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THE APPLICATION OF TSIM SOFTWARE TO ACT DESIGN AND ANALYSIS ON FLEXIBLE AIRCRAFT

By

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ABSTRACT

The TSIM software is described. This is a package which uses an interactive FORTRAN-like simulation language for the simulation on nonlinear dynamic systems and offers facilities which include: mixed continuous and discrete time systems, time response calculations, numerical optimization, automatic trimming of nonlinear aircraft systems, and linearization of nonlinear equations for eigenvalues, frequency responses and power spectral response evaluation.

Details are given of the application of TSIM to the analysis of aeroelastic systems under the RAE Farborough extension FLEX-SIM. The aerodynamic and structural data for the equations of motion of a flexible aircraft are prepared by a preprocessor program for incorporation in TSIM simulations. Within the simulation the flexible aircraft model may then be selected interactively for different flight conditions and modal reduction techniques applied. The use of FLEX-SIM is demonstrated by an example of the flutter prediction for a simple aeroelastic model.

By utilizing the numerical optimization facility of TSIM it is possible to undertake identification of required parameters in the TSIM model within the simulation. The optimizer is applied to the minimization of error between predicted and measured time responses of the system; while possibly not so efficient as dedicated identification software this has the great advantages that the identification is made directly involving the simulation model without further reprogramming or data transfer and it may be applied directly to nonlinear models. Examples are given of this analysis applied to aircraft measured responses and to simulated responses of a controlled aircraft with nonlinearities.

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PROGRAMME OBJECTIVES

1. Improvement of aeroelastic modelling techniques
2. ACT Design methods for structural applications
3. Assessment of structural impact of ACT

2. RAE FLEX-SIM

RAE EXPERIMENTAL PROGRAMMES

1. Flight data from flexible aircraft
   (VC10, Tornado)

2. Wind tunnel experiments
   (GARTEUR, 'flying model', spoiler tests)

3. RAE FLEX-SIM

AEROELASTIC MODELLING INPUT

a) STRUCTURAL MODAL DATA
   Calculated from mass and stiffness data by
   finite element or beam models AND/OR
   derived from ground resonance tests.
   Model reduction techniques used as appropriate.

b) AERODYNAMIC LOADINGS
   Calculated from geometric data by vortex lattice
   or RAE methods for steady and unsteady flow.

c) SENSOR and ACTUATOR DATA.
   Linearity assumed in these models.

4. RAE FLEX-SIM

AEROSERVOELASTIC MODEL

Combination of structural, aerodynamic, sensor and actuator data with the control system model.

Expressed in a first order form compatible with stability and control representations to allow integration between the aeroelastician and the S&C specialists.

Software required for response prediction and control design activities on these models.

5. RAE FLEX-SIM

TSIM

Time SIMulation

Non-linear dynamic simulation package

Originated and developed at RAE since late 1970s

Now documented, supported and developed as a commercial product by Cambridge Control

Used in RAE and in research organisations, aerospace industry and universities in Britain and overseas

6. RAE FLEX-SIM

TSIM FACILITIES

Interactive program using FORTRAN-like simulation language and facilitating modification of model

Simulation of linear and non-linear equations
Mixed continuous and discrete time systems
Time response calculation
Linearisation of non-linear equations for:
- Eigen values
- Frequency responses
- RMS response evaluation

Numerical optimisation
Automatic trimming of non-linear aircraft
Communication with other control design packages

7. RAE FLEX-SIM

SAMPLE OF TSIM SERIAL INTERACTION

```
SIM>
SIM>; Assign values to some TSIM variables:-
SIM>  ZPOSA 0.9  DAMPA 0.7  RTB 15
SIM>
SIM>; Enter the time response set-up module and
SIM>; define the required parameters:-
SIM>  SET TIME_RESP
SIM>
SET TIME_RESP: OUTPUT 1 NZB 2 BMR 3 TWG
SET TIME_RESP: SCALE 2 -0.8 0.8
SET TIME_RESP: RKUTTA 0.4, 0.002, 0.01
SET TIME_RESP: STEP BGO 0.0, -0.1, -0.6
SET TIME_RESP:
SIM>; Now run the time response module:-
SIM>  RUN TIME_RESP
```

