FLIGHT GUIDANCE RESEARCH FOR RECOVERY FROM MICROBURST WIND SHEAR

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ABSTRACT

Research is in progress to develop flight strategy concepts for avoidance and recovery from microburst wind shears. The objectives of this study are to evaluate the performance of various strategies for recovery from wind shear encountered during the approach-to-landing, examine the associated piloting factors, and evaluate the payoff of forward-look sensing. Both batch and piloted simulations are utilized. The industry-recommended manual recovery technique is used as a baseline strategy. Two advanced strategies were selected for the piloted tests. The first strategy emulates the recovery characteristics shown by prior optimal trajectory analysis, by initially tracking the glideslope, then commanding a shallow climb. The second strategy generates a flight path angle schedule that is a function of airplane energy state and the instantaneous shear strength. All three strategies are tested with reactive sensing only and with forward-look sensing.

Piloted simulation tests are in progress. Tentative results indicate that, using only reactive alerts, there appears to be little difference in performance between the various strategies. With forward-look alerts, the advanced guidance strategies appear to have advantages over the baseline strategy. Relatively short forward-look alert times, on the order of 10 or 15 seconds, produce a far greater recovery benefit than optimizing a recovery from a reactive alert.

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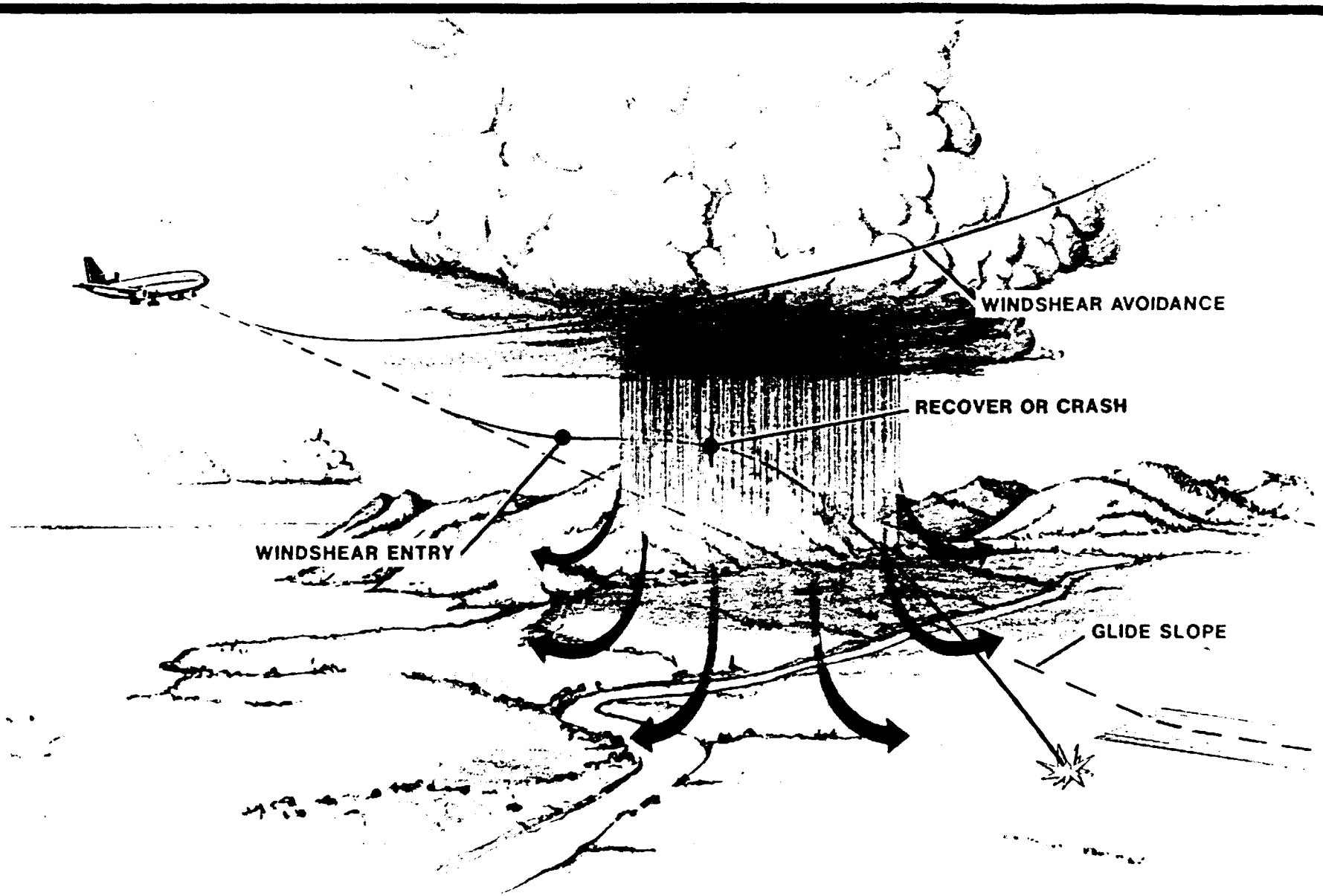
THE WINDSHEAR PROBLEM



OUTLINE

- SUMMARY OF PREVIOUS RESEARCH
- PREDICTED PAYOFF FROM FORWARD-LOOK SENSING
- APPROACH-TO-LANDING WIND SHEAR RECOVERY GUIDANCE
- CONCLUSIONS

