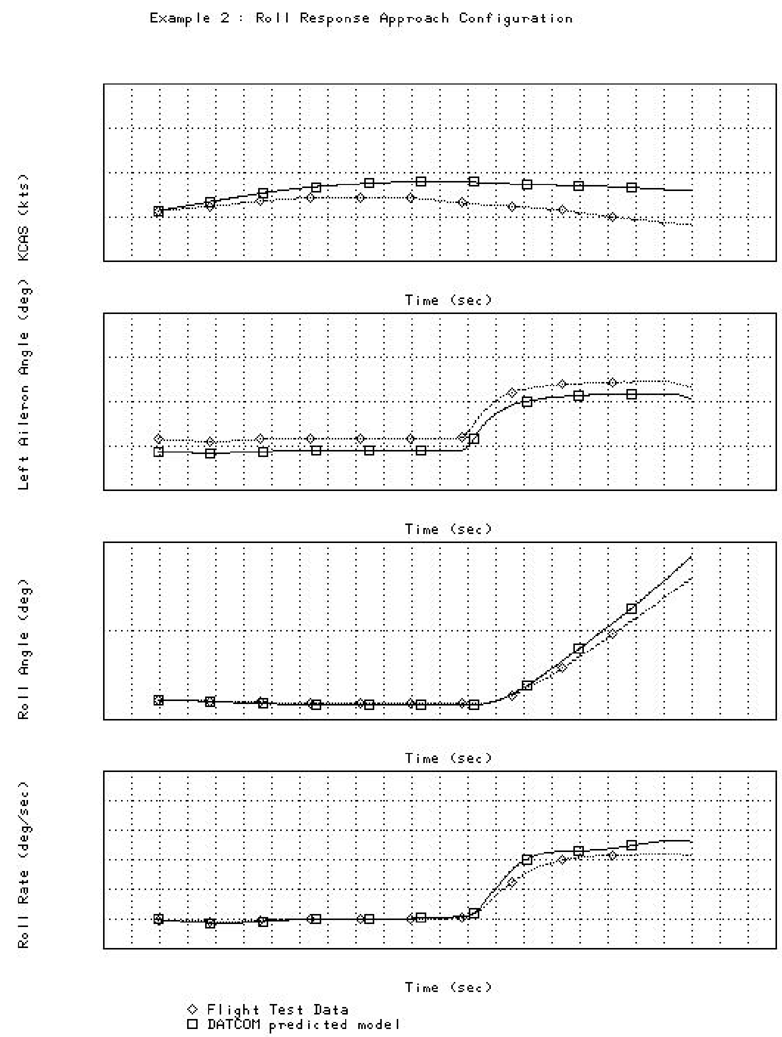
Example 2 : Phugoid Dynamics
KCAS (kts)
Time (sec)
Pitch Angle (deg)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model