8. RAE FLEX-SIM

FLEX-SIM: APPLICATION OF TSIM TO FLEXIBLE AIRCRAFT

PRE-PROCESSING FUNCTIONS:

a) structural data processing
b) aerodynamics calculations and modification
c) loads, actuator and sensor modelling
d) model reduction and combination
e) TSIM model generation

TSIM-CONCURRENT FUNCTIONS:

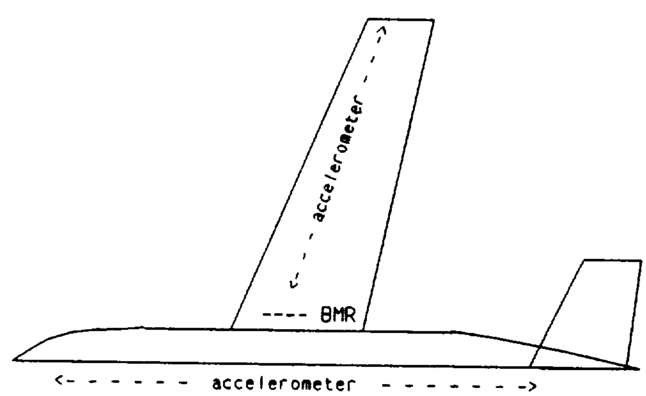
f) generation of aeroelastic input functions
g) order reduction and changes of flight conditions in the flexible aircraft model
h) flight loads and sensor response calculation
i) presentation of results

POST-PROCESSING FUNCTION:

