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ANALYSIS OF GUIDANCE LAW PERFORMANCE USING PERSONAL COMPUTERS

PRESENTED BY:

J. RENE' BARRIOS

HONEYWELL INC.
SPERRY COMMERCIAL FLIGHT SYSTEMS GROUP
PHOENIX, ARIZONA

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ABSTRACT

A POINT MASS, THREE-DEGREE OF FREEDOM MODEL IS PRESENTED AS A BASIC DEVELOPMENT TOOL FOR PC BASED SIMULATION MODELS. THE MODEL HAS BEEN USED IN THE DEVELOPMENT OF GUIDANCE ALGORITHMS AS WELL AS IN OTHER APPLICATIONS SUCH AS PERFORMANCE MANAGEMENT SYSTEMS TO COMPUTE OPTIMAL SPEEDS. ITS LIMITATIONS AND ADVANTAGES ARE DISCUSSED WITH REGARD TO THE WINDSHEAR ENVIROMENT. A METHOD FOR SIMULATING A SIMPLE AUTOPILOT IS EXPLAINED IN DETAIL AND APPLIED IN THE ANALYSIS OF DIFFERENT GUIDANCE LAWS.

THE MODEL

EQUATIONS OF MOTION

IN

RELATIVE WIND AXES

(1) $\dot{V} = G[T.\cos\alpha - D)/W - \sin\gamma] - \dot{W}x.\cos\gamma - \dot{W}z.\sin\gamma$

(2) $\dot{\gamma} = \{G[T.\sin\alpha + L)/W - \cos\gamma] + \dot{W}x.\sin\gamma - \dot{W}z.\cos\gamma\}/V$

(3) $\dot{H} = V.\sin\gamma + Wz$

(4) $\dot{x} = V.\cos\gamma + Wx$

WHERE

V = TRUE AIR SPEED IN KNOTS

T = TOTAL THRUST IN LBS.

D = TOTAL DRAG IN LBS.

L = TOTAL LIFT IN LBS.

W = GROSS WEIGHT IN LBS.

Wx= HOR. WIND COMPONENT IN KNOTS

H = ALTITUDE IN FEET

x = HORIZONTAL DISTANCE IN N. M.

G = GRAVITY ACCEL. IN KNOTS/SEC

α = ANGLE OF ATTACK IN RAD.

γ = FLIGHT PATH ANGLE IN RAD.