PREVIOUS RESEARCH

- OPTIMAL TRAJECTORY ANALYSIS, TAKEOFF AND LANDING ENCOUNTERS
- PILOTED SIMULATION OF TAKEOFF-CASE RECOVERY STRATEGIES
- SIGNIFICANT RESULTS:
  - SIGNIFICANT BENEFITS PREDICTED BY INITIALLY FLYING A LOW FLIGHT PATH ANGLE AND DELAYING STICK SHAKER ACTIVATION TILL END OF SHEAR
  - RECOVERIES HIGHLY SENSITIVE TO SMALL PERTURBATIONS
  - PERFORMANCE INCREASE OF ADVANCED STRATEGIES STATISTICALLY INSIGNIFICANT IN REAL-TIME RUNS DUE TO PILOTING FACTORS

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FORWARD-LOOK PAYOFF

- CONSIDER CHANGE IN ENERGY HEIGHT ACROSS AN EVENT, AS A FUNCTION OF FORWARD-LOOK ALERT TIME

- ENERGY HEIGHT= $\frac{V^2}{2g} + h$

- RATE OF CHANGE IN ENERGY HEIGHT IS A FUNCTION OF AIRPLANE PERFORMANCE AND F-FACTOR

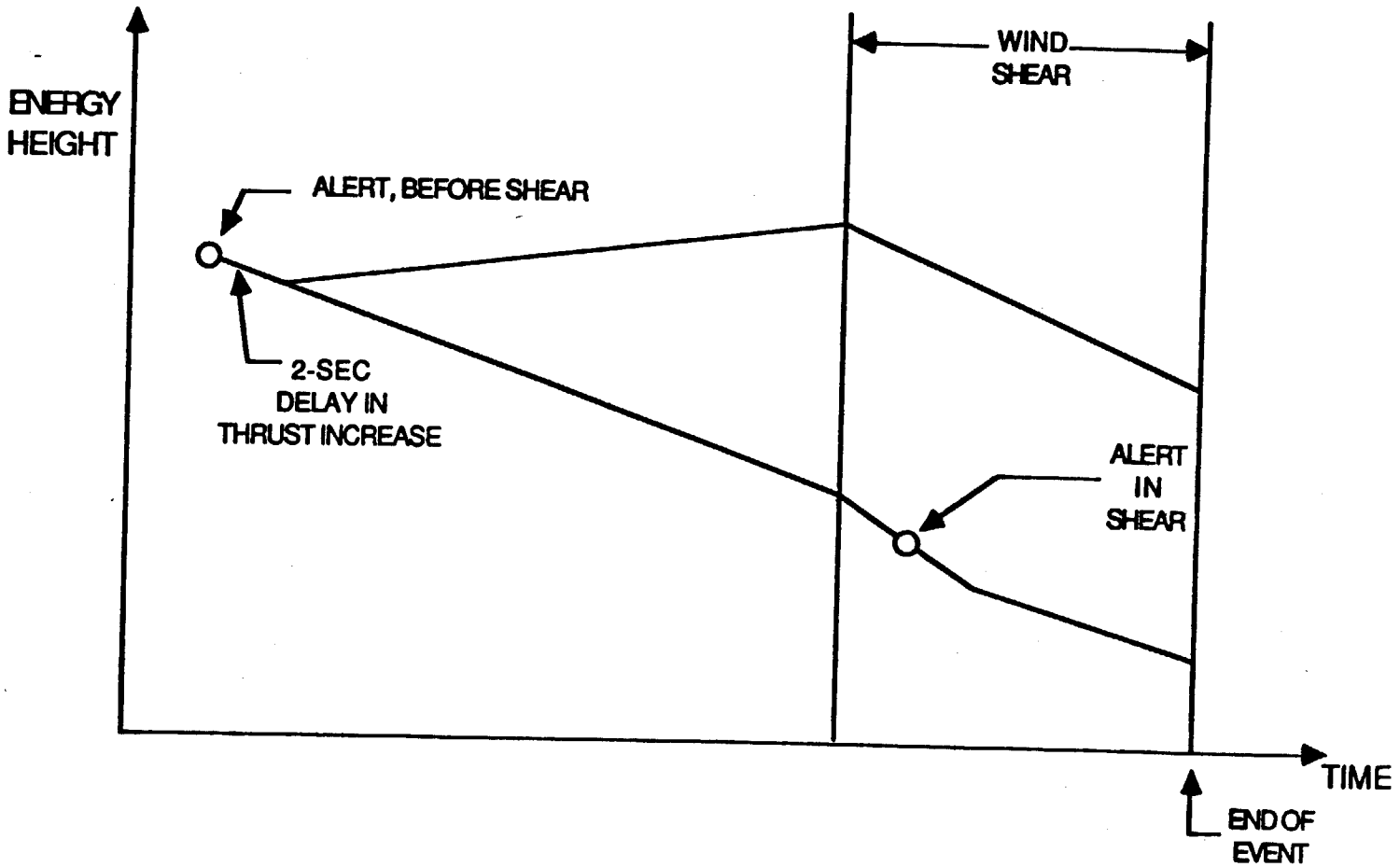
$$\dot{E}h = V\left\langle \frac{T - D}{W} - F \right\rangle$$

- ASSUMPTIONS:
  - CONSTANT F-FACTOR IN SHEAR
  - TWO THRUST VALUES, APPROACH AND GO-AROUND
  - 2-SEC DELAY FROM ALERT TO GO-AROUND
  - CONSTANT AIRPLANE CONFIGURATION