j) analysis of aeroservoelastic results

9. RAE FLEX-SIM

DEMONSTRATION LOAD ALLEVIATION - AIRCRAFT

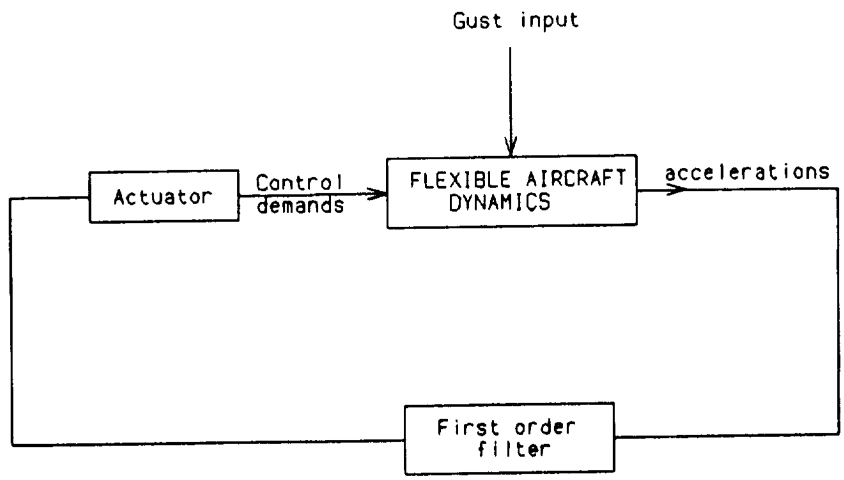


OBJECTIVE: reduction of wing loads in turbulence through outboard wing controls

INVESTIGATION: sensor location and combination

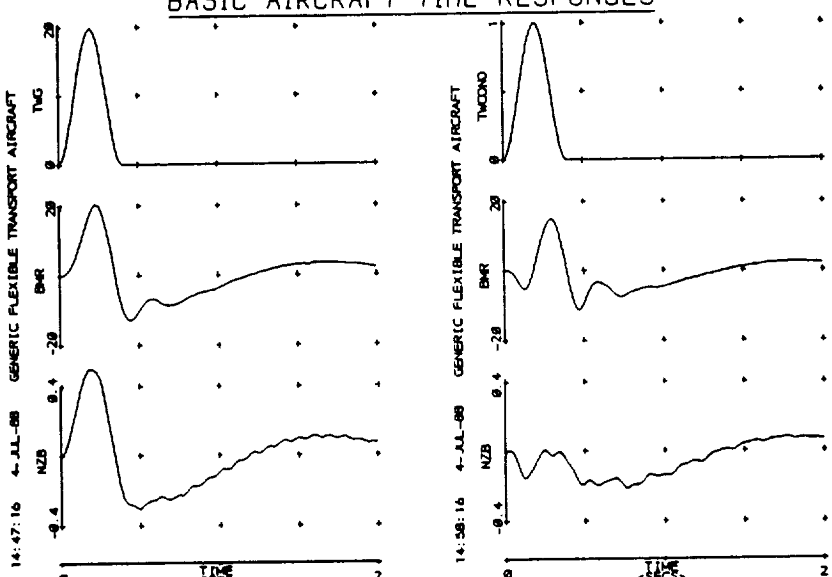
10. RAE FLEX-SIM

DEMONSTRATION LOAD ALLEVIATION - SYSTEM



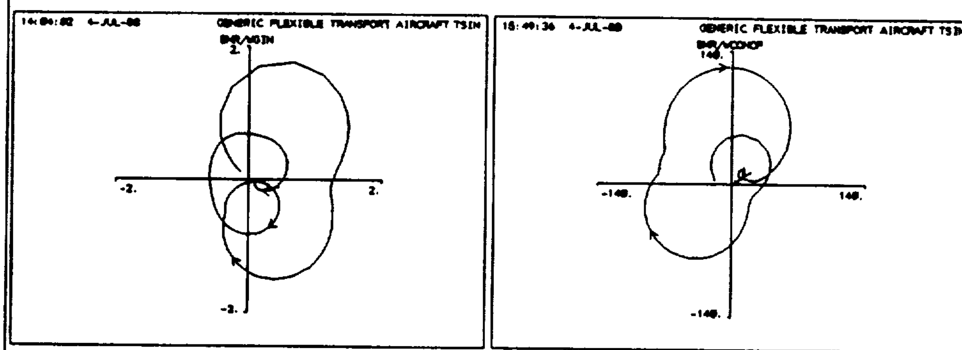
11. RAE FLEX-SIM

BASIC AIRCRAFT TIME RESPONSES



12. RAE FLEX-SIM