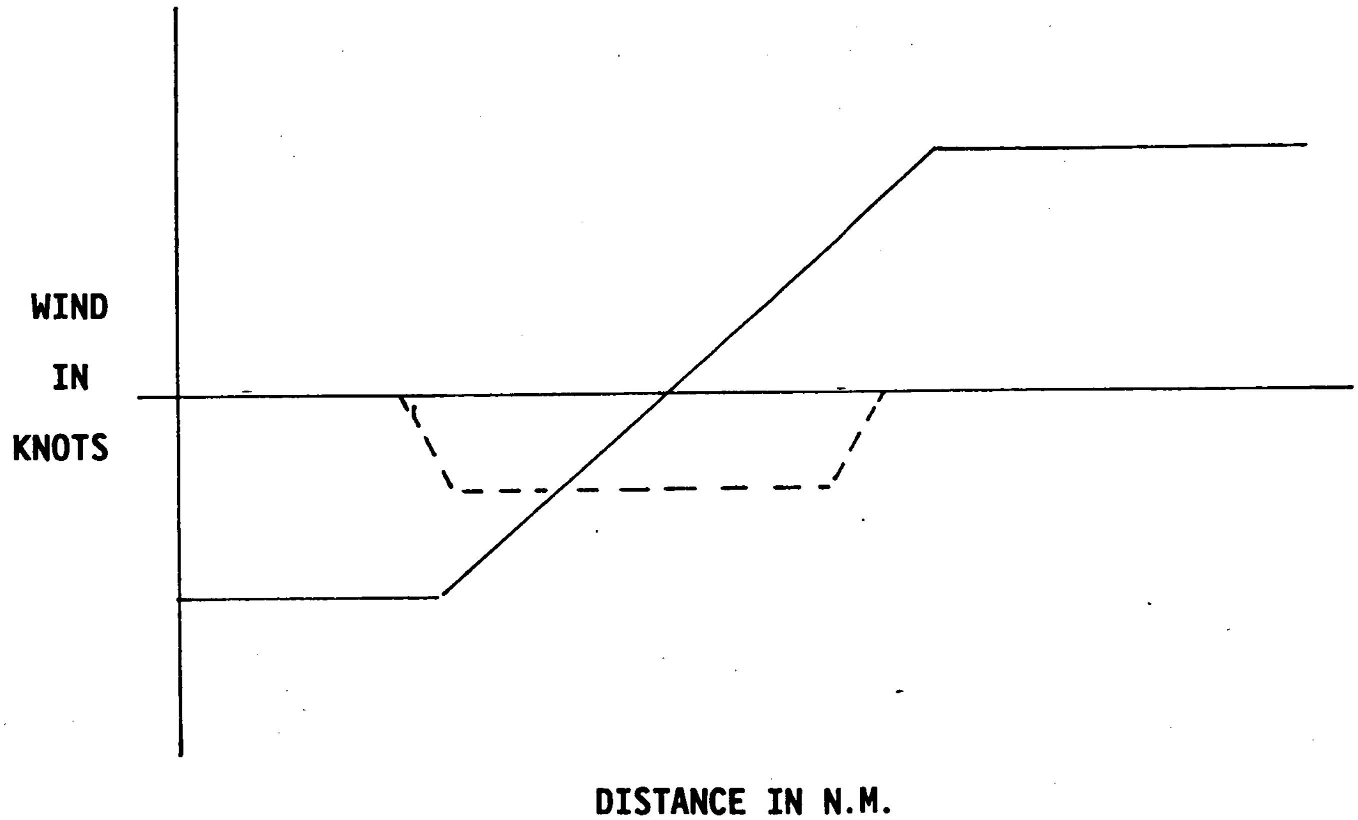
Wz= VERT. WIND COMPONENT IN KNOTS

PROGRAM MODULES

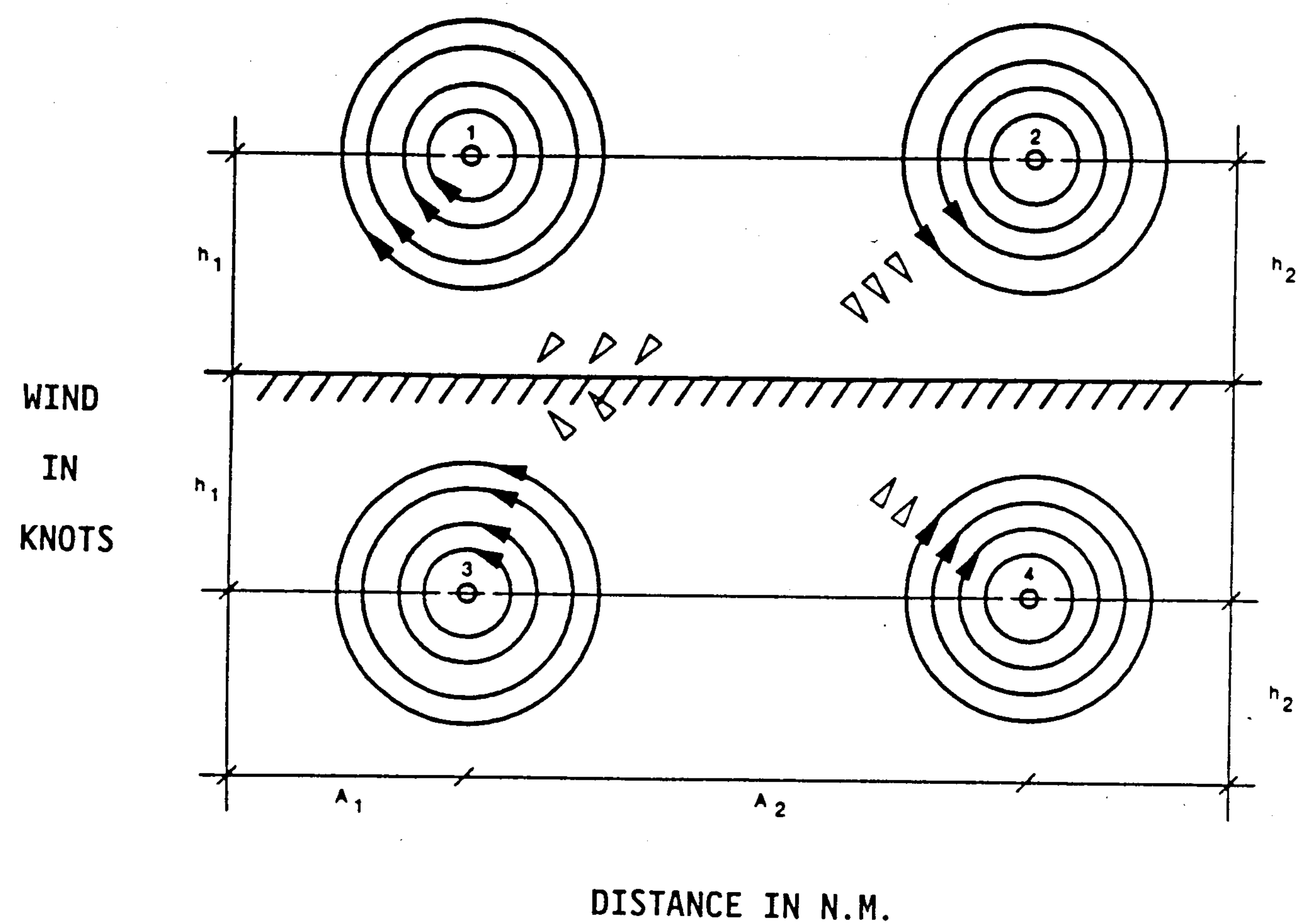
MODULE NAME	FUNCTION
MAIN	MAIN LOOP AND SUBROUTINE CALLS
ATMOSPHERE	TEMP, PRES. RATIO & MACH NO.
EQUATIONS OF MOTION	STATE VARIABLES RATES
AERO-COEFFICIENTS	C_L, C_D, LIFT & DRAG
ENGINES	THRUST & ENGINE DYNAMICS
WINDS	WIND & WIND RATES
DETECTION	CAUTION & WARNING FLAGS
INTEGRATION	STATE VARIABLE UPDATE
GUIDANCE (A/P)	CONTROL VARIABLE COMPUTATION
ALPHA LIMIT	PITCH DYNAMICS
PRINT	PRINTS & CREATES FILES
GRAPH	PROVIDES GRAPHIC OUTPUT

