N90-10089

DYSCO - A SOFTWARE SYSTEM FOR MODELING GENERAL DYNAMIC SYSTEMS

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ABSTRACT

The DYSCO program has been under development since 1979. It has been funded by Army and Air Force laboratories and by the Kaman Aerospace Corporation. It is presently available at a number of government and nongovernment installations. It has been used to analyze a very broad range of dynamics problems.

A principle feature of the software design of DYSCO is the separation of the executive from the technology. The executive, which controls all the operations, is "intelligent" in the sense that it "knows" that its function is to assemble differential equations and to prepare them for solution. The "technology library" contains FORTRAN routines which perform standard functions, such as, computing the equation coefficients of an element (or "component") given the local state at any time. The technology library also contains algorithms and procedures for solving the coupled system equations.

The system was designed to allow easy additional of technology to the library. Any linear or nonlinear structural entity, control system, or set of ordinary differential equations may be simply coded and added to the library, as well as algorithms for time or frequency domain solution.

The program ~~will be~~ is described with emphasis on its usefulness in easily modeling unusual concepts and configurations, performing analysis of damage, evaluating new algorithms, and simulating dynamic tests. Illustrations of several typical and illustrative applications ~~will be~~ presented. A summary of the technology presently residing in the technology libraries at the various sites ~~will also be~~ given.
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DYSCO - A SOFTWARE SYSTEM FOR MODELING GENERAL DYNAMIC SYSTEMS

ALEX BERMAN
KAMAN AEROSPACE CORPORATION

WORKSHOP ON COMPUTATIONAL ASPECTS IN THE CONTROL OF FLEXIBLE SYSTEMS
WILLIAMSBURG, VIRGINIA, JULY 12-14, 1988

INTRODUCTION TO DYSCO

- o DYNAMIC SYSTEM COUPLER (DYSCO)
- o INITIAL DEVELOPMENT - 1979
- o FUNDED BY ARMY, AIR FORCE, KAMAN
- o PRESENTLY OPERATIONAL ON IBM AND VAX
- o SIZE - 50000+ LINES OF CODE
  350+ SUBROUTINES
  4+ MEGABYTES OF STORAGE

DEFINITION OF DOMAIN OF DYSCO

DYSCO COUPLES AND SOLVES SECOND ORDER ODE

- $M_I \ddot{X}_I + C_I \dot{X}_I + K_I X_I = F_I$ (COMPONENT I)
- $X_I = T_I X_S$
- $M_S \ddot{X}_S + C_S \dot{X}_S + K_S X_S = F_S$ (SYSTEM)

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DEFINITION OF COMPONENT

- o "COMPONENT" IS MORE GENERAL THAN "FINITE ELEMENT"
- o M_I, C_I, K_I, F_I = ARBITRARY FUNCTIONS OF STATE
- o X_I = ANY GENERALIZED DOF - PHYSICAL, MODAL, OTHER
- o COMPONENT MAY BE
  - FINITE ELEMENT
  - ASSEMBLY OF FINITE ELEMENTS (SUBSYSTEM, OUTPUT OF FE ANALYSIS)
  - SPECIAL SET OF EQUATIONS (E.G., HELICOPTER ROTOR, SPECIAL MECHANISM)
  - CONTROL ALGORITHM (MIMO, NON-SYMMETRICAL MATRICES, NONLINEAR)
  - FORCE ALGORITHM (M, C, K = NULL, AERO, ELECTROMAGNETIC)
  - ETC., ETC.

DEFINITION OF MODEL

- A MODEL IS A DESCRIPTION OF A COUPLED SET OF COMPONENT EQUATIONS
- COMPONENT EQUATIONS ARE DEFINED BY
  - NAME OF THE ALGORITHM IN "TECHNOLOGY LIBRARY"
  - NAME OF DATA SET IN "MODELING DATABASE"
- COMMAND "RUN" COUPLES EQUATIONS
- NEXT STEP IS TO SPECIFY SOLUTION ALGORITHM

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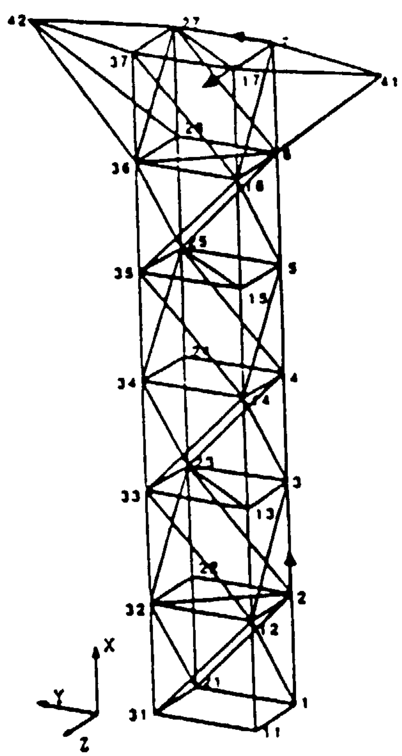
ILLUSTRATIVE MODEL



	COMPONENT	NO.	DATA SET
1	CTR4	1	ABCD1
2	CTR4	3	ABCD1
3	CTR4	5	ABCD1
4	CTR4	2	ABCD2
5	CTR4	4	ABCD2
6	CTR4	6	ABCD2
7	CSF1		TOPR
8	CSF1		TOPL
9	CSF1		CONTR
10	CLC1		GROUND

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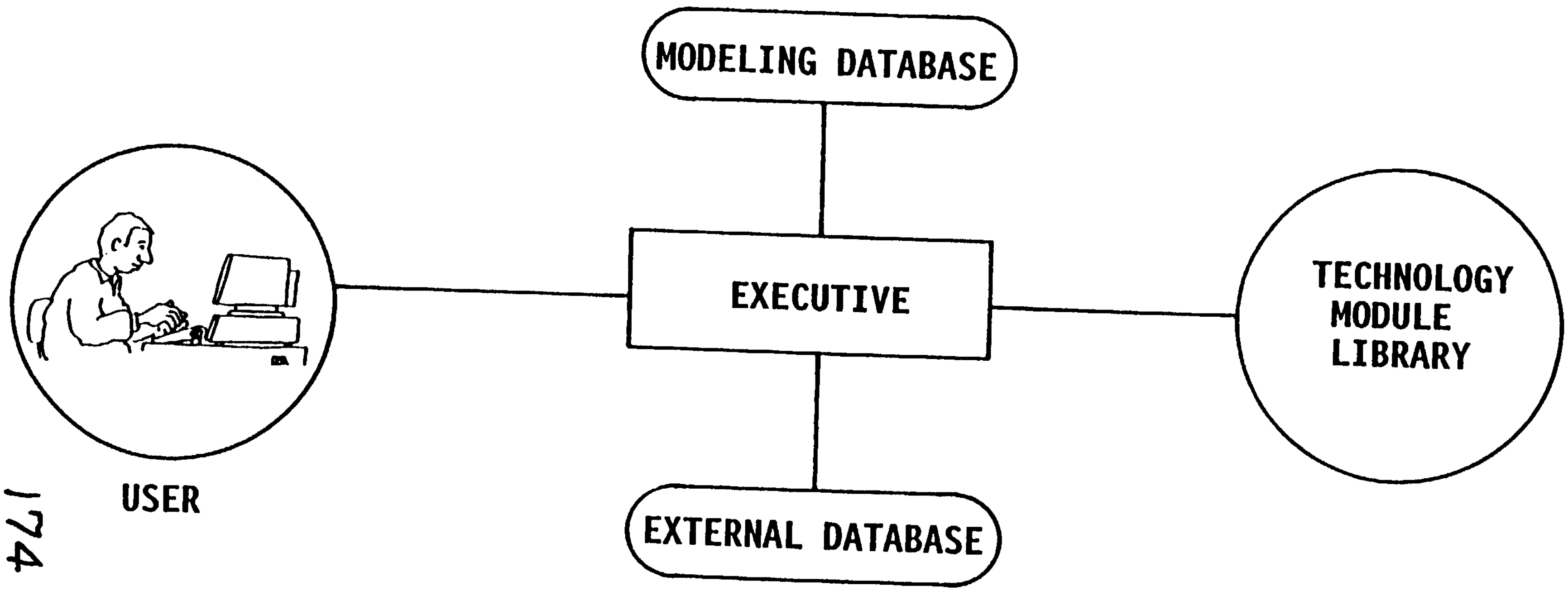
DYSCO SYSTEM OVERVIEW



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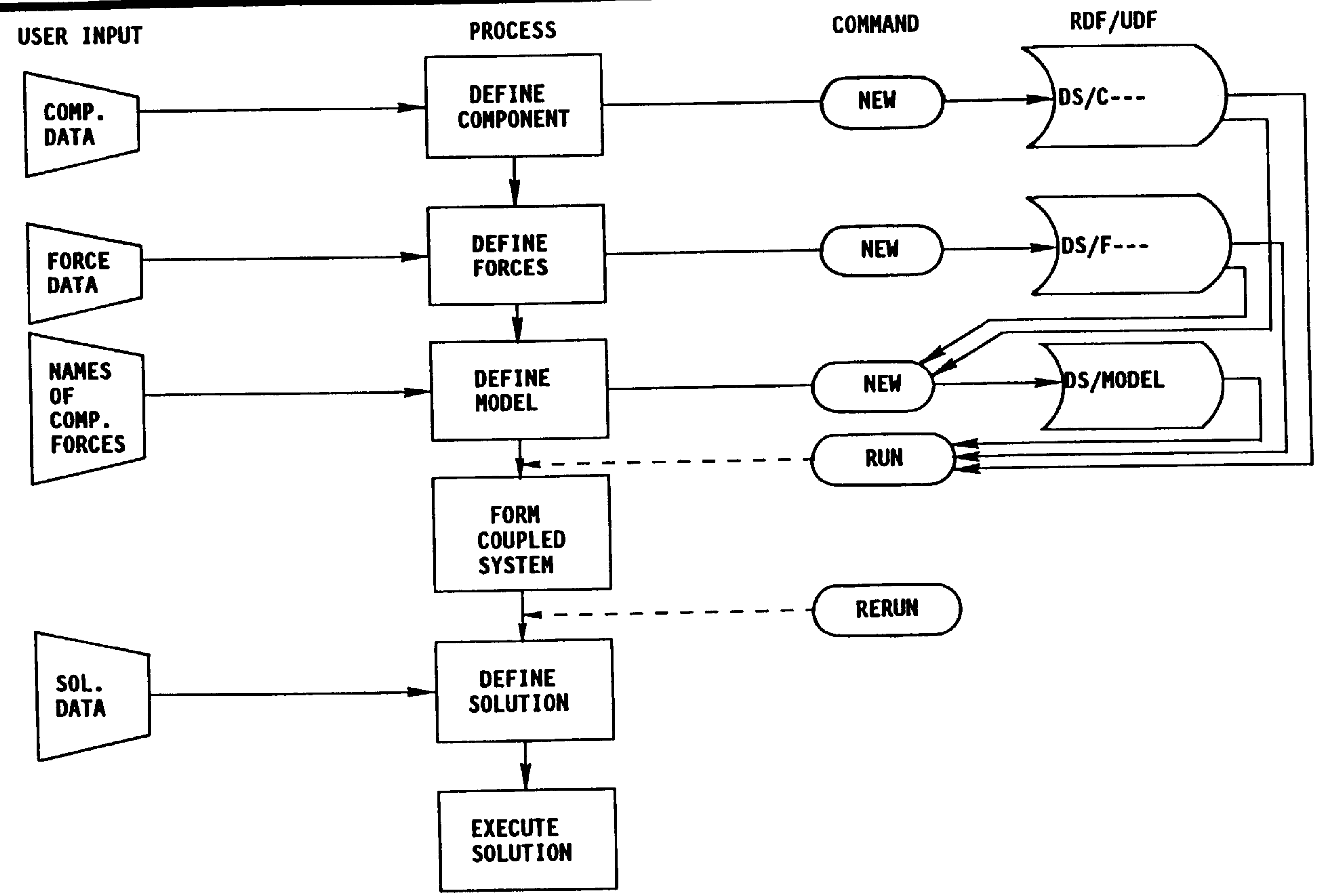
MODELING SCENARIO AND COMMAND RELATIONSHIP