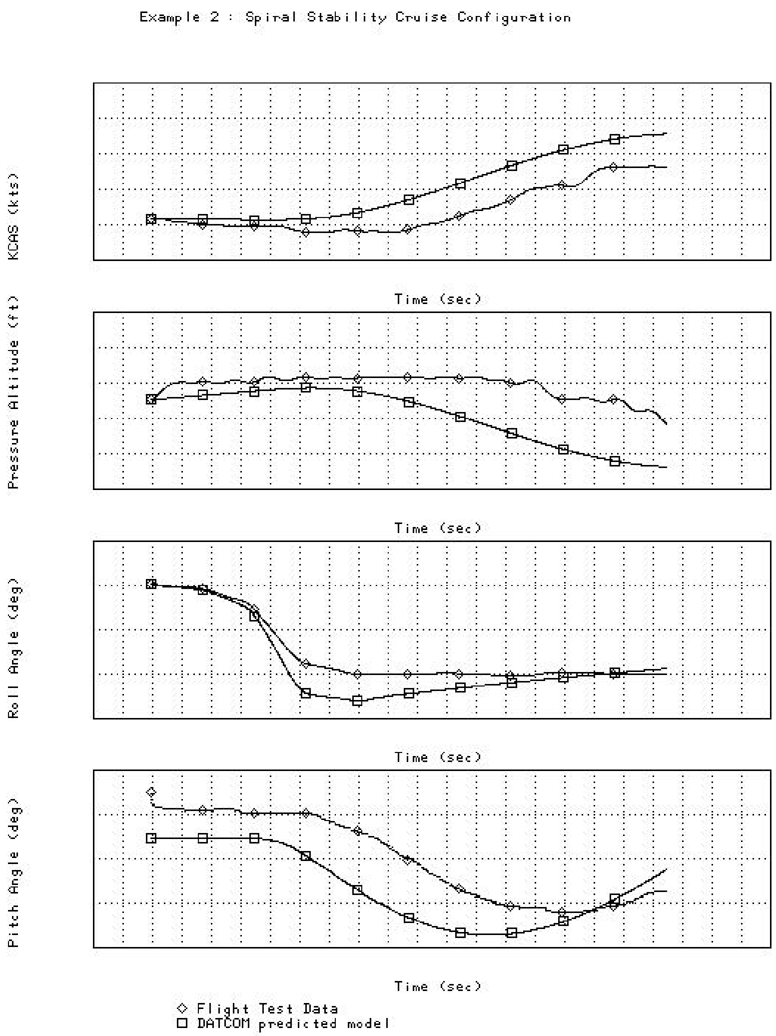


Example 2 : Phugoid Dynamics
Angle Of Attack (deg)
Time (sec)
Pitch Rate (deg/sec)
Time (sec)
Pressure Altitude (ft)
Time (sec)
Elevator Angle (deg)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model

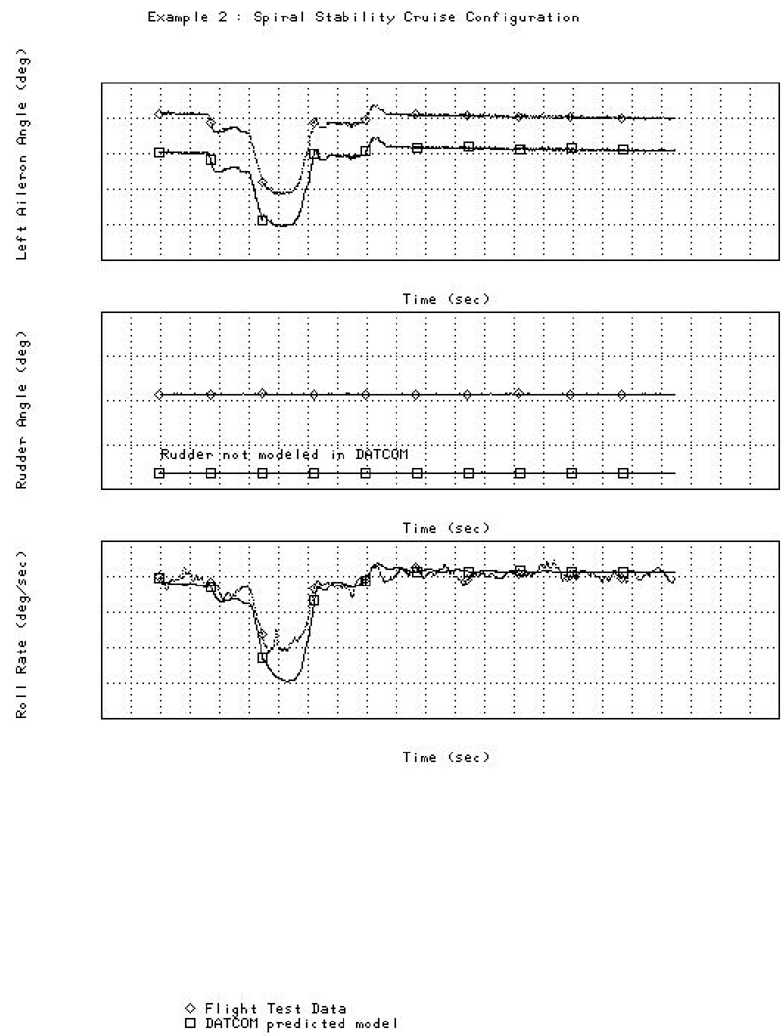

Example 2 : Short Period Dynamics
KCAS (kts)
Pressure Altitude (ft)
Pitch Angle (deg)
Body Axis Z Accel (g)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model