THE WIND MODELS

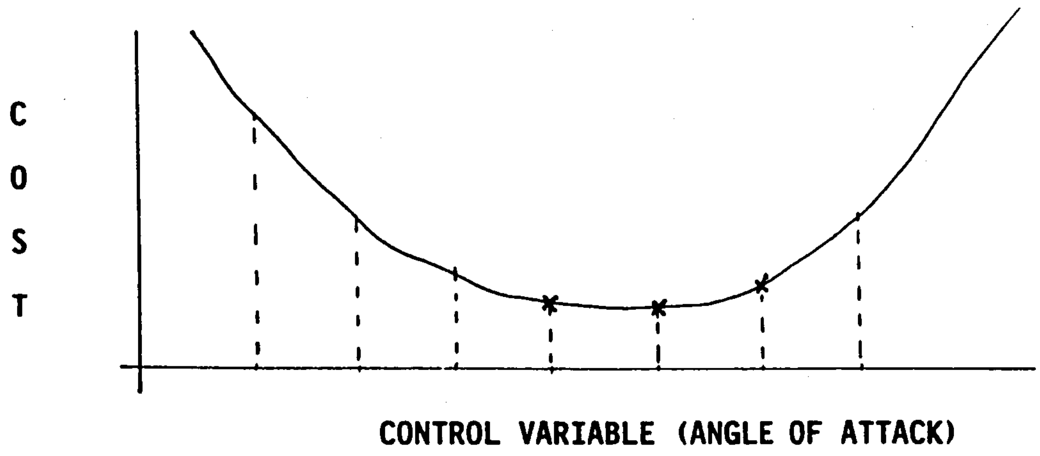
THE CONSTANT SHEAR MODEL



THE QUAD-VORTEX MODEL



THE GUIDANCE MODULE



DEFINITION OF COST FUNCTIONS

1) 1.1*VSTALL — $COST = (V + \dot{V}*DT - 1.1*V_S)^2$
2) STICK SHAKER — $COST = (ALPHA - A_{STKR})^2$
3) $A_X = 0$ — $COST = (\dot{V} - V*\dot{G}_M*G_M + W_X)^2$
4) 15 DEG. PITCH — $COST = (G_M + \dot{G}_M*DT + ALPHA - 15)^2$
5) HONEYWELL'S — $COST = (G_M + \dot{G}_M*DT - G_{MR})^2$