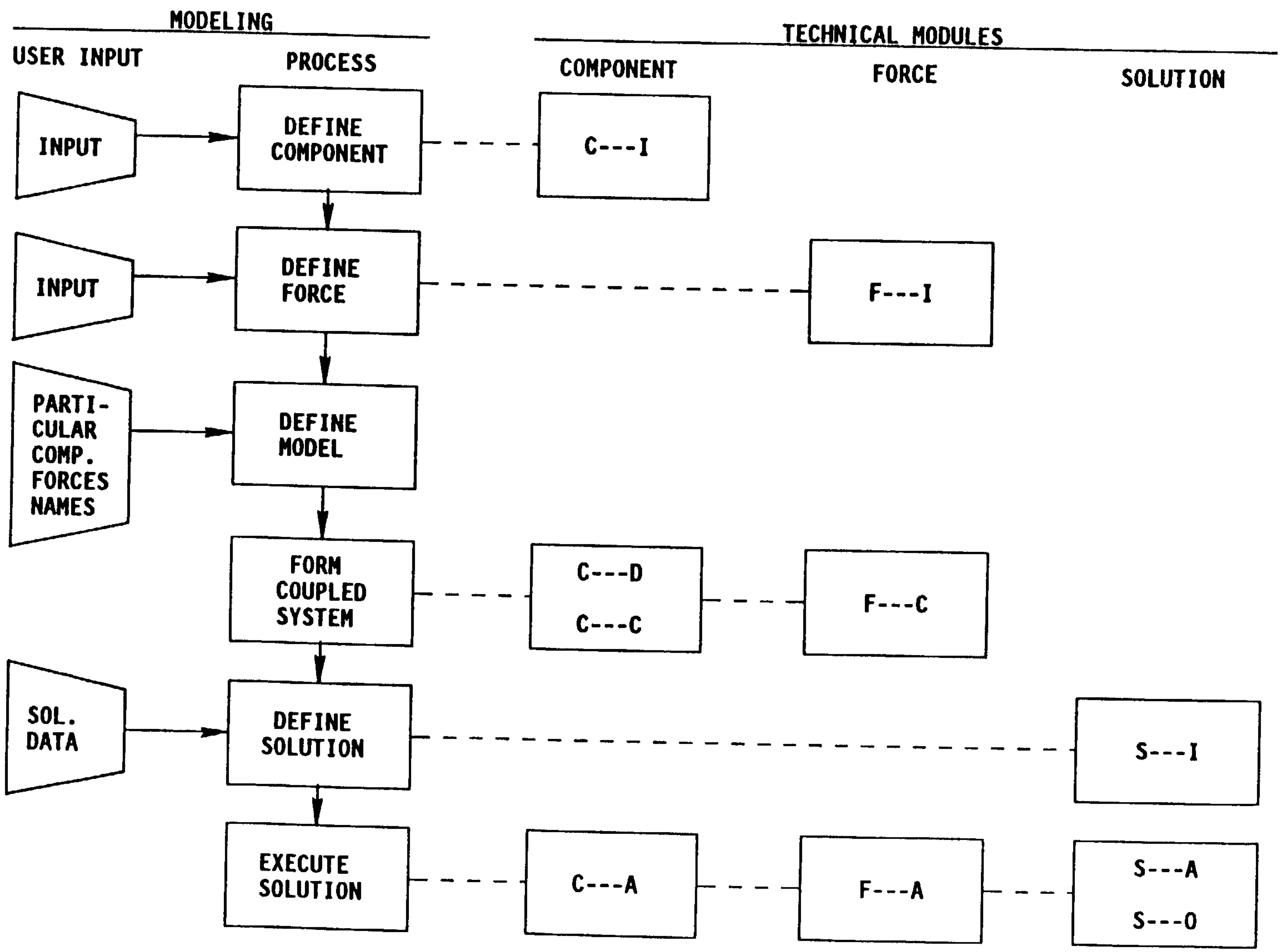
STANDARD TECHNICAL MODULES

FUNCTION	COMPONENT	FORCE	SOLUTION
INPUT	C---I	F---I	S---I
DEFINITION	C---D	N/A	N/A
COEFFICIENT	C---C	F---C	N/A
ACTIVE	C---A	F---A	S---A
OUTPUT	N/A	N/A	S---O
LOADS	C---L	N/A	N/A

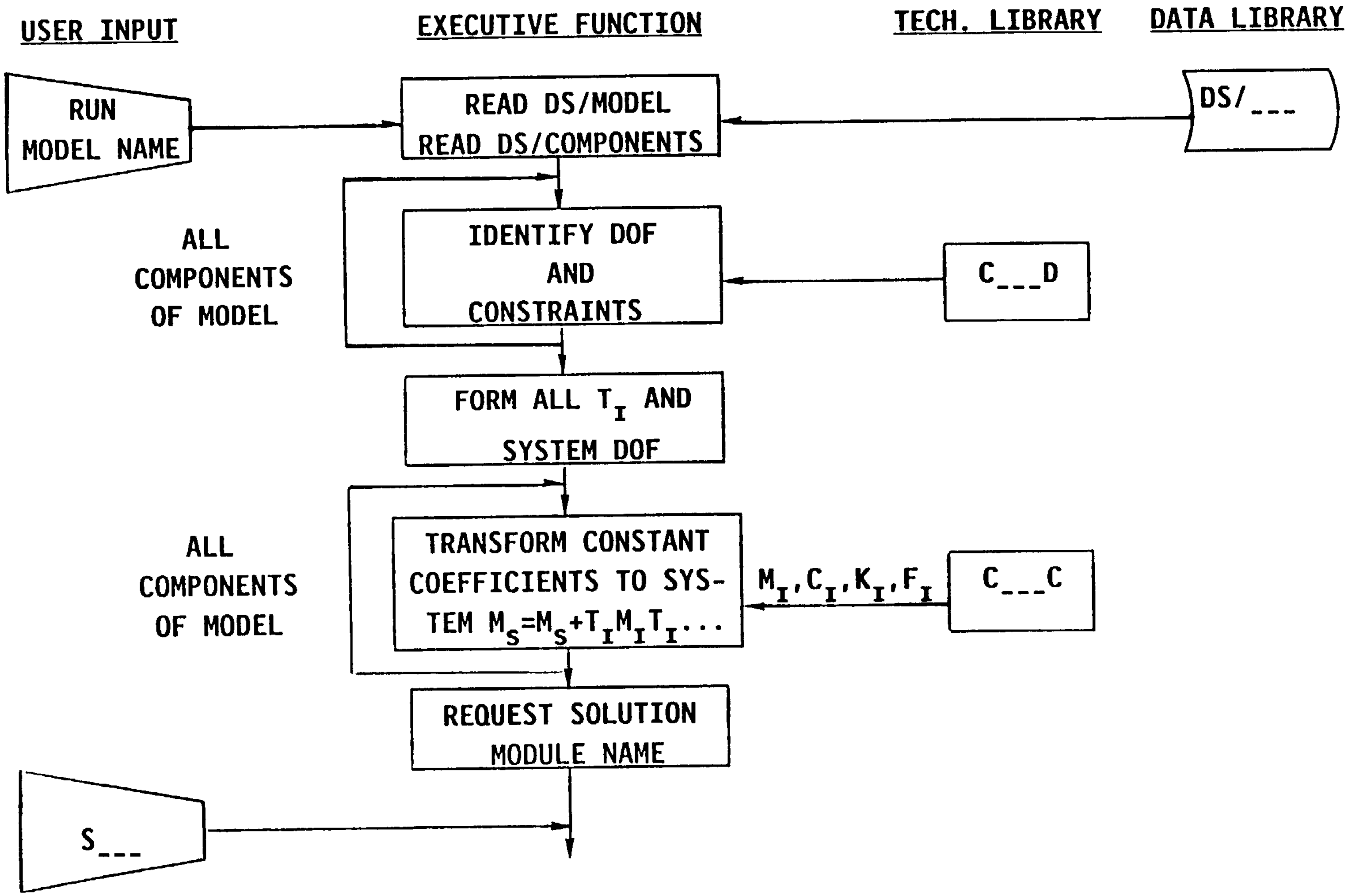
TECHNICAL MODULES

---I	INPUT DEFINITION
---D	DEFINE DEGREES OF FREEDOM
---C	COMPUTE CONSTANT COEFFICIENTS IN EQUATIONS
---A	COMPUTE NON-CONSTANT COEFFICIENTS, FUNCTION OF TIME AND STATE
---O	OUTPUT
---L	INTERNAL LOADS, FUNCTION OF STATE