Example 2 : Short Period Dynamics
Angle Of Attack (deg)
Pitch Rate (deg/sec)
Column Position (inches)
Elevator Angle (deg)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model

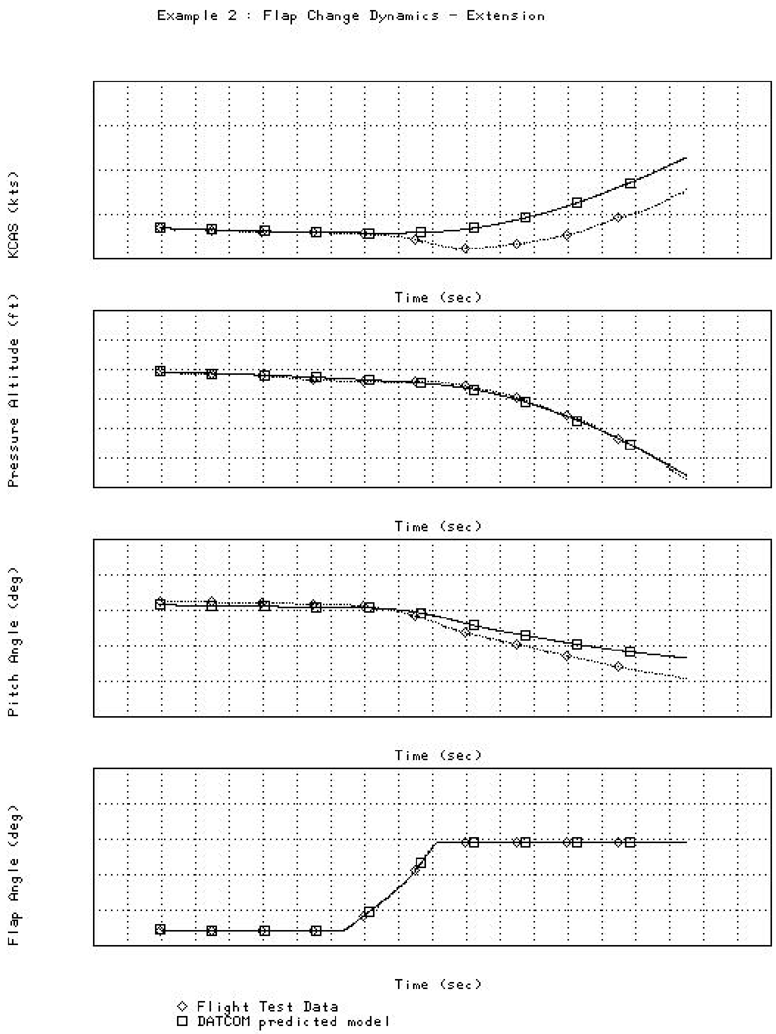

Example 2 : Roll Response Approach Configuration
KCAS (kts)
Time (sec)
Left Aileron Angle (deg)
Time (sec)
Roll Angle (deg)
Time (sec)
Roll Rate (deg/sec)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model