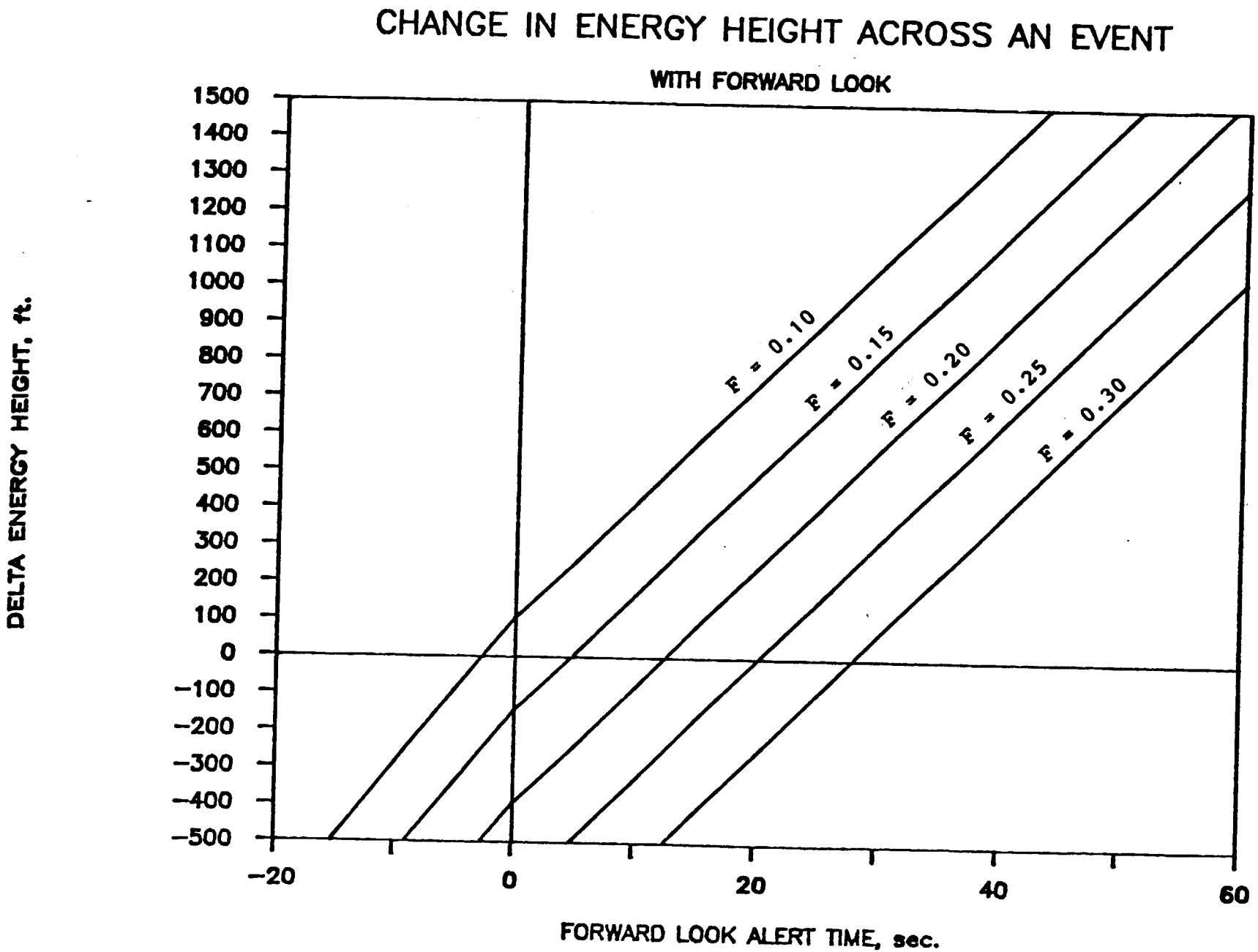
- CAN BE COMPARED TO USEFUL ENERGY HEIGHT AT BEGINNING OF AN EVENT

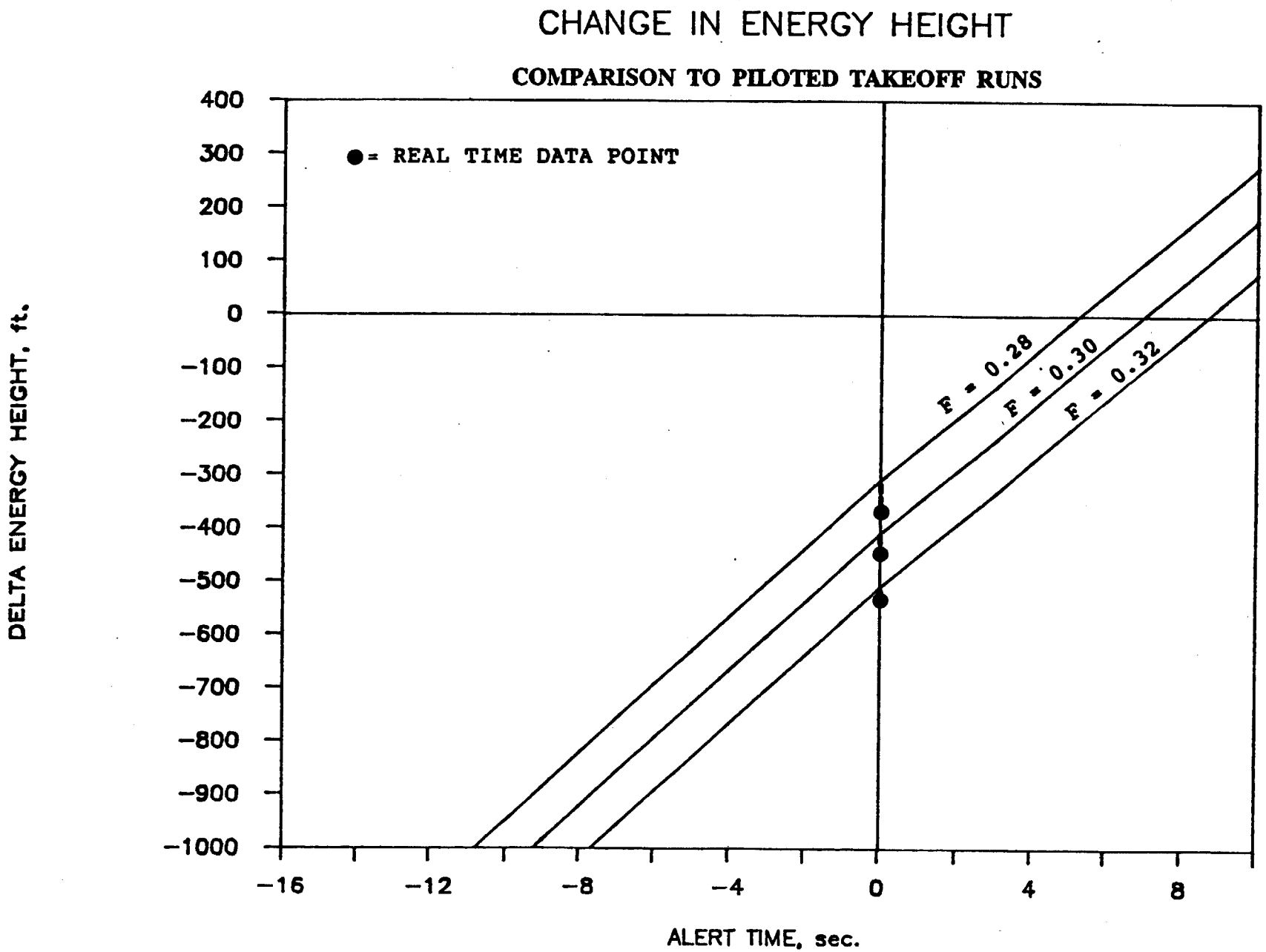
$$Eh_u = \frac{V^2}{2g} - \frac{V_{ss}^2}{2g} + h$$

SCENARIO FOR ENERGY HEIGHT ANALYSIS



- INTEGRATE $\dot{h}_p$ FROM ALERT (OR FROM SHEAR ENTRY IF ALERT IS GIVEN IN THE SHEAR) TO SHEAR EXIT.


CHANGE IN ENERGY HEIGHT ACROSS AN EVENT
WITH FORWARD LOOK
DELTA ENERGY HEIGHT, ft.
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
−100
−200
−300
−400
−500
F = 0.10
F = 0.15
F = 0.20
F = 0.25
F = 0.30
−20
0
20
40
60
FORWARD LOOK ALERT TIME, sec.


CHANGE IN ENERGY HEIGHT
COMPARISON TO PILOTED TAKEOFF RUNS
● = REAL TIME DATA POINT
F = 0.28
F = 0.30
F = 0.32
DELTA ENERGY HEIGHT, ft.
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-16
-12
-8
-4
0
4
8
ALERT TIME, sec.

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APPROACH TO LANDING RECOVERY GUIDANCE