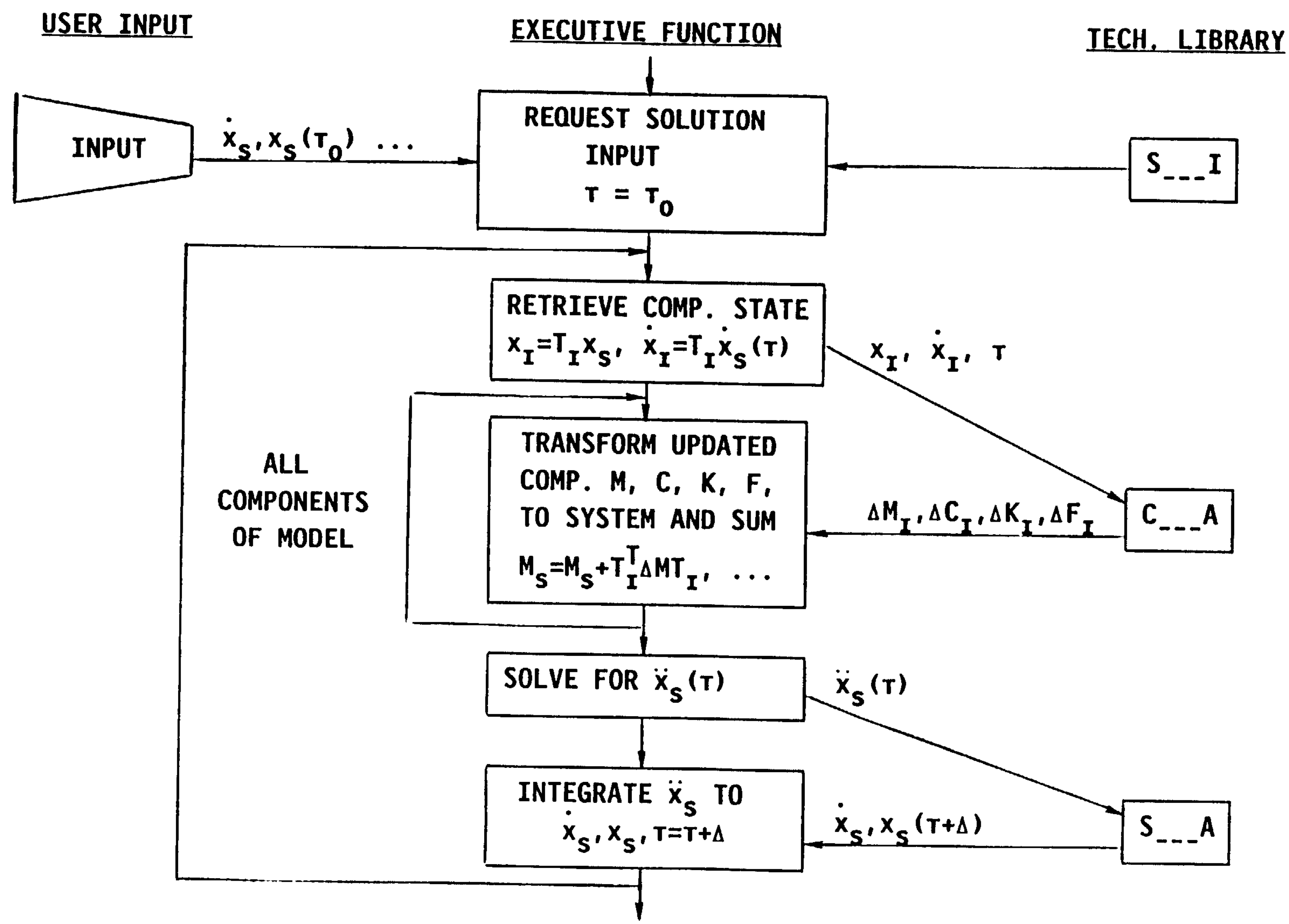
RELATIONSHIP BETWEEN MODELING SCENARIO AND TECHNICAL MODULES



RUN COMMAND
(ASSEMBLY OF MODEL)



TIME HISTORY SCENARIO
(CONTINUATION OF RUN)



FEATURES OF EXECUTIVE

- o EXECUTIVE IS SPECIFICALLY BUILT TO MANAGE STRUCTURAL DYNAMIC ANALYSIS
- o IT UNDERSTANDS AND MANAGES
  - INPUT: IDENTIFICATION, STORAGE, EDITING
  - MODEL BUILDING: RETRIEVAL OF DATA, CALLS TO TECHNOLOGY LIBRARY
  - ASSEMBLY OF EQUATIONS: APPLIES MPC, SPC
  - SOLUTION OF EQUATIONS: CALLS TO TECHNOLOGY LIBRARY, RETRIEVAL OF LOCAL STATES, INTERFACE LOADS
- o EXECUTIVE INDEPENDENT OF ANY PARTICULAR AREA OF TECHNOLOGY
  - UNIFORM ABSTRACT INTERFACES TO TECHNOLOGY LIBRARY

FEATURES OF TECHNOLOGY LIBRARY

- NEW TECHNOLOGY EASILY ADDED
  - COMPONENT, FORCE, SOLUTION
  - UNIFORM INTERFACES TO EXECUTIVE
  - FORTRAN CODING
- COMPONENTS ARE ANY SECOND ORDER ODE, SUCH AS,
  - SINGLE SPRING, DAMPER, OR MASS
  - ANY FINITE ELEMENT
  - COMPLETE NASTRAN MODEL
  - HELICOPTER ROTOR
  - MIMO CONTROL ALGORITHM
- SOLUTIONS ACT ON MODEL EQUATIONS, E.G.
  - EIGENANALYSIS
  - FREQUENCY RESPONSE
  - TIME HISTORY
  - HELICOPTER TRIM (PERIODIC SHOOTING)
  - PERIODIC SYSTEM STABILITY
  - STATE FEEDBACK OPTIMIZATION

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OTHER FEATURES

- o VALIDATED INPUT AND EDITING
  - USES KNOWLEDGE TABLE: TYPE, CHARACTERISTICS, EXISTENCE, RANGE
  - PROMPTED INPUT
  - INSTANTANEOUS VALIDATION
  - ASSURED COMPLETE AND CONSISTENT DATA

- o SIMPLE EDITING OF MODEL
  - CONFIGURATION CHANGES
  - PARAMETER VARIATION
  - DAMAGE ANALYSIS

- o INTELLIGENT COUPLING PROCEDURES
  - RECOGNITION OF DOF NAMES
  - MPC OPTIONALLY AUTOMATICALLY FORMED
  - GENERAL MPC SOLVED FOR DOF EQUATIONS

DYSCO
BASIC TECHNOLOGY MODULES

- CSF1 - LINEAR FINITE ELEMENT

  USER SUPPLIES: NAMES OF DOF
  M, C, K, F

- CFM3 - 3D MODAL STRUCTURE

  RIGID BODY, ELASTIC MODES (ALL OPTIONAL)
  DOF NAMES AUTOMATICALLY GENERATED
  AUTOMATIC COUPLING AT SPECIFIED NODES

- CSB2 - GENERAL BAR ELEMENT* (NOT AVAILABLE IN GOVT VERSION)

  MAY BE USED AS A BEAM OR ROD ELEMENT
  SHEAR FACTORS, CONSISTENT MASS, RAYLEIGH DAMPING
  UP TO 12 DOF

DYSCO
BASIC TECHNOLOGY MODULES (CONT'D)

- o CES1 - ELASTIC STOP

  NONLINEAR SPRING, DAMPING, WITH GAP

- o CGF2 - GENERAL FORCE
  - POLYNOMIAL, FOURIER SERIES, OR TABULAR
  - PERIODIC
- o CLC0 - SINGLE POINT CONSTRAINTS
- o CLC1 - MULTIPOINT CONSTRAINTS
- o CLC2 - ADVANCED MULTIPOINT CONSTRAINT

DYSCO
BASIC TECHNOLOGY MODULES (CONT'D)

- SEA4 - EIGENANALYSIS, REAL
- SEA5 - COMPLEX EIGENANALYSIS
- STH4 - TIME HISTORY
  - CONDITION CODES
- SFD1 - FREQUENCY DOMAIN MOBILITY
  - RESPONSE PER UNIT FORCE
- STCO - OPTIMIZER FOR LINEAR STATE FEEDBACK* (NOT AVAILABLE IN GOVT VERSION)
  - SOLVES MATRIX RICCARTI EQUATION
  - INTEGRATES SYSTEM STATE EQUATIONS
- SII3 - INTERFACE AND INTERNAL LOADS
  - RESIDUAL FORCES AT INTERFACES
  - FORCES, STRAIN ENERGY, BENDING MOMENTS

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DYSCO - OTHER TECHNOLOGY MODULES

- CRR2, CRR3 - HELICOPTER ROTOR
- CCE0, CCE1 - ROTOR CONTROL SYSTEM
- CRD3 - ROTOR DAMAGE
- CFM2 - HELICOPTER FUSELAGE
- CLG2 - NONLINEAR LANDING GEAR
- CLS2 - LIFTING SURFACE
- FRA0, FRA2, FRA3 - ROTOR AERODYNAMICS
- FFA0, FFC2 - FUSELAGE AERODYNAMICS
- STH3 - TIME HISTORY, HELICOPTER CONTROLS
- STR3 - HELICOPTER TRIM
- SSF3 - FLOQUET STABILITY

DYSCO AND FE CODES

- DYSCO DOES NOT COMPETE WITH FE CODES
- DYSCO COMPLEMENTS FE CODES
- FE ANALYSIS FOR DETAILED STRUCTURAL ANALYSIS
- DYSCO CAN START WITH FE MODEL AND:
  - MODIFY CONFIGURATION
  - SIMULATE DAMAGE
  - ADD CONTROL ALGORITHMS
  - ADD SPECIAL COMPONENTS
  - PERFORM SOLUTIONS ON ALL MODIFICATIONS
  - STUDY EFFECTS OF CHANGE
  - ANALYZE CONFIGURATIONS NOT POSSIBLE (OR CONVENIENT) WITH FE CODES
- DYSCO CAN ALSO MODEL STRUCTURES ON ITS OWN

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WHAT DYSCO CAN DO FOR YOU

- SIMPLE PROBLEMS ARE EASY AND INEXPENSIVE TO SOLVE
- PROBLEMS NOT CONVENIENTLY MODELED ELSEWHERE CAN BE SOLVED
- PHENOMENA CAN BE BETTER UNDERSTOOD:
  - START WITH SIMPLE REPRESENTATION
  - GRADUALLY INCREASE COMPLEXITY
  - VARY PARAMETERS
  - VARY CONFIGURATION
- NOVEL CONCEPTS CAN BE EASILY MODELED AND EVALUATED
- NEW ALGORITHMS CAN BE TESTED AND EVALUATED