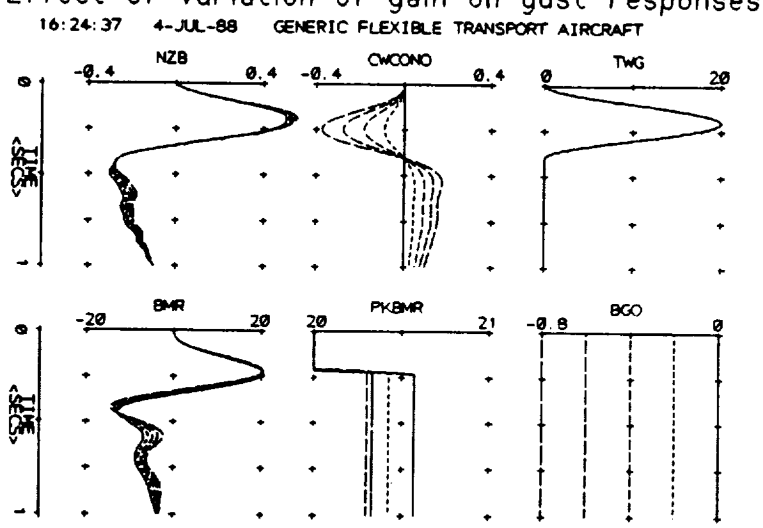
BASIC AIRCRAFT FREQUENCY RESPONSES



13. RAE FLEX-SIM

GLA WITH ACCELEROMETER AT CG

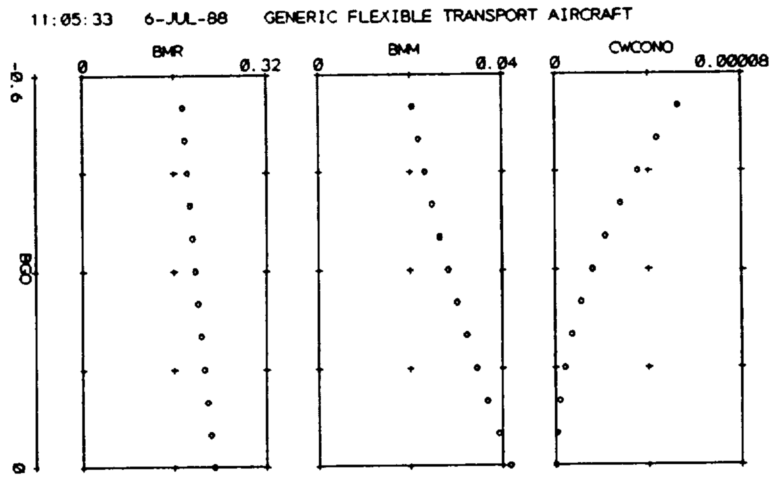
Effect of variation of gain on gust responses



14. RAE FLEX-SIM

GLA WITH ACCELEROMETER AT CG

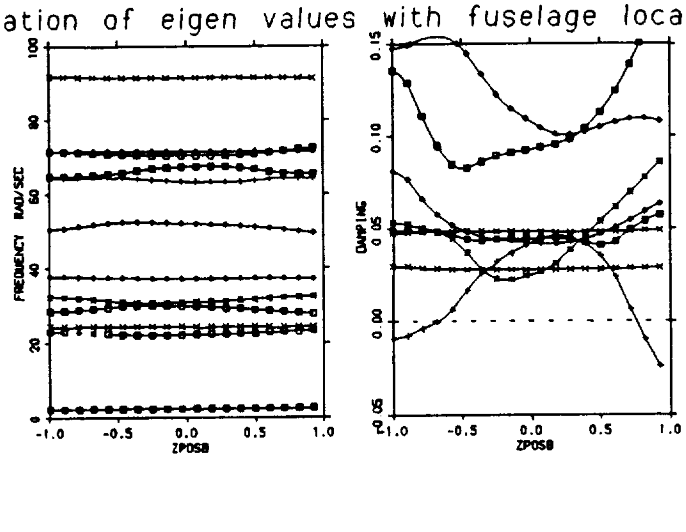
Effect of variation of gain on PSD gust responses



15. RAE FLEX-SIM

GLA WITH ACCELEROMETER IN FUSELAGE

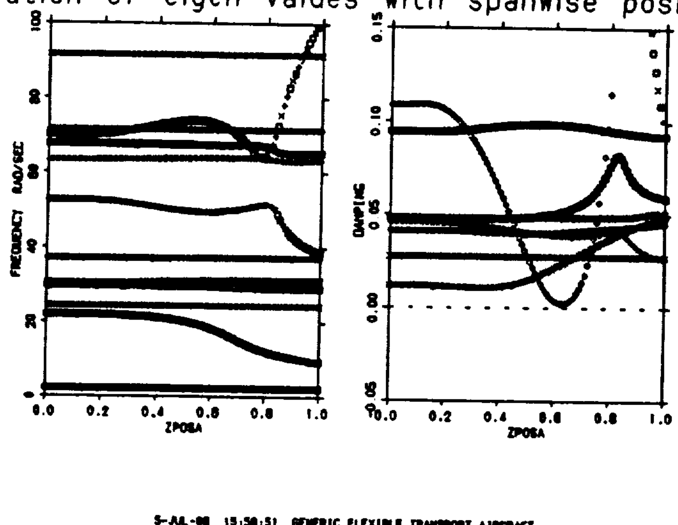
Variation of eigen values with fuselage location