WHERE

G_M = FLIGHT PATH ANGLE W/RT AIR MASS

G_I = INERTIAL FLIGHT PATH ANGLE

$G_{MR} = G_I*(1 + W_X/V) - W_Z/V$

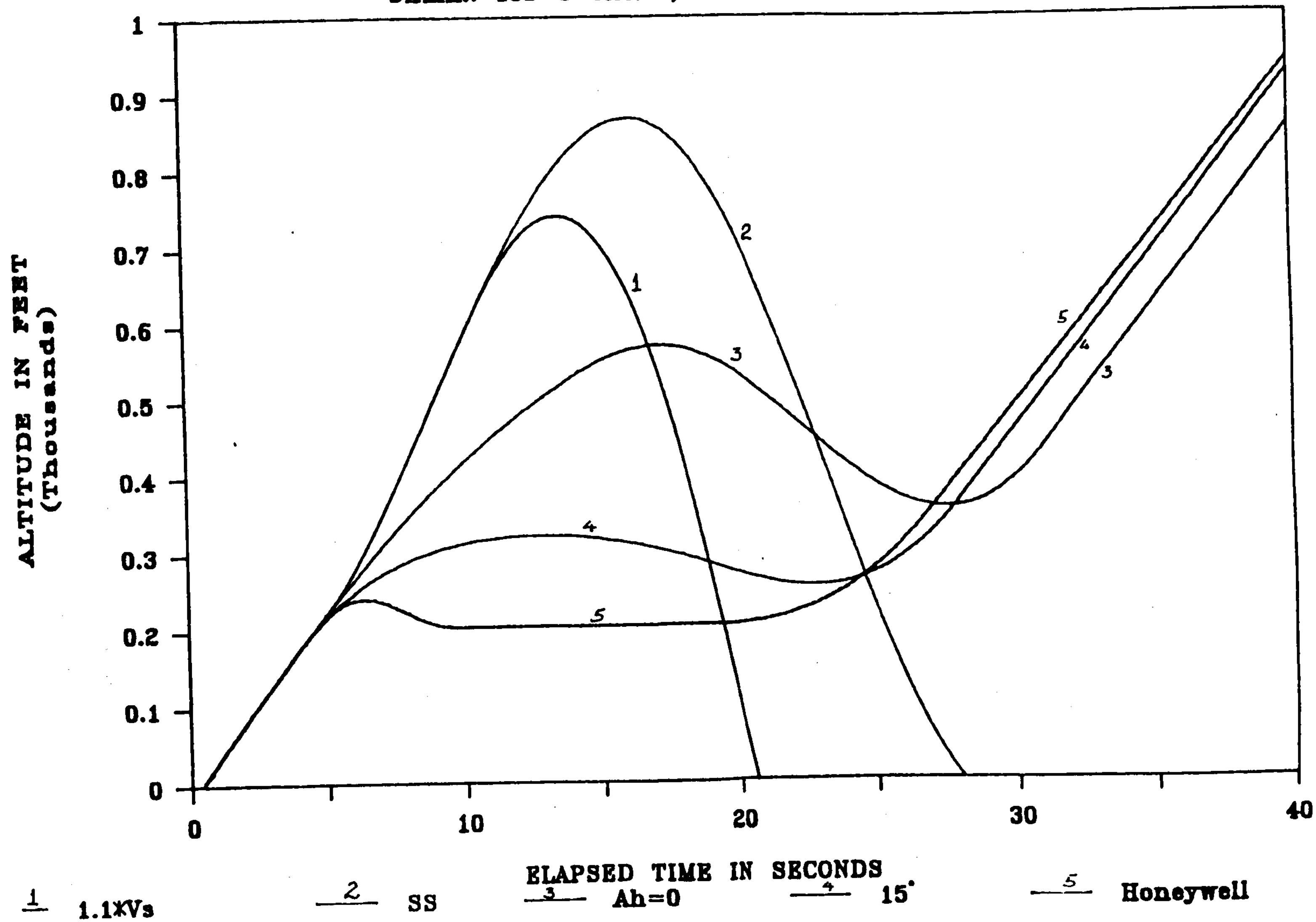
PC MODEL APPLICATIONS

* PERFORMANCE MANAGEMENT SYSTEMS
  - DETERMINATION OF OPTIMAL SPEEDS FOR MINIMUM COST TRAJECTORIES
  - DETERMINATION OF OPTIMUM ALTITUDE FOR SHORT RANGE FLIGHTS

* WINDSHEAR GUIDANCE ALGORITHMS
  - DEVELOPMENT OF THEORETICAL GUIDANCE LAWS USING DIFFERENT CONCEPTS SUCH AS GAMMA REFERENCE, ENERGY ETC.
  - DEVELOPMENT OF NUMERICAL ALGORITHMS FOR THE SOLUTION OF THE "GAMMA REFERENCE GUIDANCE AS A MAYER PROBLEM IN THE CALCULUS OF VARIATIONS".