LIST OF ILLUSTRATIVE PROBLEMS

- PACOSS TOWER DYNAMIC ANALYSIS
- TRUSS STRUCTURE WITH ACTIVE ELEMENTS - VIBRATION CONTROL
- PIEZOELECTRIC SENSORS/ACTUATORS ON BEAM - VARY CONTROL LAWS, ADD ELASTIC STOP, STABILITY, TIME, FREQUENCY DOMAIN
- POINTING-TRACKING SYSTEM - MOTOR DRIVEN MIRRORS - MOVING, ACCELERATING TARGET, VARY CONTROL GAINS
- ROTORCRAFT TRIM - DAMAGED BLADE - INTERNAL LOADS
- RAIL GUN PNEUMATIC ACCELERATOR - GAS PRESSURE - BOLT MOTION
- ALGORITHM EVALUATION - REDUCED MODELS, SYSTEM IDENTIFICATION, SIMULATE EFFECTS OF MEASUREMENT ERRORS

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DYSCO MODELING

- DYSCO COUPLES THE EQUATIONS OF INDIVIDUAL COMPONENTS TO FORM THE EQUATIONS OF A MODEL

- EACH COMPONENT AND MODEL ARE OF THE FORM

$$M\ddot{X} + C\dot{X} + KX = F$$

$$M,\ C,\ K,\ F = f(T,\ \dot{X},\ X)$$

- M, C, K, F MAY BE ARBITRARY FUNCTIONS OF TIME OR STATE

- X MAY REPRESENT PHYSICAL, MODAL, OR ANY GENERALIZED DOF

- EACH COMPONENT IS REPRESENTED BY FORTRAN SUBROUTINES IN THE TECHNOLOGY LIBRARY

COUPLING

- o DYSCO USES AN "INTELLIGENT" PROCEDURE FOR COUPLING DEGREES OF FREEDOM

- o DEGREES OF FREEDOM OF COMPONENTS MAY BE:
  - PHYSICAL COORDINATES
  - MODAL DISPLACEMENTS
  - ANY GENERALIZED COORDINATES

- o COUPLING INCLUDES
  - PHYSICAL TO PHYSICAL
  - PHYSICAL TO MODAL
  - MODAL TO MODAL
  - SINGLE POINT CONSTRAINTS
  - MULTIPLE POINT CONSTRAINTS
  - ANY LINEAR RELATIONSHIPS

- o EFFECTS SIMULATED
  - RIGID PHYSICAL LINKAGES
  - OPTICAL BEAM COORDINATES
  - CONTROL ALGORITHMS

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COUPLING

C-3

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X, X_I ARE VECTORS OF THE DOFs OF THE SYSTEM (MODEL) AND THE COMPONENTS

T_I IS A TRANSFORMATION MATRIX

$$X_I = T_I X$$

THE EQUATION OF THE MODEL IS

$$MX + CX + KX = F$$

WHERE

$$M = \sum T_I^T M_I T$$

$$C = \sum T_I^T C_I T$$

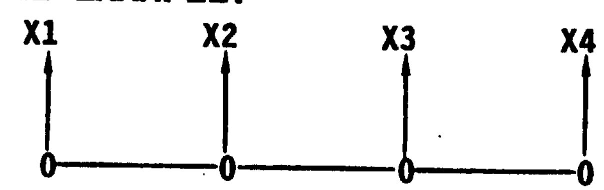
$$K = \sum T_I^T K_I T$$

$$F = \sum T_I^T F_I$$

EACH T_I IS AUTOMATICALLY FORMED IN DYSCO

COUPLING BY NAME

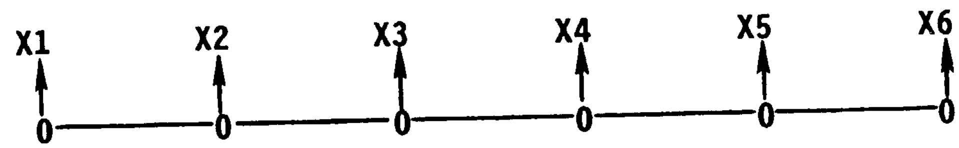
- DYSCO USES A UNIQUE PROCEDURE WHERE VARIABLE NAMES (A4, I4) ARE RECOGNIZED AND PROCESSED
- NAMES ARE AUTOMATICALLY FORMED OR USER SUPPLIED
- LIKE NAMES IN COMPONENTS IMPLY CONNECTION
- SIMPLE EXAMPLE:



TO CONSTRAIN X3 TO GROUND BY A SPRING, κ, USER SIMPLY ADDS COMPONENT TO MODEL WITH FOLLOWING INFORMATION

NO OF DOF = 1
NAME = X3
M = C = F = NULL
K = κ

SIMPLE CONTROL SYSTEM EXAMPLE



SENSOR LOCATIONS X1, X4, X6

ACTUATOR LOCATIONS X3, X4

$F_{X3} = A*X1 + B*X4 + C*X6 + D*\dot{X}4$

$F_{X4} = E*\dot{X}1 + F*X6 + G*\dot{X}6$

THIS MAY BE REPRESENTED BY COMPONENT WITH

DOF = [X1, X3, X4, X6]

M = 0

$$C = - \begin{matrix} 0 & 0 & 0 & 0 \\ 0 & 0 & D & 0 \\ E & 0 & 0 & G \\ 0 & 0 & 0 & 0 \end{matrix}$$

$$K = - \begin{matrix} 0 & 0 & 0 & 0 \\ A & 0 & B & C \\ 0 & 0 & 0 & F \\ 0 & 0 & 0 & 0 \end{matrix}$$

SENSOR AND ACTUATOR LOCATIONS MAY BE CHANGED BY EDITING DOF NAMES. GAINS MAY BE CHANGED BY EDITING MATRICES.

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GENERAL COUPLING

- COUPLING MAY ALSO USE OPTIONAL LINEAR RELATIONS
- SINGLE POINT, MULTIPOINT, CONNECTIVITY CONSTRAINTS

  X1 = 1.0 * X2
  X10 = 0

  A * X10 + B * Y100 + C * Z20 = 0

- REPRESENTATION OF MECHANICAL LINKAGES
- CONVERSION TO CONVENIENT PARAMETERS
  - OPTICAL BEAM ANGLE AS FUNCTION OF MIRROR DOF
  - TIP DISPLACEMENT OF BEAM AS FUNCTION OF MODAL DOF

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DYSCO IS A DOMAIN EXECUTIVE CONTROL SYSTEM

THE DOMAIN IS "COUPLED DYNAMIC EQUATIONS"

IT EXECUTES TECHNICAL MODULES IN "PARALLEL" (RATHER THAN IN SEQUENCE)

SIMPLE COMMANDS PERFORM NUMEROUS MODULE EXECUTIONS (E.G., RUN)

INVALID COMMAND SEQUENCES ARE NOT ACCEPTED
INVALID DATA USAGE IS NOT POSSIBLE

ALL DATA PLACED ON FILES OR EDITED IS ASSURED TO BE VALID (E.G., CONSISTENCY AND FORMAT)

TERMINOLOGY

- COMPONENT - ALGORITHM FOR COMPUTING M, C, K, F FOUND IN TECHNOLOGY LIBRARY

  NAME: C---

- DATA SET - SPECIFIC SET OF DATA TO BE USED WITH A COMPONENT FOUND IN DATA LIBRARY. INPUT BY USER. USER SUPPLIES DATA SET "NAME"

- MODEL - COLLECTION OF COMPONENTS AND ASSOCIATED DATA SETS

SAMPLE MODEL

COMPONENT	DATA SET
CSF1	STRUT1
CSF1	STRUT2
CFM2	FUSELAGE
CSF1	CONTROL 3
CES1	K100

MODEL PATIE12

************************ MODEL PATIE12 *************************

CATSTAR: SAME AS PATIE11 BUT CLC1 REWRITTEN FOR PHIP1 IMPLICIT

INDEX	COMP	NO.	DATA SET	FORCE	DATA SET
1	CSF1		PRIMARY	NONE	
2	CSF1		BASE P-S	NONE	
3	CSF1		SECONDRY	NONE	
4	CSF1		BASE S-M	NONE	
5	CSF1		MOTOR	NONE	
6	CSF1		TRUSS-PR	NONE	
7	CSF1		TRUSS-DI	NONE	
8	CSF1		TRUSS-MO	NONE	
9	CFM2	1	SHUTTLE	NONE	
10	CSF1		CONTROL1	NONE	
11	CSF1		TARGET	NONE	
12	CSF1		NOMAL	NONE	
13	CLC1		OPTICS3	NONE	

****

****

GLOBAL VARIABLES

NO INPUT REQUIRED

****

```
***************        CONTROL1/CSF1        ***************

CONTROL LAW 1 FOR GIMBALLED MIRROR

***********************************************************************
INPUT FOR COMPONENT CSF1. FINITE ELEMENT

  1 NCDF      - NUMBER OF DOF          =              3
  2 CDFLI     - (DOF) DOF NAME
            PHIP1000  DSTR1000  MTH 1000
  3 CM        - (REAL) MASS MATRIX VALUES
            NULL MATRIX

  4 CC        - (REAL) DAMPING MATRX VALUES
            GENERAL MATRIX

    ROW    1      NULL ROW
    ROW    2
          3.70000E+02  0.00000E+00  0.00000E+00

    ROW    3
         -3.70000E+02  0.00000E+00  0.00000E+00
  5 CK        - (REAL) STIFFNESS MTRX VALUES
            GENERAL MATRIX

    ROW    1      NULL ROW
    ROW    2
          1.23300E+06  0.00000E+00  0.00000E+00
    ROW    3
         -1.23300E+06  0.00000E+00  0.00000E+00
  6 CF        - (REAL) FORCE VECTOR VALUES
            0.00000E+00  0.00000E+00  0.00000E+00
***********************************************************************
```

HELIUM1/CAG1
HELIUM ACCUMULATOR FOR ET1 MODEL

```
***************       HELIUM1 /CAG1       ***************

HELIUM ACCUMULATOR FOR ET1 MODEL

***********************************************************************
INPUT FOR COMPONENT CAG1. ADIABATIC GAS

 1 NCDF       - NUMBER OF DOF        =              3
 2 CDFLI      - (DOF) DOF NAME
           PROJ1000   BOLT1000   MAGZ1000
 3 GVECT      - (REAL) INITIAL GAS VECTOR
             4.55000E+03   4.00000E+00   1.66700E+00   2.07703E+00
             8.40000E+04
 4 AREA       - (REAL) MATRIX FOR AREA CALC
           GENERAL MATRIX

   ROW     1
          2.00000E+00  2.00000E+00  3.00000E+00

   ROW     2
          1.00000E+00  1.00000E+00  6.66670E-01
 5 GOVDOF     - (DOF) AREA EXIST CRITERIA
           PROJ1000   BOLT1000   BOLT1000
 6 AECV       - (REAL) GOVDOF CRITICAL VALU
            -1.00000E+04 -1.00000E+04  1.00000E+00
 7 PECDOF     - PRESSURE EX CRITERIA=      PROJ1000
 8 PECVAL     - CRITICAL VALUE       =  7.75000E+00
***********************************************************************
```

DYSCO LIBRARIES

- TECHNOLOGY LIBRARY CONTAINS

  COMPONENT REPRESENTATIONS (C ...)
  FORCE ALGORITHMS (F ...)
  SOLUTION ALGORITHMS (S ...)