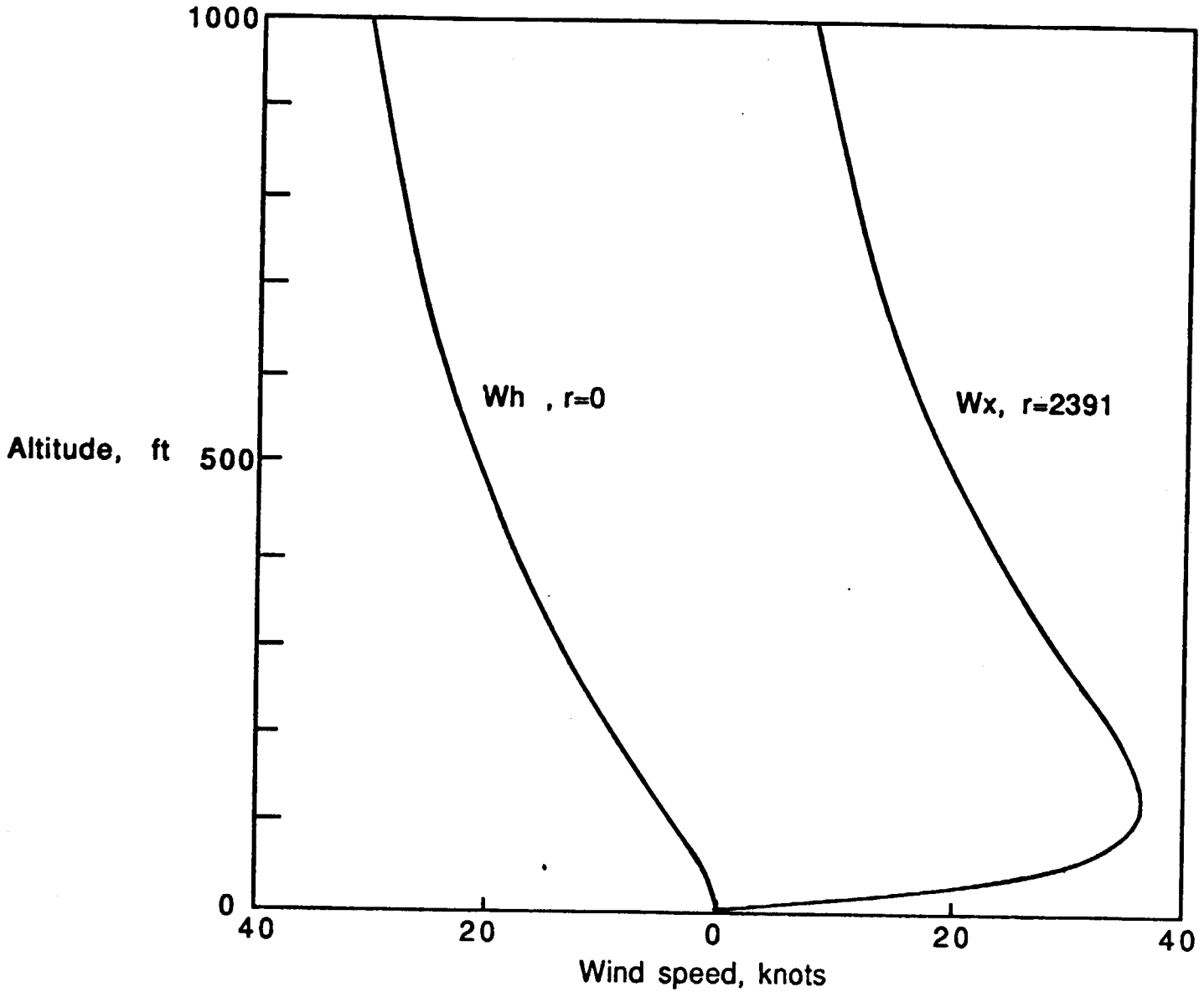
OBJECTIVE: DETERMINE PERFORMANCE OF CANDIDATE ADVANCED RECOVERY STRATEGIES, PILOTING FACTORS, AND FORWARD-LOOK PAYOFF IN APPROACH CASE ENCOUNTERS

APPROACH: BATCH AND PILOTED SIMULATION OF WIND SHEAR ENCOUNTERS

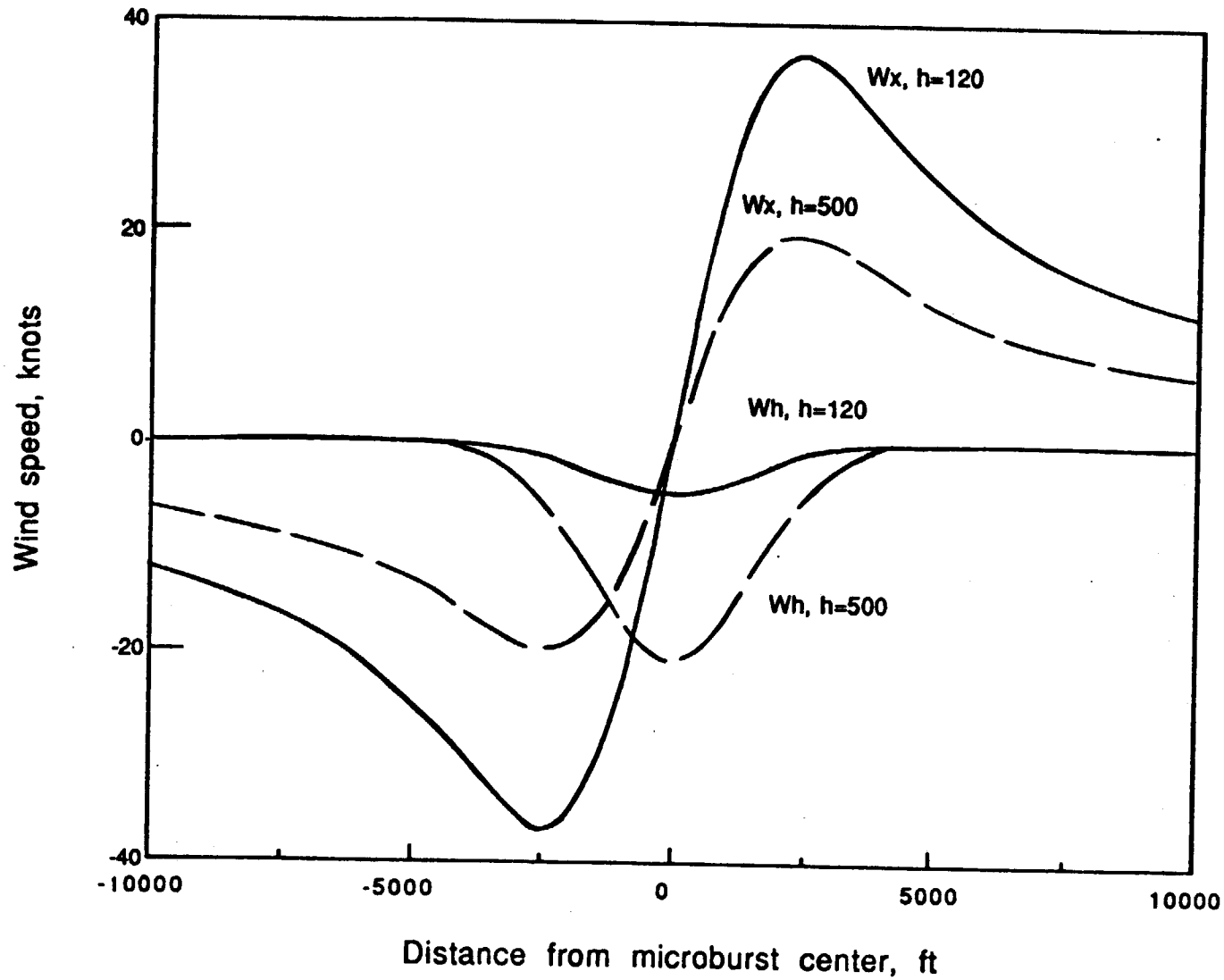
TOOLS:

- ADVANCED ANALYTICAL WIND SHEAR MODEL
- NUMERIC MODEL, DFW BASED
- VISUAL MOTION SIMULATOR

ALTITUDE PROFILES FOR ANALYTICAL MODEL



RADIAL AND VERTICAL WIND COMPONENTS OF ANALYTICAL MICROBURST MODEL



BATCH SIMULATIONS

- POINT-MASS PERFORMANCE MODEL OF B737-100, INCLUDING VARIABLE CONFIGURATION AND AUTOTHROTTLE

- F-FACTOR BASED WIND SHEAR DETECTION

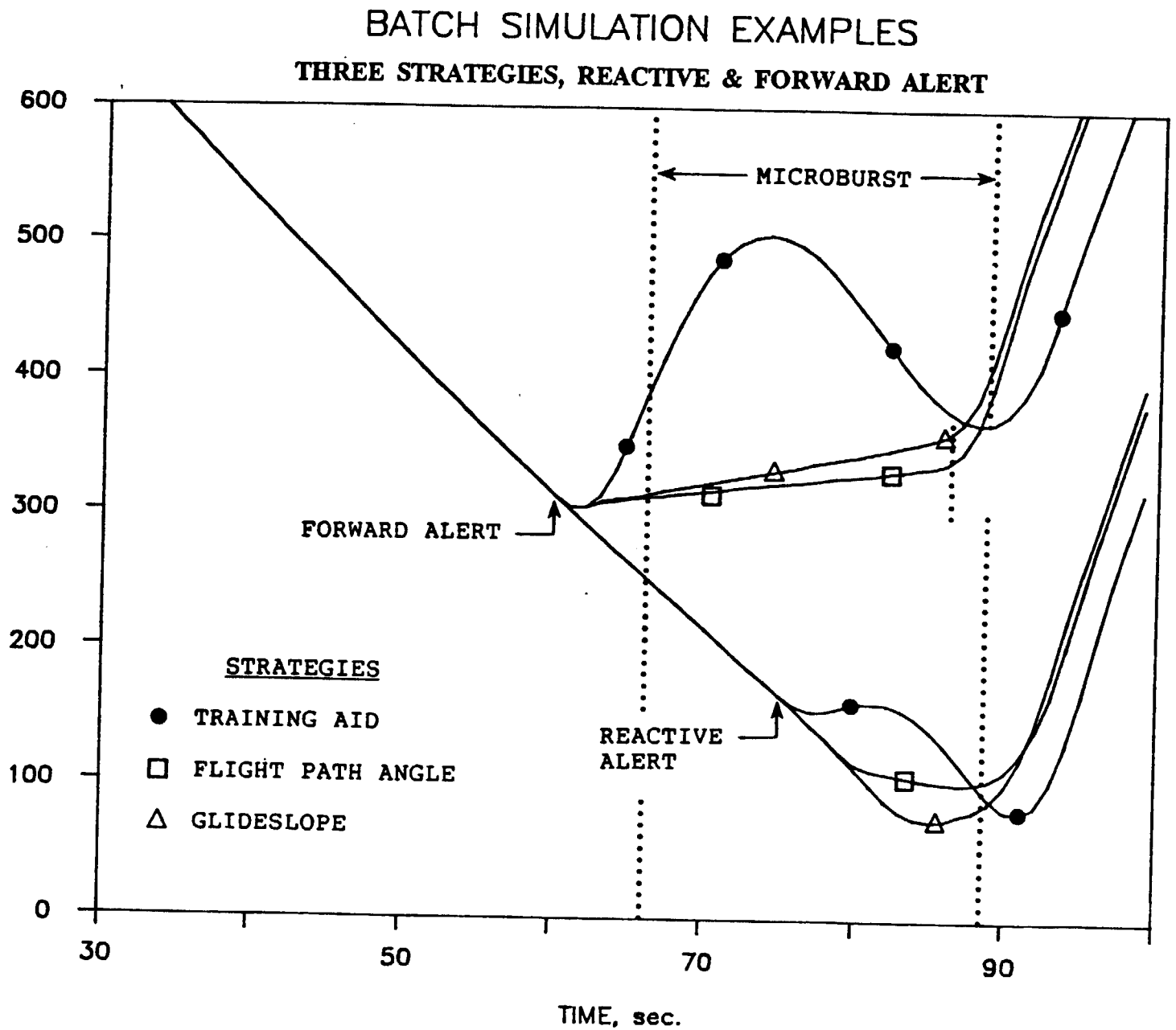
- TESTED 7 RECOVERY STRATEGIES, THREE SELECTED FOR PILOTED TESTS:

  1) TRAINING AID PROCEDURE (BASELINE)