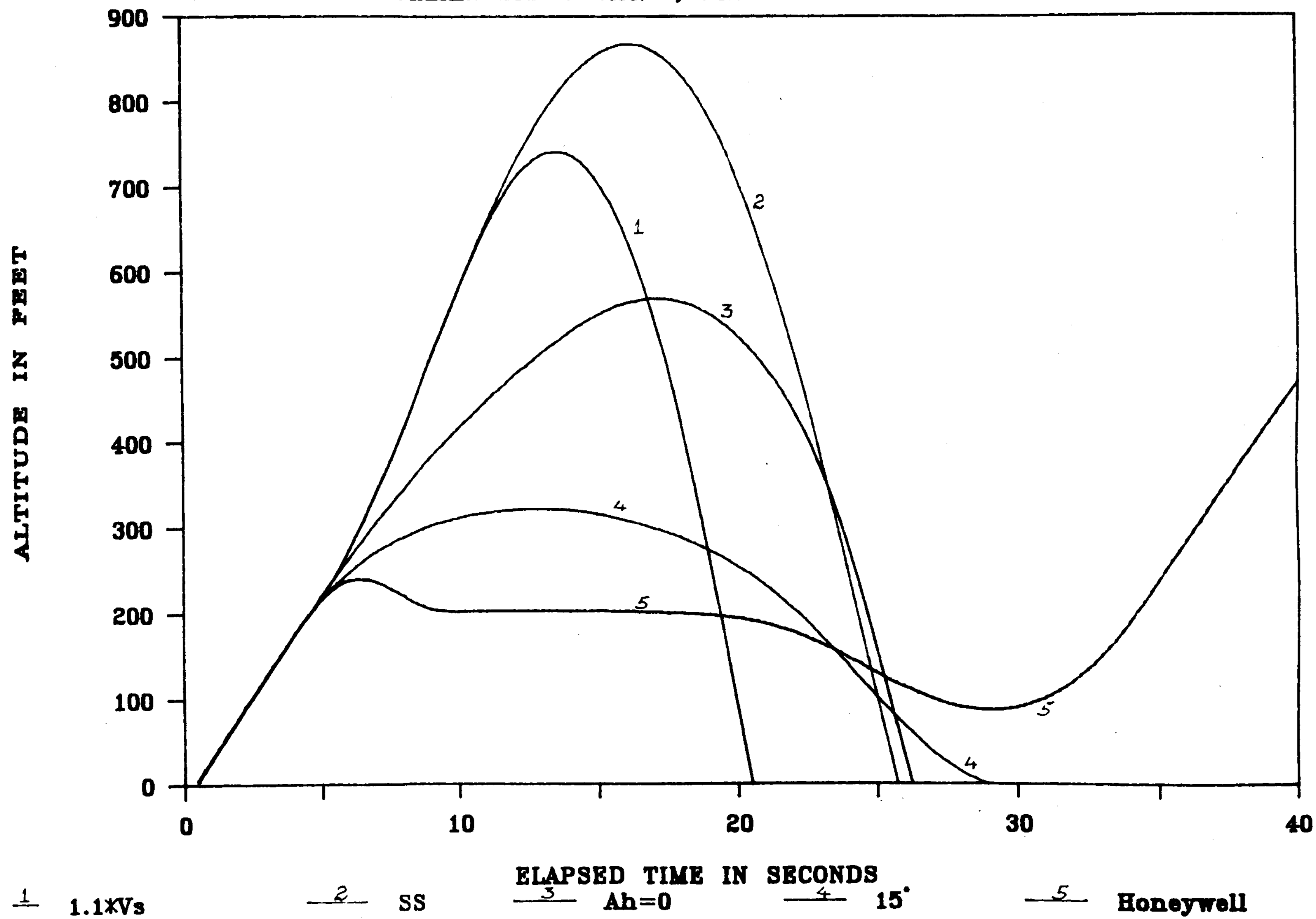
737 WINDSHEAR GUIDANCE

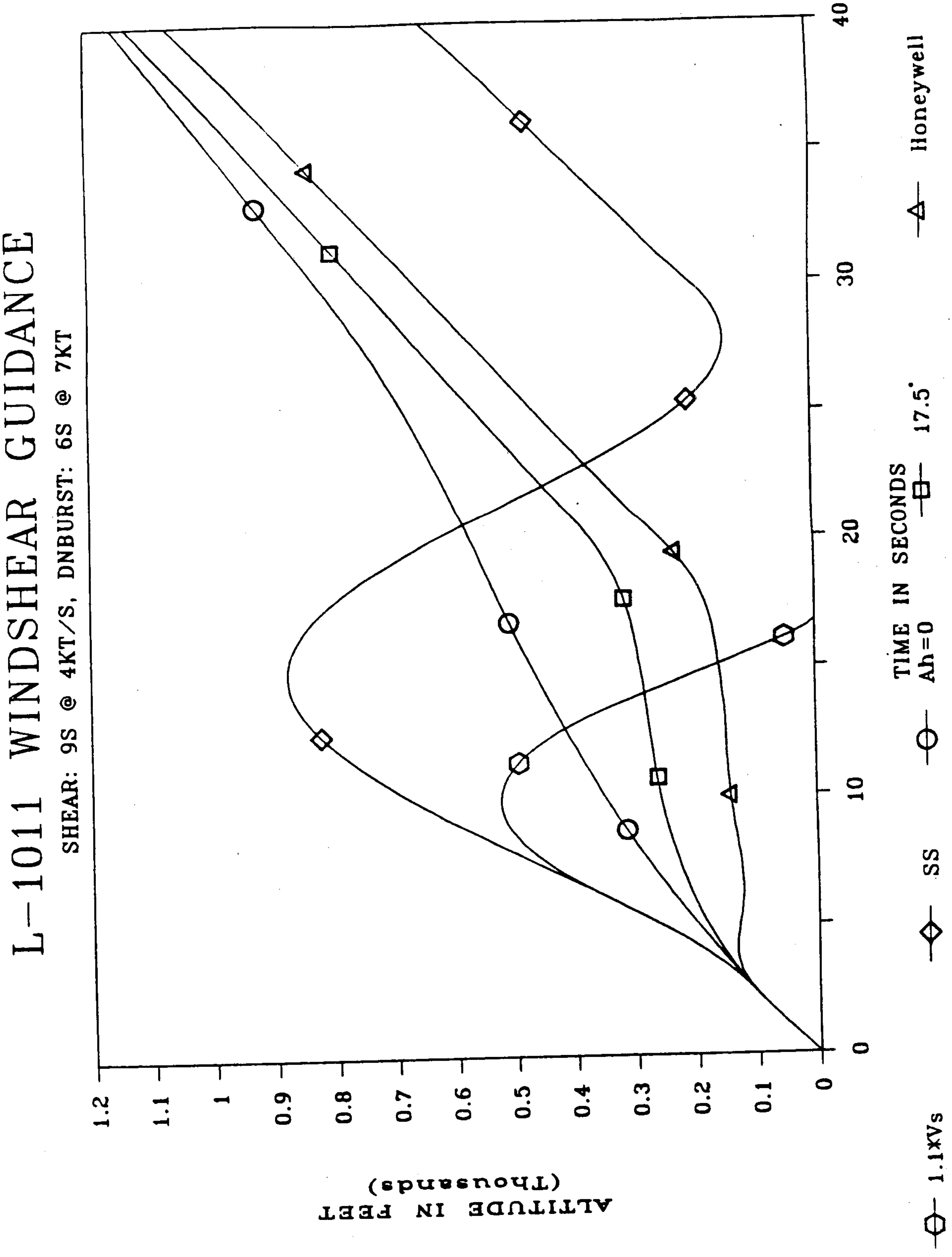
SHEAR: 15S @ 5KT/S, DNBURST: 13S @ 7KT

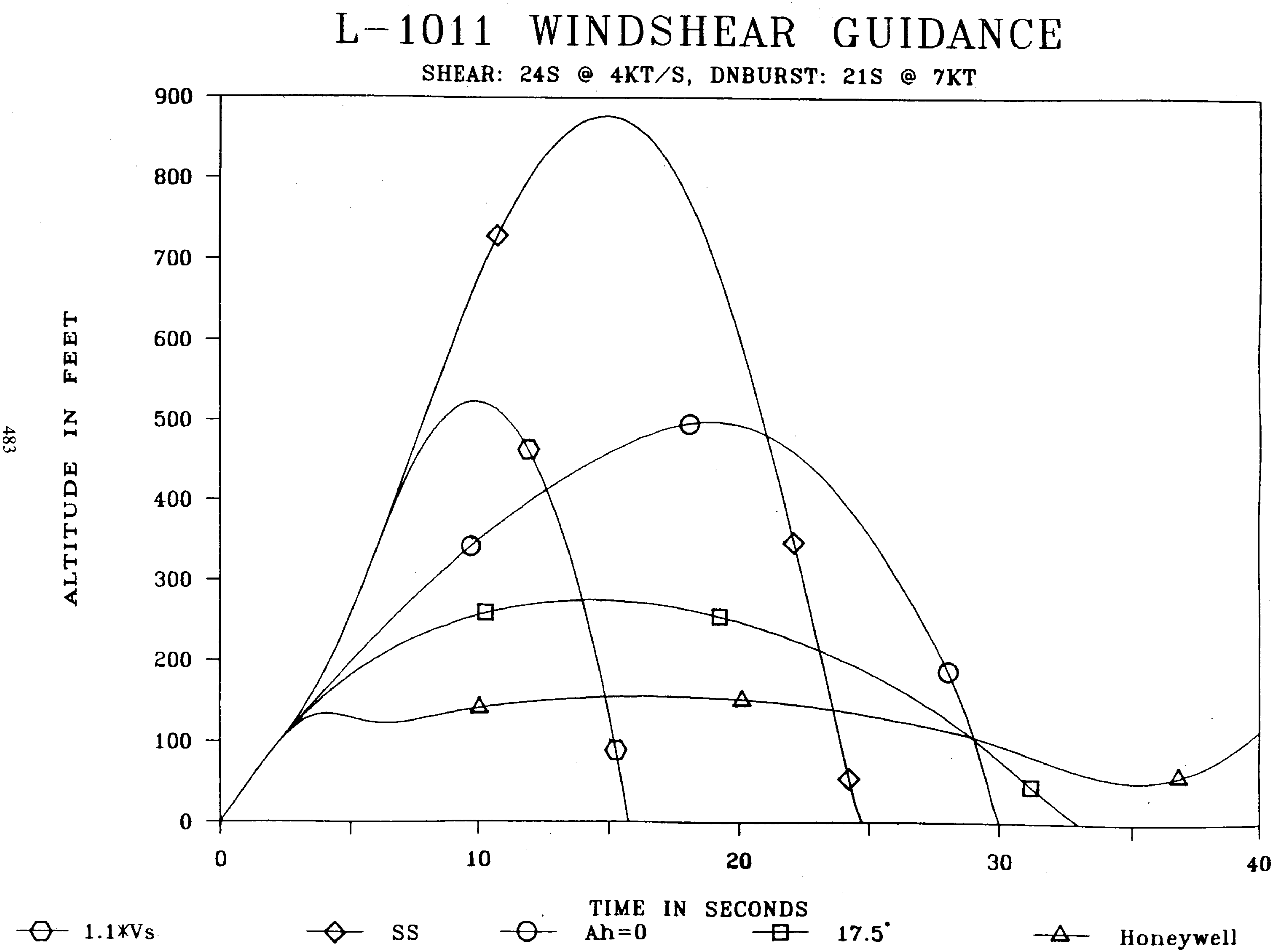


737 WINDSHEAR GUIDANCE

SHEAR: 20S @ 5KT/S, DNBURST: 18S @ 7KT




L-1011 WINDSHEAR GUIDANCE
SHEAR: 9S @ 4KT/S, DNBURST: 6S @ 7KT
ALTITUDE IN FEET
(Thousands)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
TIME IN SECONDS
1.1KVs
SS
Ah=0
17.5°
Honeywell


L-1011 WINDSHEAR GUIDANCE
SHEAR: 24S @ 4KT/S, DNBURST: 21S @ 7KT
ALTITUDE IN FEET
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
TIME IN SECONDS
1.1*Vs
SS
Ah=0
17.5°
Honeywell

Future Enhancements

On

PC-Based Models

* Six Degrees of Freedom
* Control Surface Dynamics
* 3-D Wind Models
* Real Time I/O
* Takeoff/Roll Dynamics
* Instrument Error Models