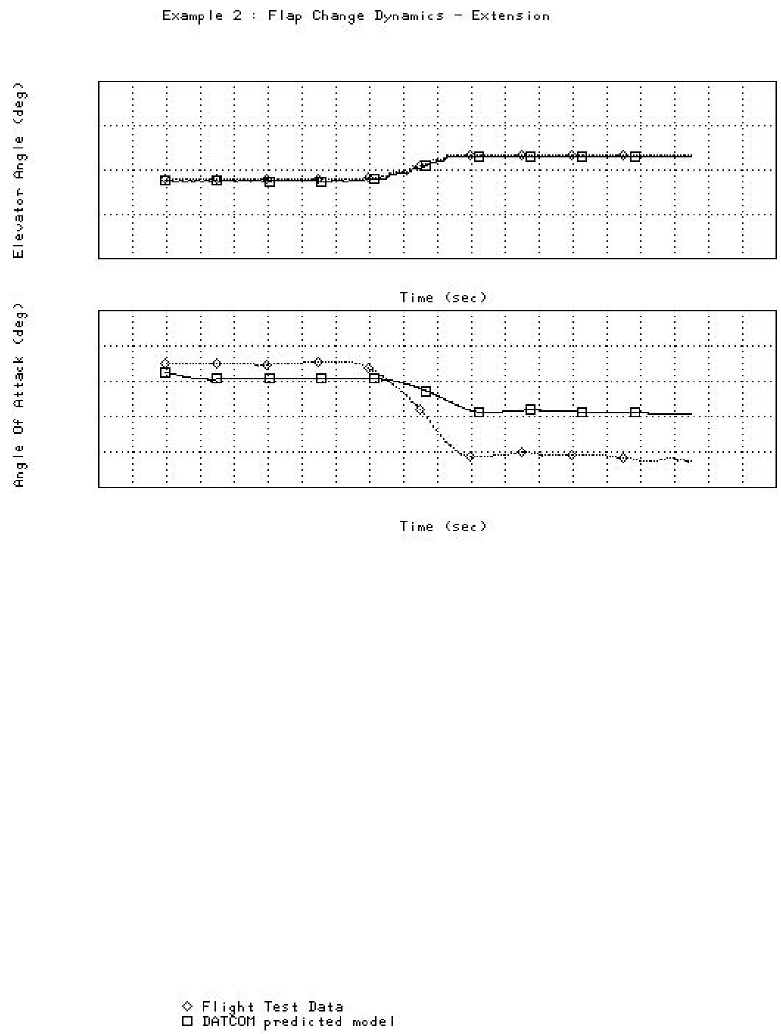


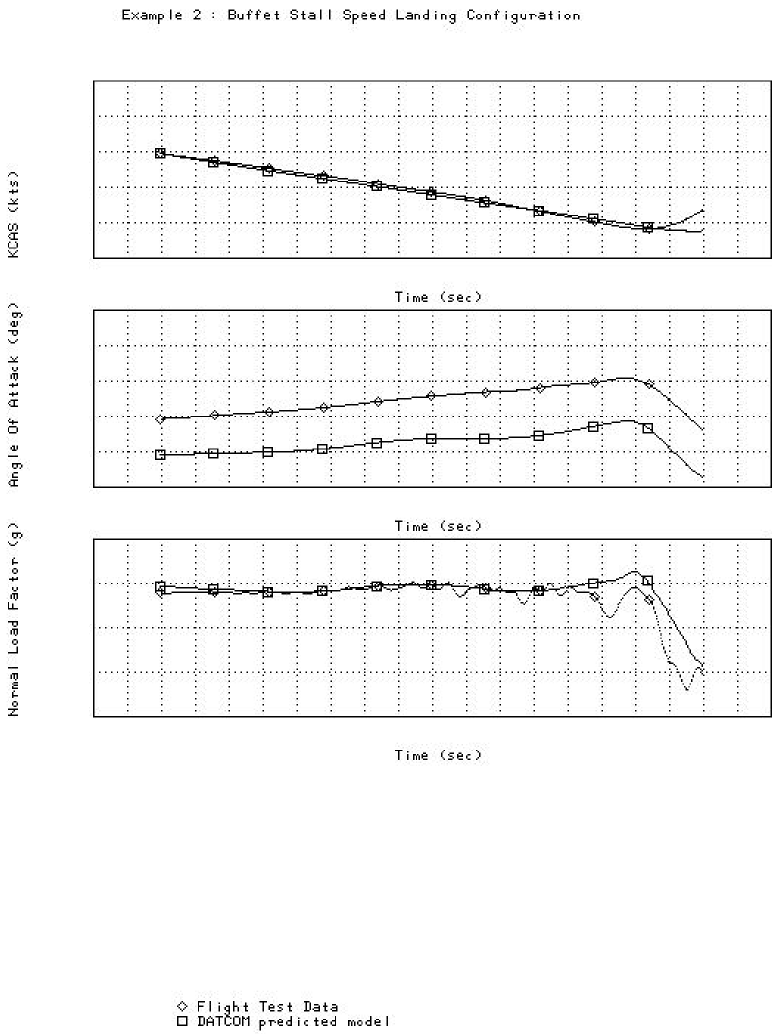
Example 2 : Spiral Stability Cruise Configuration
KCAS (kts)
Time (sec)
Pressure Altitude (ft)
Time (sec)
Roll Angle (deg)
Time (sec)
Pitch Angle (deg)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model