  2) GLIDESLOPE STRATEGY

  3) FLIGHT PATH ANGLE STRATEGY

- RESULTS:
  - BENEFITS OF SHORT-RANGE FORWARD ALERT (5-10 SEC) MUCH GREATER THAN IMPROVING GUIDANCE IN REACTIVE ALERT CASE
  - BASELINE STRATEGY PERFORMANCE SIMILAR TO OTHERS IN REACTIVE ALERT CASE, LESS THAN OTHERS WITH FORWARD ALERT

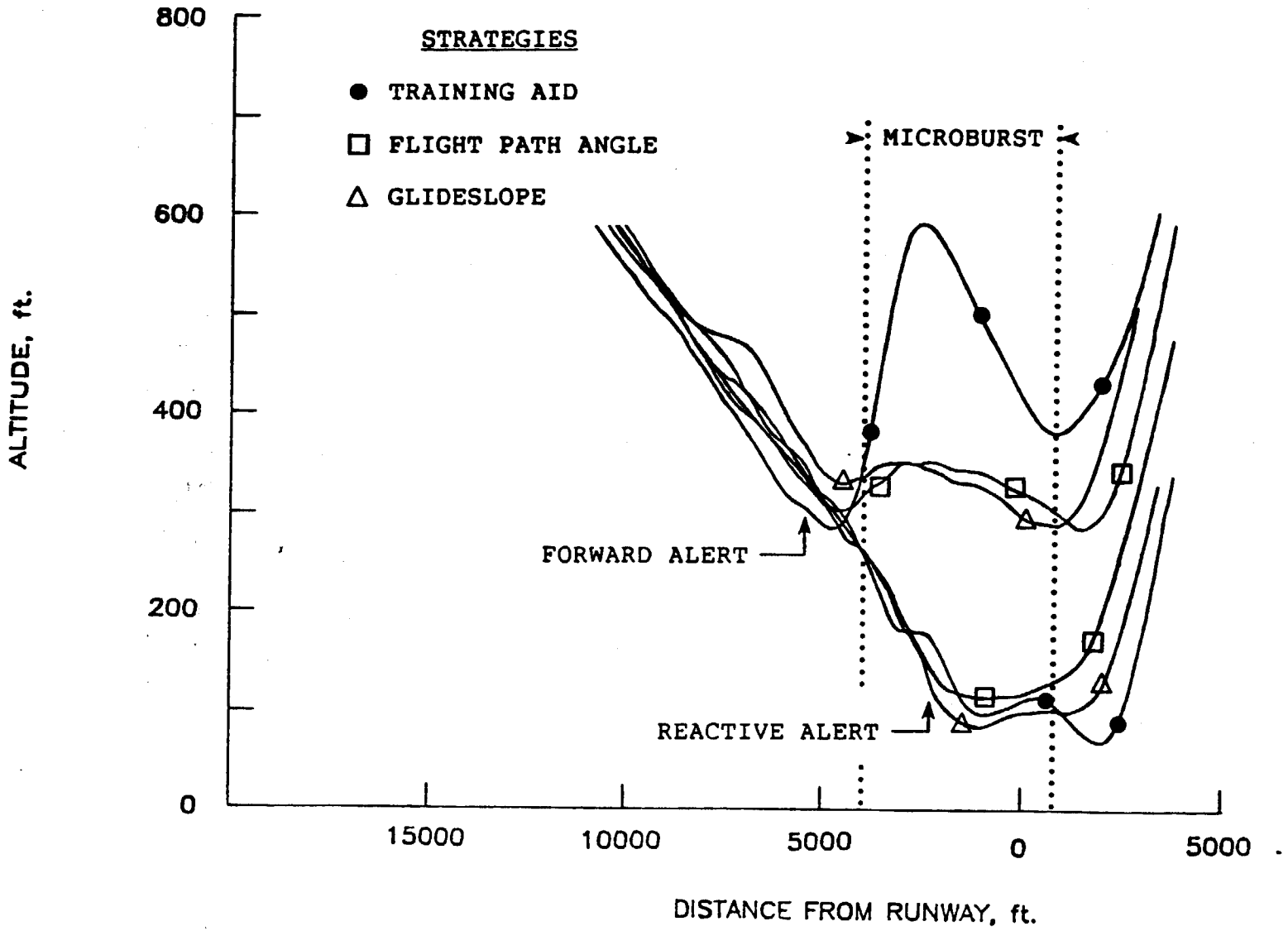

BATCH SIMULATION EXAMPLES
THREE STRATEGIES, REACTIVE & FORWARD ALERT
ALTITUDE, ft.
600
500
400
300
200
100
0
30
50
70
90
TIME, sec.
MICROBURST
FORWARD ALERT
REACTIVE ALERT
STRATEGIES
TRAINING AID
FLIGHT PATH ANGLE
GLIDESLOPE

PILOTED SIMULATIONS

- IMPLEMENT THREE STRATEGIES ON ELECTROMECHANICAL ADI
- IMPLEMENT TWO MICROBURST MODELS, TURBULENCE
- IMPLEMENT REACTIVE AND FORWARD-LOOK ALERTING
- TEST TWO ALERT TIMES (-5 AND +10 SEC)