- DATA LIBRARIES CONTAIN

  DATA ASSOCIATED WITH PARTICULAR C ..., F ...
  AND IDENTIFIED BY DATA SET NAME
  SUPPLIED BY USER

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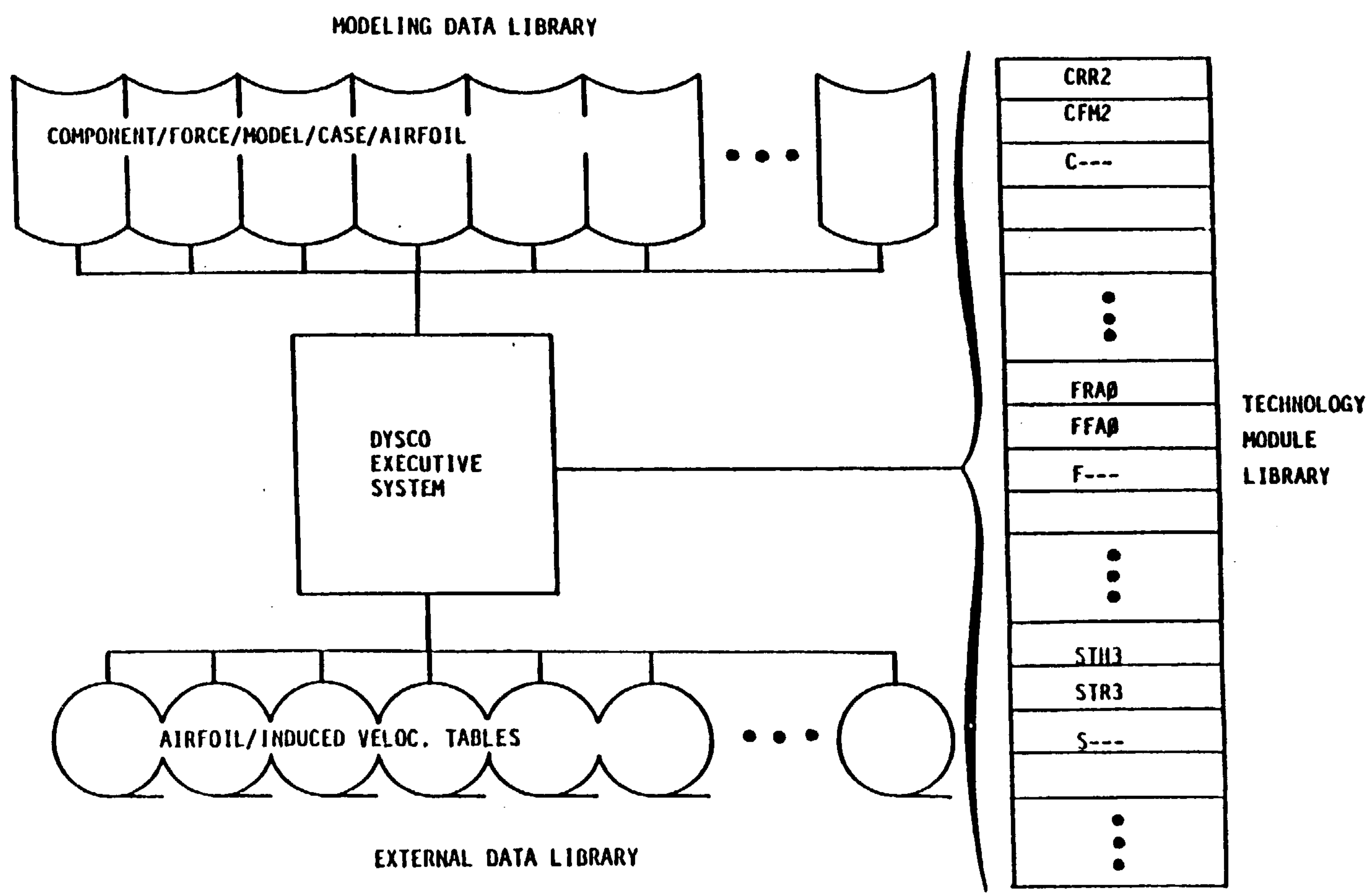
DYSCO LIBRARIES



TECHNOLOGY LIBRARY

ANY TECHNOLOGY MODULE MAY BE ADDED TO LIBRARY IF:

COMPONENT, FORCE

M, C, K, F MAY BE COMPUTED AS FUNCTIONS OF LOCAL STATE VECTOR AND TIME BY A FORTRAN PROGRAM

SOLUTION

ALGORITHM MAY BE WRITTEN IN FORTRAN, GIVEN SYSTEM M, C, K, F, AS ABOVE

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TYPICAL COMMANDS

COMMAND	
NEW	ALLOWS USER TO MODIFY MODEL ALLOWS USER TO CREATE NEW COMPONENT/FORCE INPUT DATA
RERUN	NEW SOLUTION FOR MODEL JUST RUN
RUN	FORMS EQUATIONS OF MODEL AND EXECUTES A SOLUTION
EDIT	ALLOWS USER TO TO MODIFY MODEL AND PERFORM VALIDATED EDIT OF INPUT DATA

ABSTRACT BASIS OF DYSCO

DYSCO ACHIEVES ITS MULTIPURPOSE CAPABILITY BY A COMPLETE SEPARATION OF ABSTRACT AND SPECIFIC DATA.

SINCE DYSCO DOES NOT TREAT SPECIFIC PHYSICAL COMPONENTS, FORCES, OR SOLUTIONS, IT CAN SOLVE PROBLEMS INVOLVING ANY COMPONENTS, FORCES, OR SOLUTIONS.

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USER'S APPROACH TO DYSCO ANALYSIS

THE USER PERCEIVES A "MODEL" MADE UP OF COMPONENTS

HE THEN:

SELECTS APPROPRIATE REPRESENTATIONS FOR EACH COMPONENT FROM THE LIBRARY

SELECTS APPROPRIATE FORCE ALGORITHMS FOR EACH COMPONENT

SELECTS APPROPRIATE SOLUTION METHODS.

NOTE THAT THE ORIGINAL MODEL FORMULATION REQUIRES AN APPROPRIATE LEVEL OF ENGINEERING JUDGEMENT.

FOR EACH COMPONENT AND FORCE, THE DATA MUST BE IDENTIFIED AS RESIDING ON A USER FILE OR THE DATA MUST BE PLACED ON A FILE USING DYSCO.

THE MODEL AND VARIATIONS MAY THEN BE FORMED INTERACTIVELY AND SPECIFIED SOLUTIONS MAY BE CARRIED OUT.

ILLUSTRATIVE APPLICATIONS

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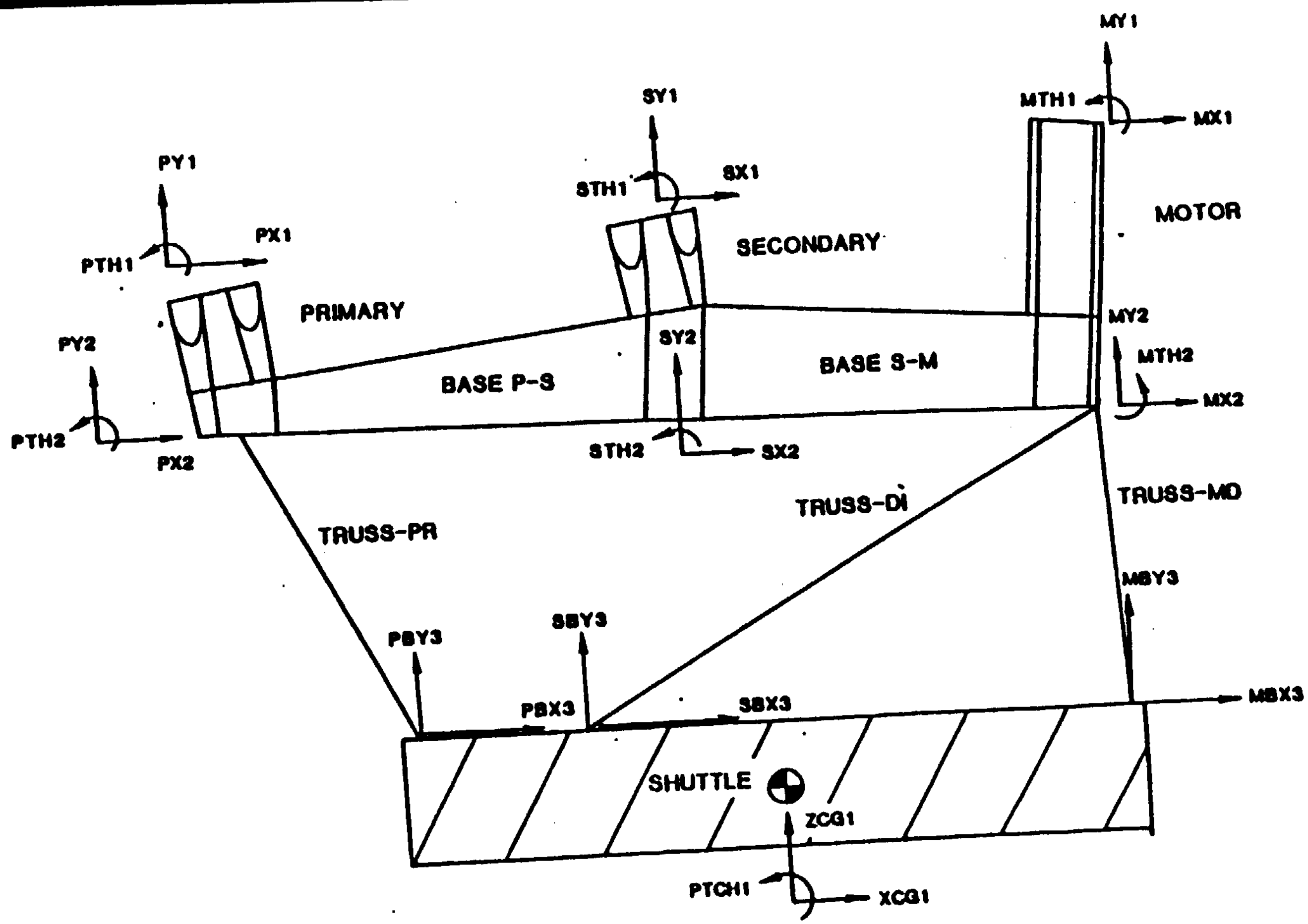
DYSCO 2D STRUCTURAL MODEL