16. RAE FLEX-SIM

GLA WITH ACCELEROMETERS ON WING AND AT CG

Variation of eigen values with spanwise position

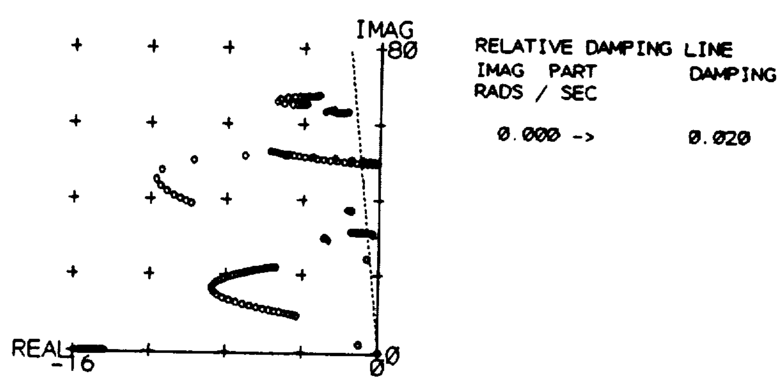


17. RAE FLEX-SIM

GLA WITH ACCELEROMETERS ON WING AND AT CG

Root locus with spanwise position

11:34:34 5-JUL-88 GENERIC FLEXIBLE TRANSPORT AIRCRAFT

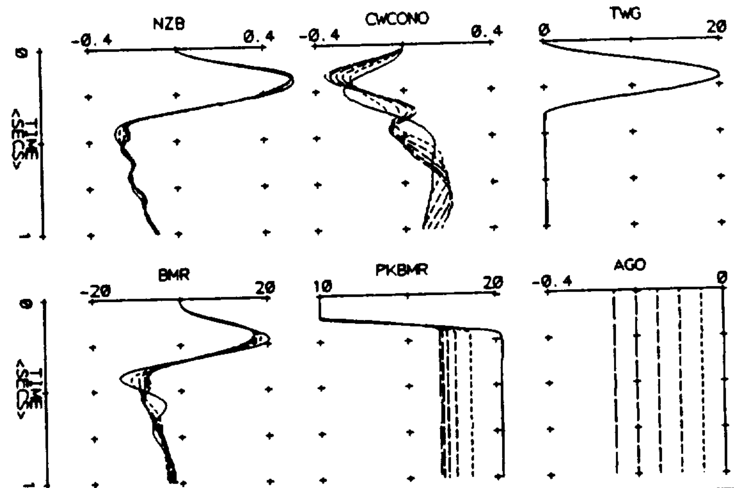


18. RAE FLEX-SIM

GLA WITH ACCELEROMETERS ON WING AND AT CG

Effect of wing tip accel gain variations, time

10:06:43 7-JUL-88 GENERIC FLEXIBLE TRANSPORT AIRCRAFT

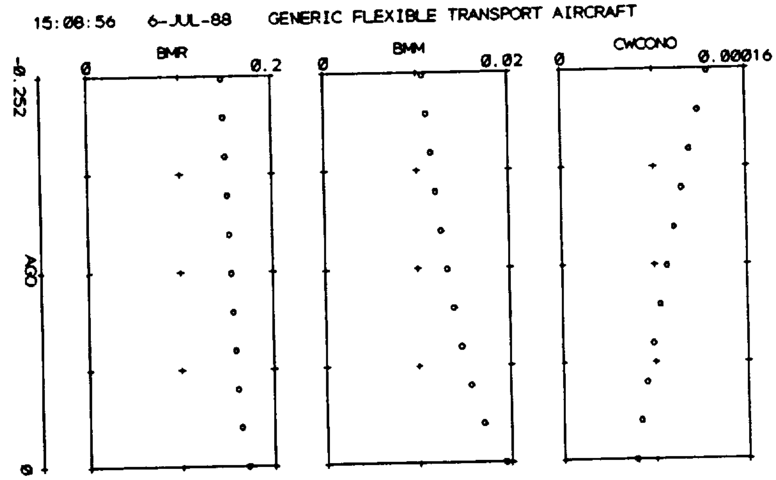