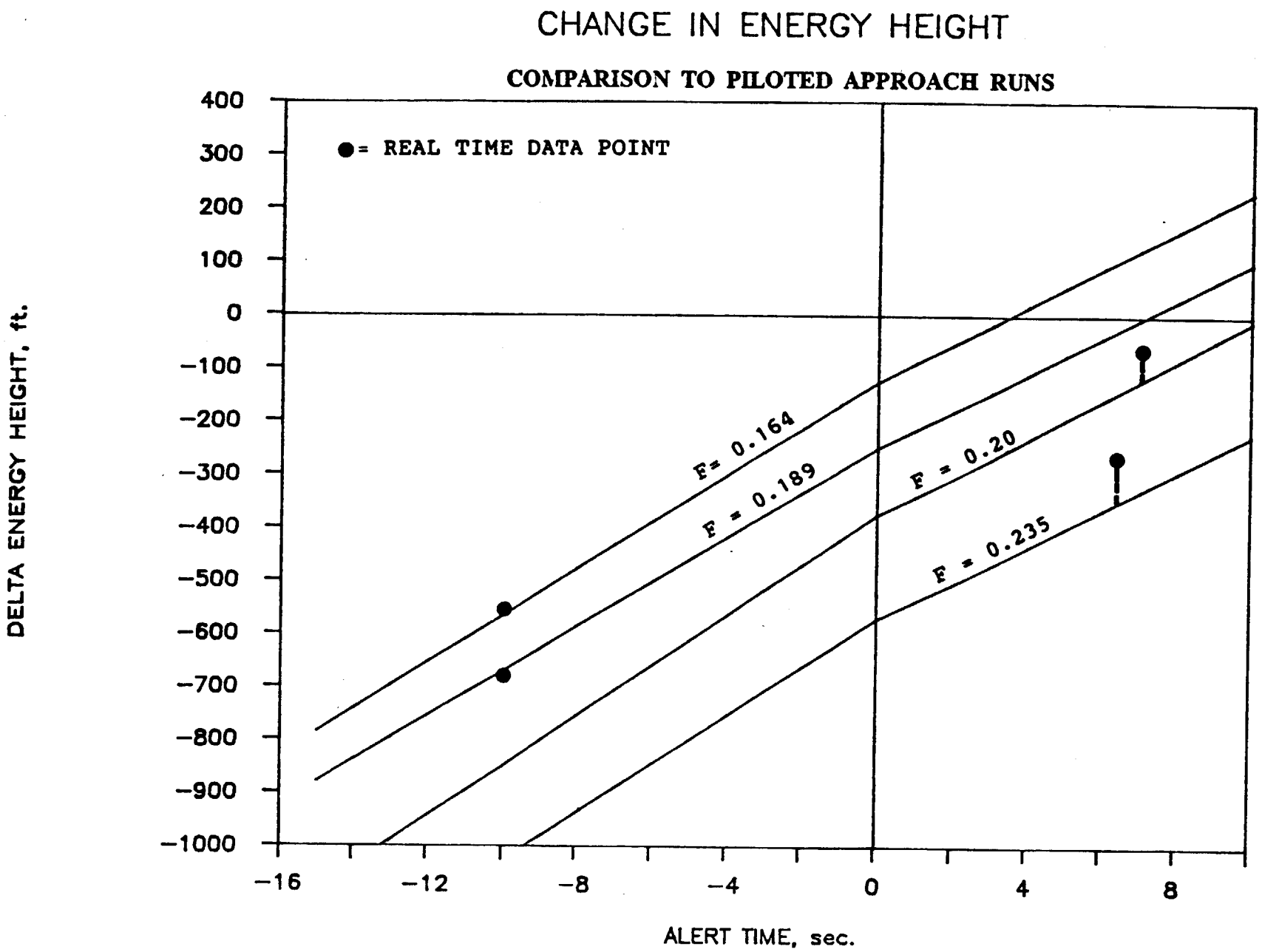
PILOTED SIMULATION EXAMPLES

THREE STRATEGIES, REACTIVE & FORWARD ALERT



PRELIMINARY TRENDS

- TWO PILOTS HAVE COMPLETED MATRIX
- MINIMUM RECOVERY ALTITUDES SIMILAR WITH ALL THREE STRATEGIES
- LARGE PAYOFF SEEN WITH SHORT-RANGE FORWARD LOOK
  - NUMEROUS CRASHES AND BELOW 100 FT RECOVERIES WITH REACTIVE ALERT, AVERAGE 110 FT
  - LOWEST RECOVERY WITH FORWARD LOOK HAS BEEN 268 FT, AVERAGE 387 FT
  - NORMAL GO-AROUND PROCEDURE TRIED WITH FORWARD LOOK, WITH EQUIVALENT PERFORMANCE TO GUIDED PROCEDURES


CHANGE IN ENERGY HEIGHT
COMPARISON TO PILOTED APPROACH RUNS
● = REAL TIME DATA POINT
F= 0.164
F = 0.189
F = 0.20
F = 0.235
DELTA ENERGY HEIGHT, ft.
400
300
200
100
0
−100
−200
−300
−400
−500
−600
−700
−800
−900
−1000
−16
−12
−8
−4
0
4
8
ALERT TIME, sec.

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- PREDICTED BENEFITS OF ADVANCED RECOVERY PROCEDURES MAY NOT BE ACHIEVED WHEN MANUALLY FLOWN

- CURRENT TRAINING AID PROCEDURE IS APPROPRIATE FOR MANUALLY FLOWN RECOVERIES FROM A REACTIVE ALERT

- BENEFITS OF FORWARD- LOOK SENSING FAR EXCEED ENHANCED GUIDANCE

- RESEARCH NEEDED IN: - AUTOMATED RECOVERIES
  - FORWARD LOOK HAZARD DISPLAYS
  - COCKPIT INTEGRATION