MODEL 1 18 DOF (GROUNDED)
2-5 VARIOUS BASE SHAKES
6 21 DOF (3 BASE DOF)

CONTROL GAINS

I. MAX TORQUE FOR MOTOR AT MAX RATE .05 R/s - 370 IN #

II. DESIGN TORQUE T = 185 IN #

III. INITIAL TRIAL GAINS

1. DISPLACEMENT GAIN
   IF ϕ IS AT A MAX ALLOWABLE ERROR OF 15 μR, LET MOTOR BE DRIVEN AT MAX SPEED

   T = 185 IN # AT 15 μR

   = 0 IN # AT 0

   $K_2 = 1.233 \times 10^7$ IN #/R OF ϕ

2. VELOCITY GAIN

   IF $\dot{\phi}$ IS AT MAX RECESSION OR APPROACH OF .05 R/s, LET MOTOR BE DRIVEN AT MAX SPEED

   T = 185 IN # AT .05 R/s

   = 0 IN # AT 0

   $K_1 = 3.7 \times 10^3$ IN # SEC/R OF ϕ

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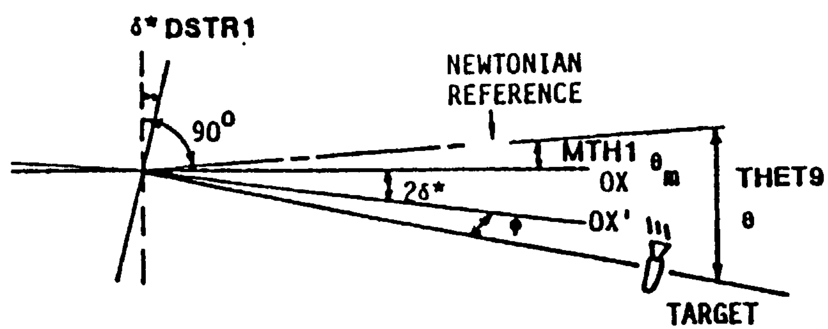
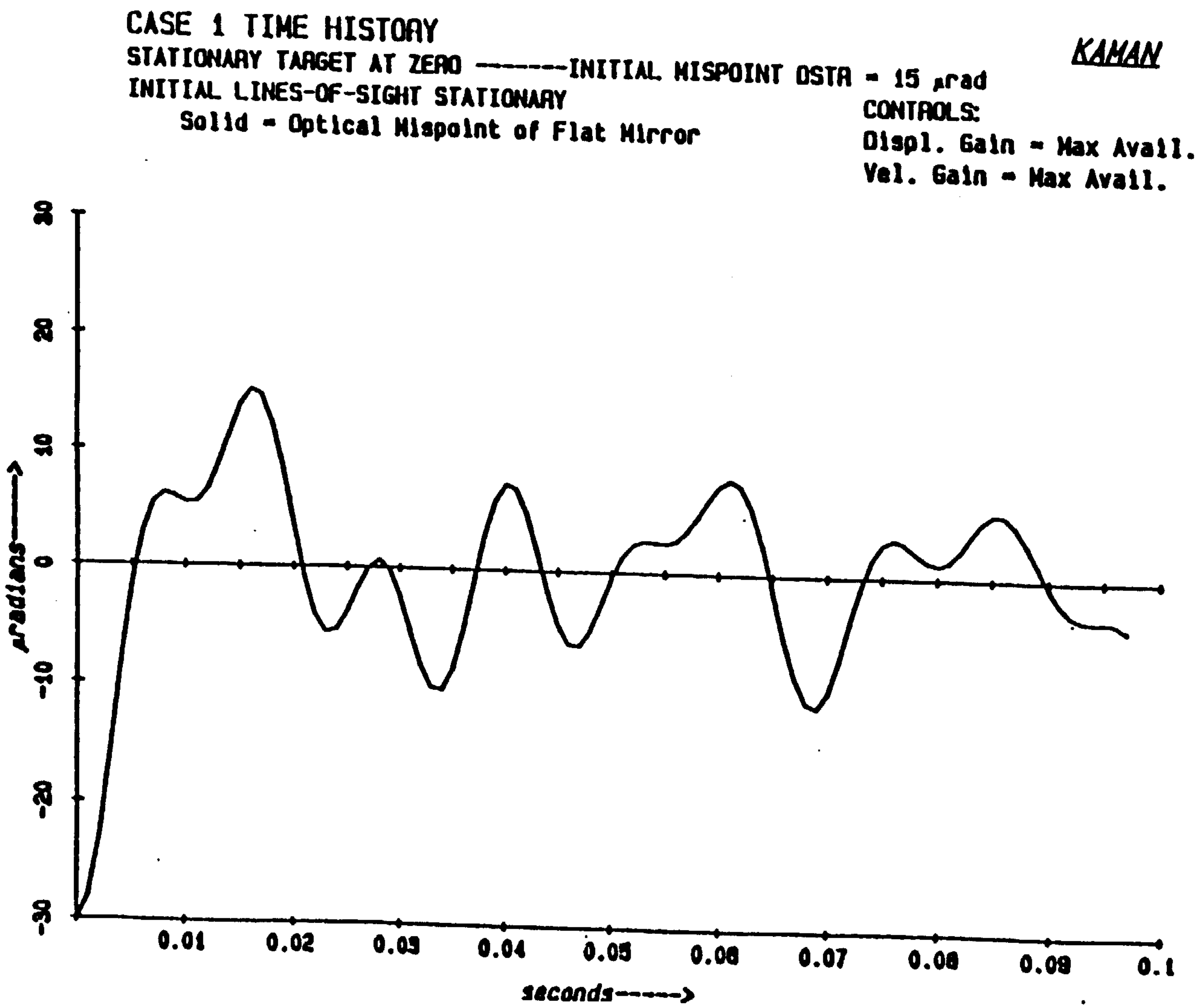
TYPICAL STRUCTURAL VARIABLES MONITORED

I. MIRROR AND MOTOR

1. THET9 = θ = TARGET L.O.S. FROM INERTIAL REFERENCE
2. DSTR1 = $\delta*$ = ACTUAL DRIVE ANGLE OF MIRROR
3. MTH1 = θ_M = STRUCTURAL VIBRATION OF THE MOTOR MOUNT
4. $2\delta* + \theta_M$ = OX' (BENT OPTICAL AXIS) FROM INERTIAL REFERENCE
5. $\phi = \theta - \theta_M - 2\delta*$ = OPTICAL MISPOINT



CASE 1 TIME HISTORY
(PAGE 1 OF 3)



CASE TIME HISTORY
(PAGE 2 OF 3)

CASE 8 TIME HISTORY

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ACCELERATING TARGET -------INITIAL MISPOINT DSTR = 15 µrad

INITIAL LINES-OF-SIGHT APPROACHING

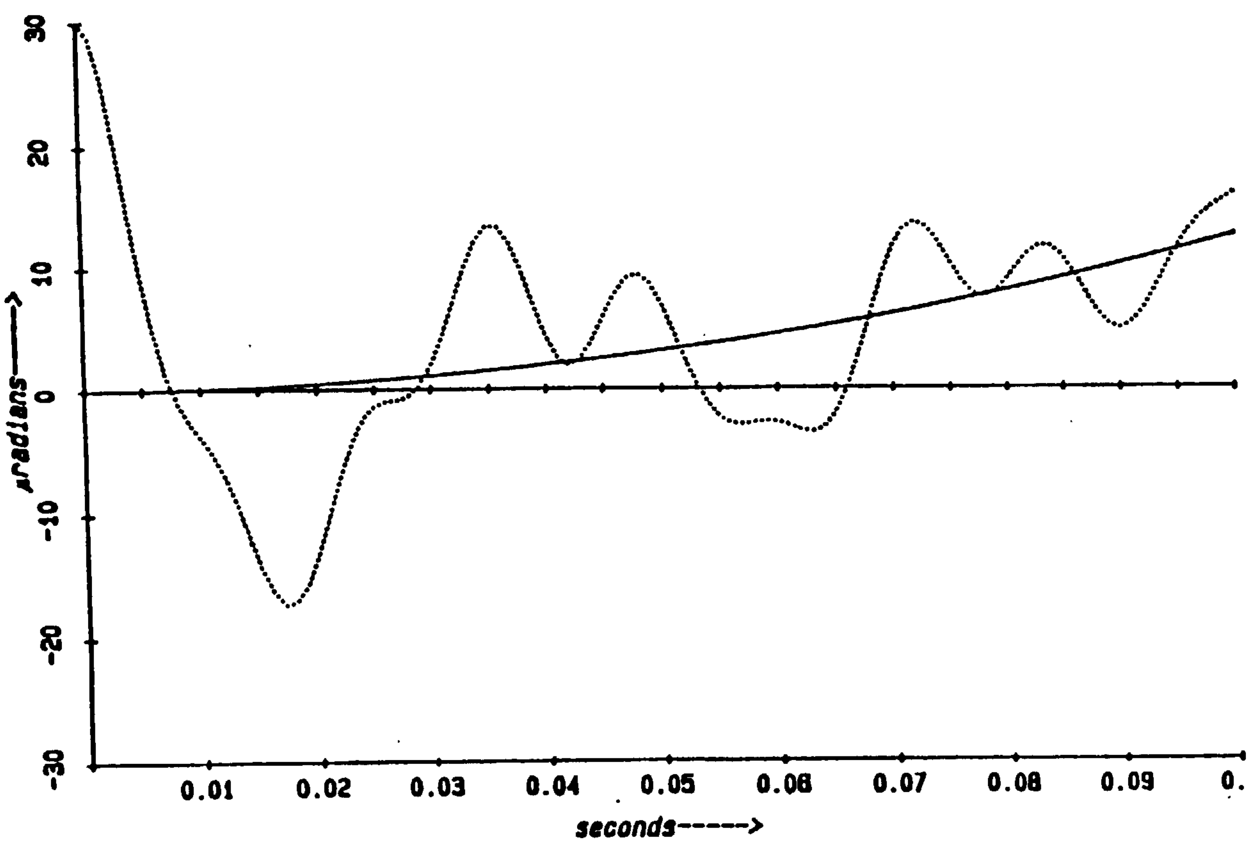
Solid = Target

Dotted = Pointing Axis L.O.S.