19. RAE FLEX-SIM

GLA WITH ACCELEROMETERS ON WING AND AT CG

Effect of wing tip accel gain variations, PSD

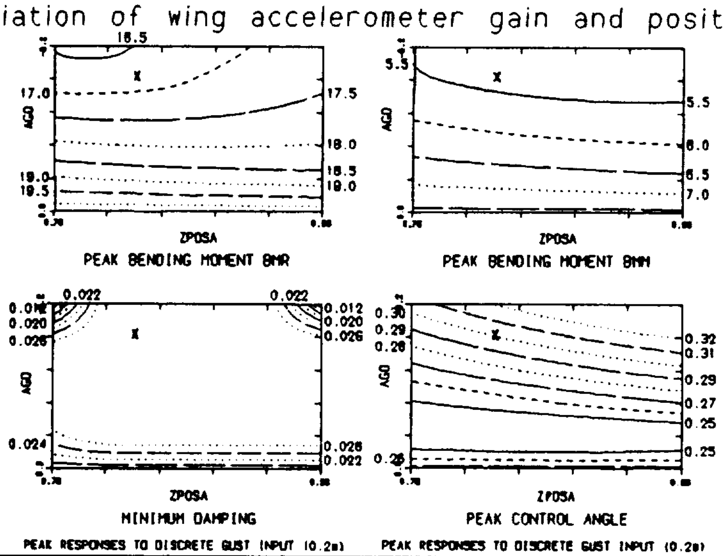
15:08:56 6-JUL-88 GENERIC FLEXIBLE TRANSPORT AIRCRAFT



20. RAE FLEX-SIM

GLA WITH ACCELEROMETERS ON WING AND AT CG

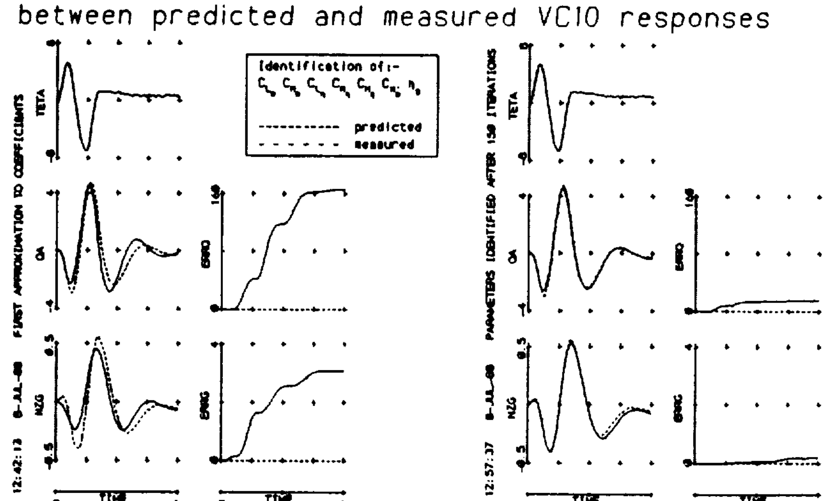
Variation of wing accelerometer gain and position



21. RAE FLEX-SIM

PARAMETER IDENTIFICATION VIA TSIM

Numerical optimisation to minimise G and Q errors between predicted and measured VC10 responses



22. RAE FLEX-SIM