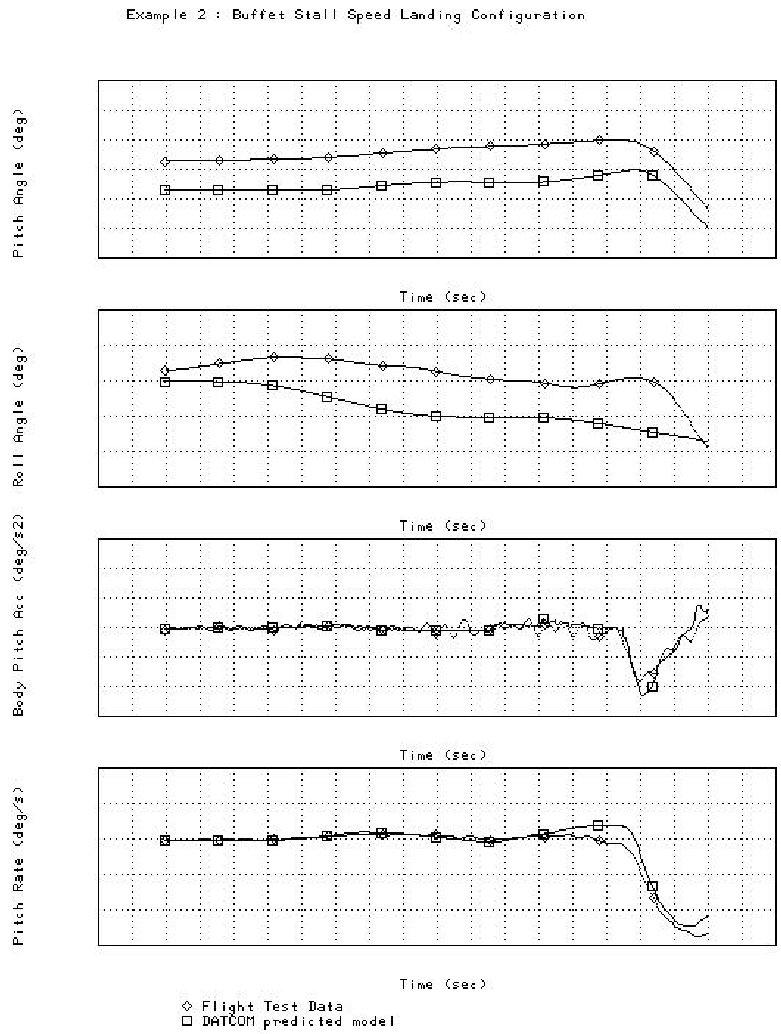


Example 2 : Spiral Stability Cruise Configuration
Left Aileron Angle (deg)
Time (sec)
Rudder Angle (deg)
Rudder not modeled in DATCOM
Time (sec)
Roll Rate (deg/sec)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model


Example 2 : Flap Change Dynamics - Extension
KCAS (kts)
Time (sec)
Pressure Altitude (ft)
Time (sec)
Pitch Angle (deg)
Time (sec)
Flap Angle (deg)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model


Example 2 : Flap Change Dynamics - Extension
Elevator Angle (deg)
Time (sec)
Angle Of Attack (deg)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model


Example 2 : Buffet Stall Speed Landing Configuration
KCAS (kts)
Time (sec)
Angle Of Attack (deg)
Time (sec)
Normal Load Factor (g)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model


Example 2 : Buffet Stall Speed Landing Configuration
Pitch Angle (deg)
Time (sec)
Roll Angle (deg)
Time (sec)
Body Pitch Acc (deg/s2)
Time (sec)
Pitch Rate (deg/s)
Time (sec)
◇ Flight Test Data
□ DATCOM predicted model