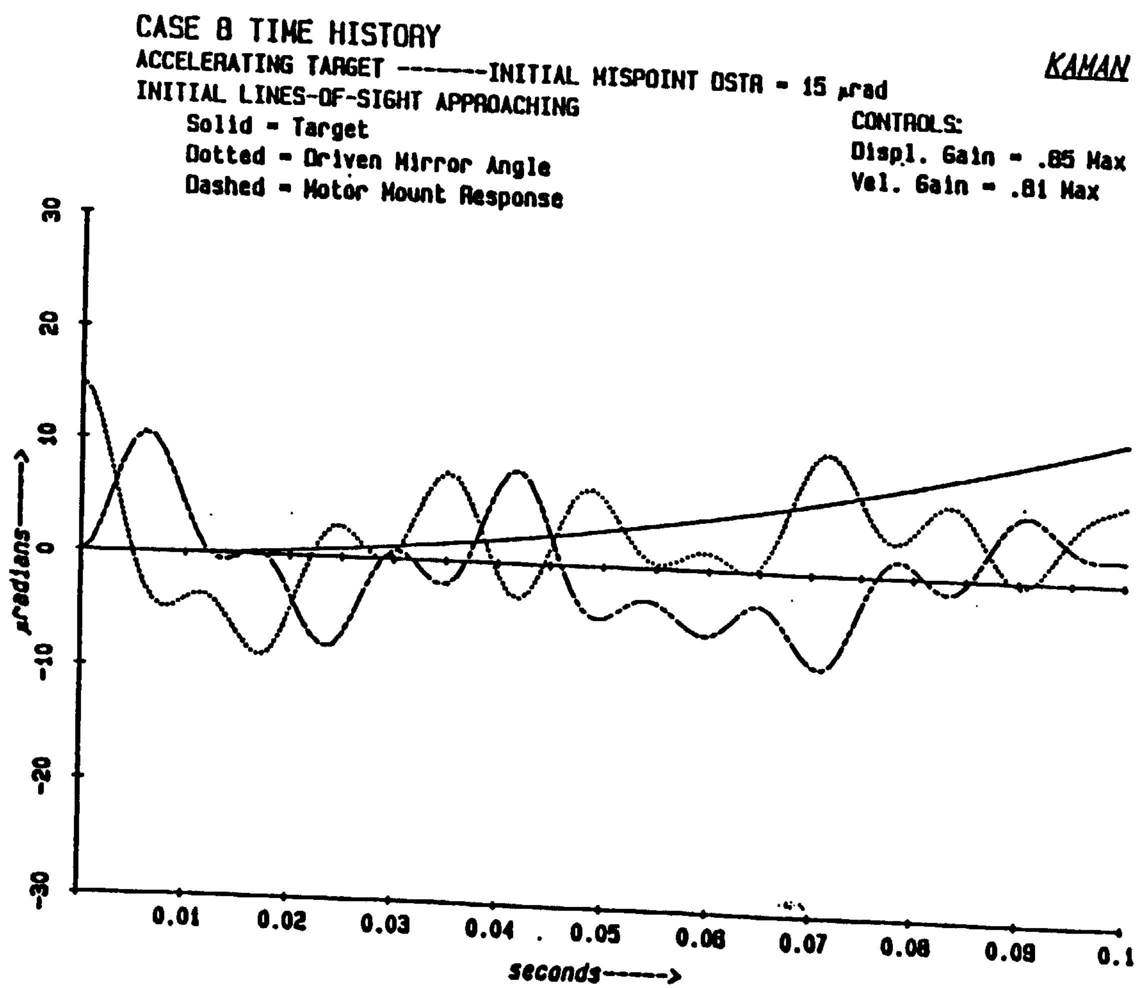
CONTROLS:

Displ. Gain = .65Max

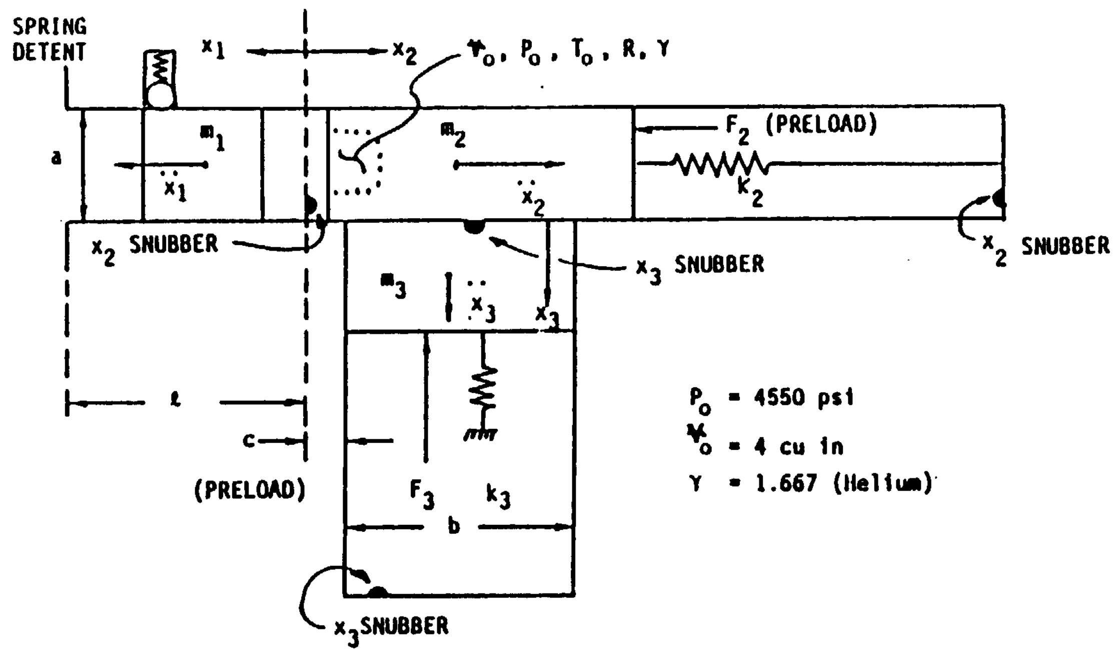
Vel. Gain =.81 Max



CASE TIME HISTORY
(PAGE 3 OF 3)



RAIL GUN PNEUMATIC PRE-ACCELERATOR



P_o = 4550 psi
V_o = 4 cu in
γ = 1.667 (Helium)

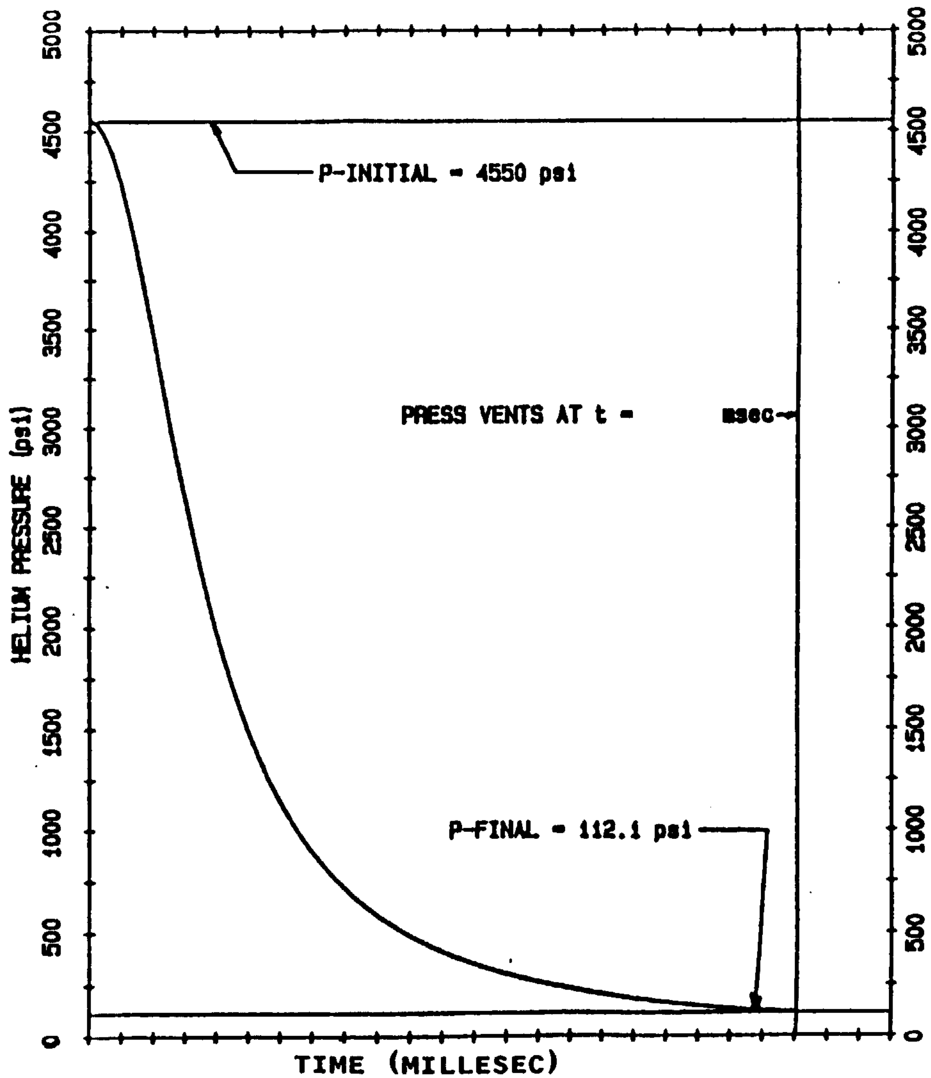
m_1 = PROJECTILE m_2 = BREECH BOLT m_3 = MAGAZINE STACK

EQUATION OF MOTION -

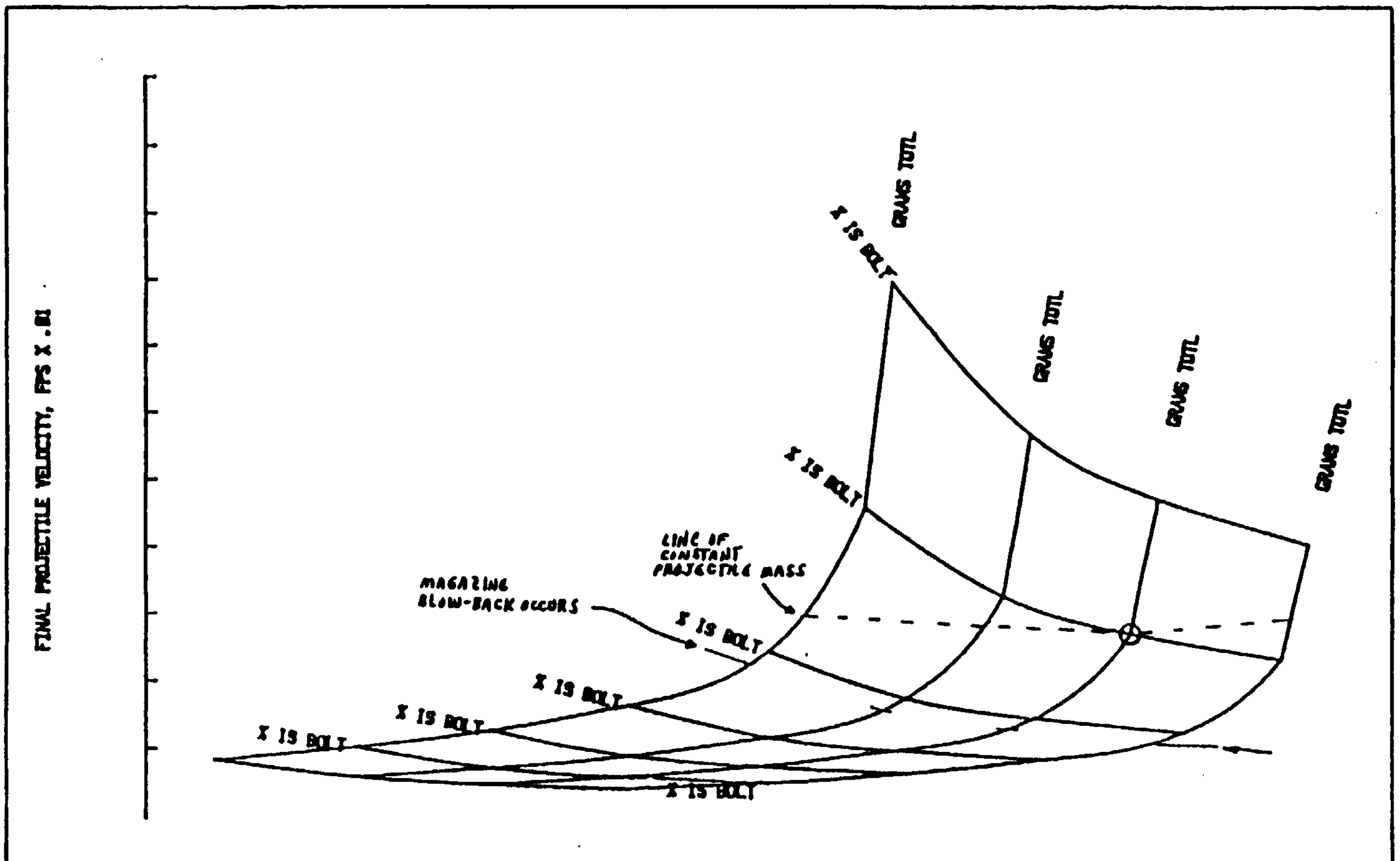
$$\begin{bmatrix} m_1 & & 0 \\ & m_2 & \\ 0 & & m_3 \end{bmatrix} \begin{Bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \\ \ddot{x}_3 \end{Bmatrix} + [\,0\,] \begin{Bmatrix} \dot{x} \end{Bmatrix} \begin{bmatrix} 0 & & 0 \\ & k_2 & \\ 0 & & k_3 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} A_1P(t) \\ A_2P(t)-F_2 \\ A_3P(t)-F_3 \end{Bmatrix}$$

A_3 = 0 UNLESS
$x_2 >$ C BEFORE
PRESSURE VENTS

ET PRE-ACCELERATOR PRESSURE CASCADE



TRADES STUDIES FOR PRE-ACCELERATOR



ET PREACCELERATOR, BEHAVIOR VS. TOTAL
MASS AND PERCENT ALLOTTED TO BOLT

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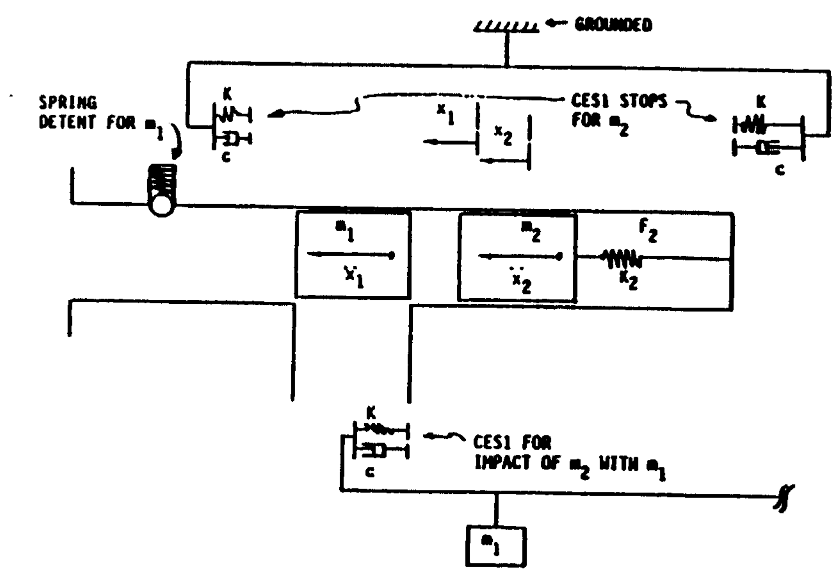
MODEL FOR HARMONIC BOLT RETURN AND IMPACT WITH FRESHLY LOADED PROJECTILE



VARIOUS COEFFICIENTS OF RESTITUTION CAN BE MODELLED BY JUDICIOUS CHOICE OF K AND C

************************** MODEL IMPACT 2 ***************************

IMPACT MODEL PLUS BARREL FIT/MAGAZINE FRICTION AND BALL SPRING DETENT

INDEX	COMP	NO.	DATA SET	FORCE	DATA SET
1	CSF1		BR1DYN	NONE	
2	CES1		BOLT2.0	NONE	
3	CSD1		BALL2	NONE	
4	CDF1		IMPMU	NONE	

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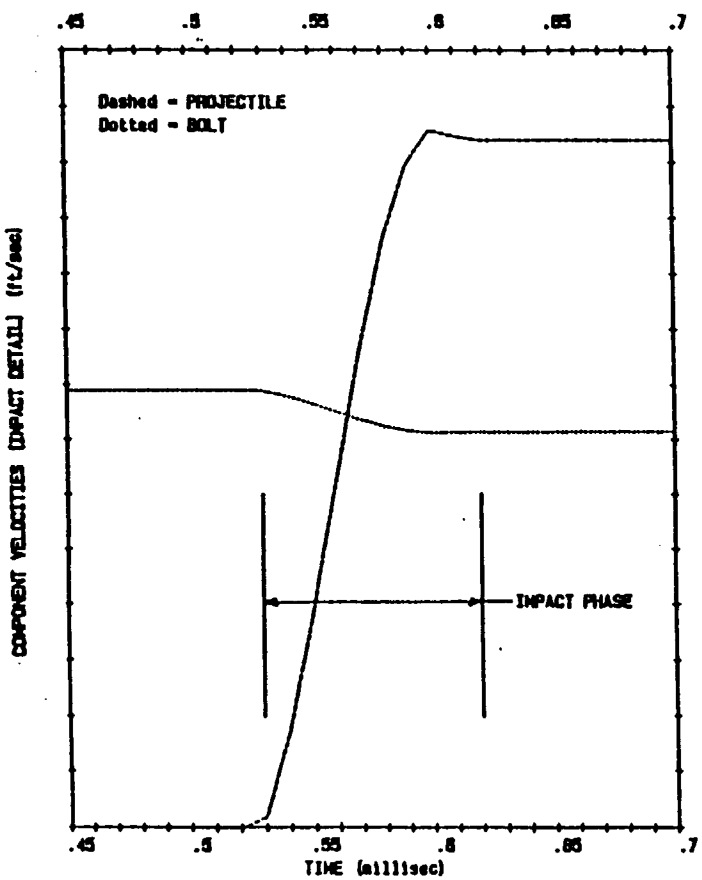
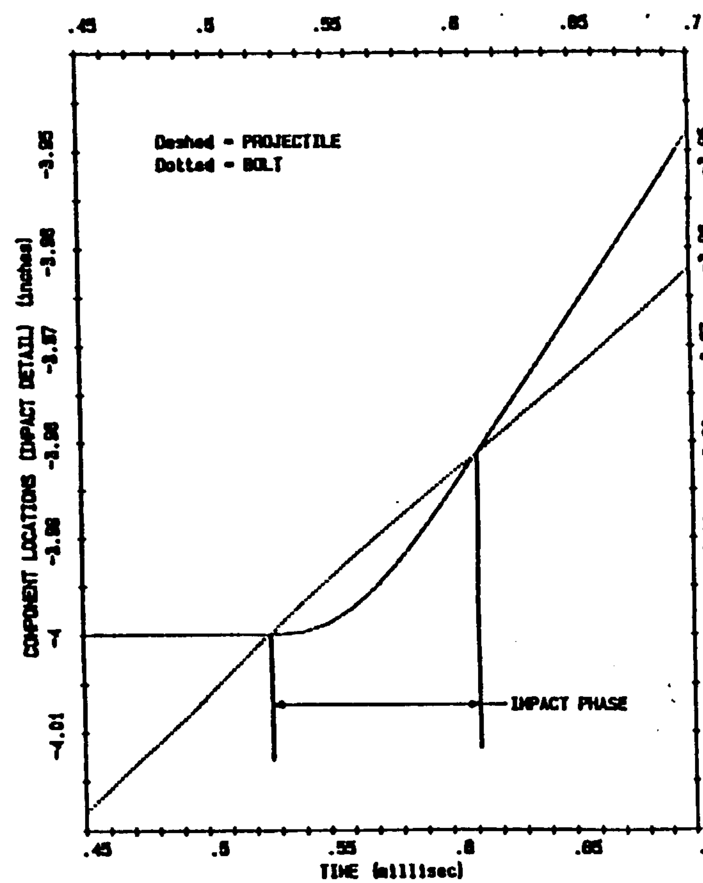
IMPACT DETAIL
DISPLACEMENT AND VELOCITY



ET PRE-ACCELERATOR
TIME DOMAIN VELOCITIES



ET PRE-ACCELERATOR
TIME DOMAIN DISPLACEMENTS