



# Outbrief for CIBX Experiment

E. Braden / EGS

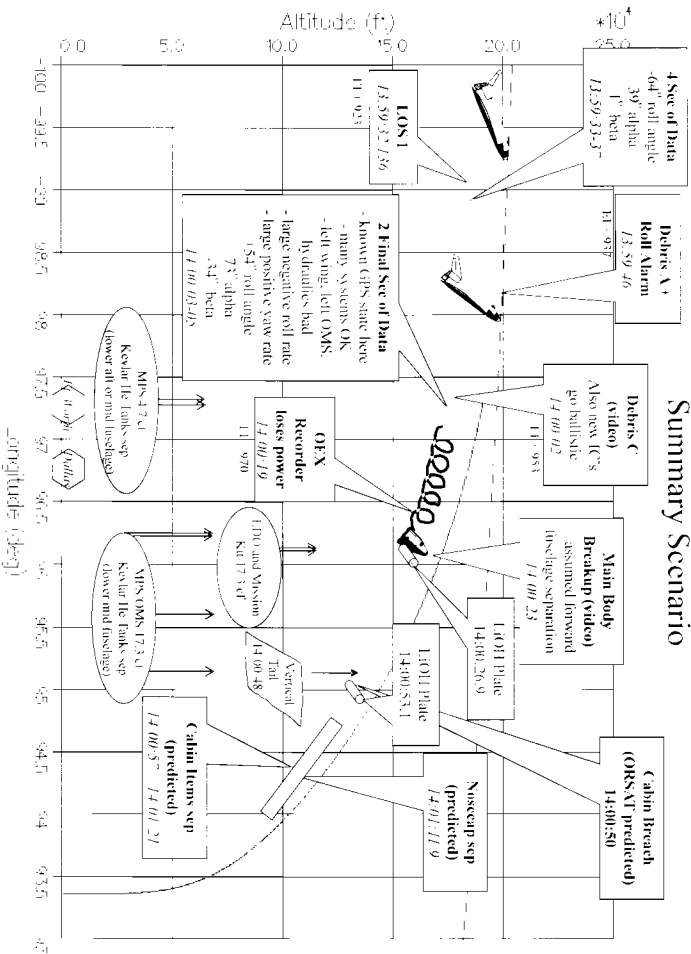
October 22, 2009



# Introduction

- Columbia breakup scenario and timeline
- Debris footprint and map
- Ballistics
- “Black” box
- “Opened” box
- Release times
- Refrigerator door
- Future work and questions

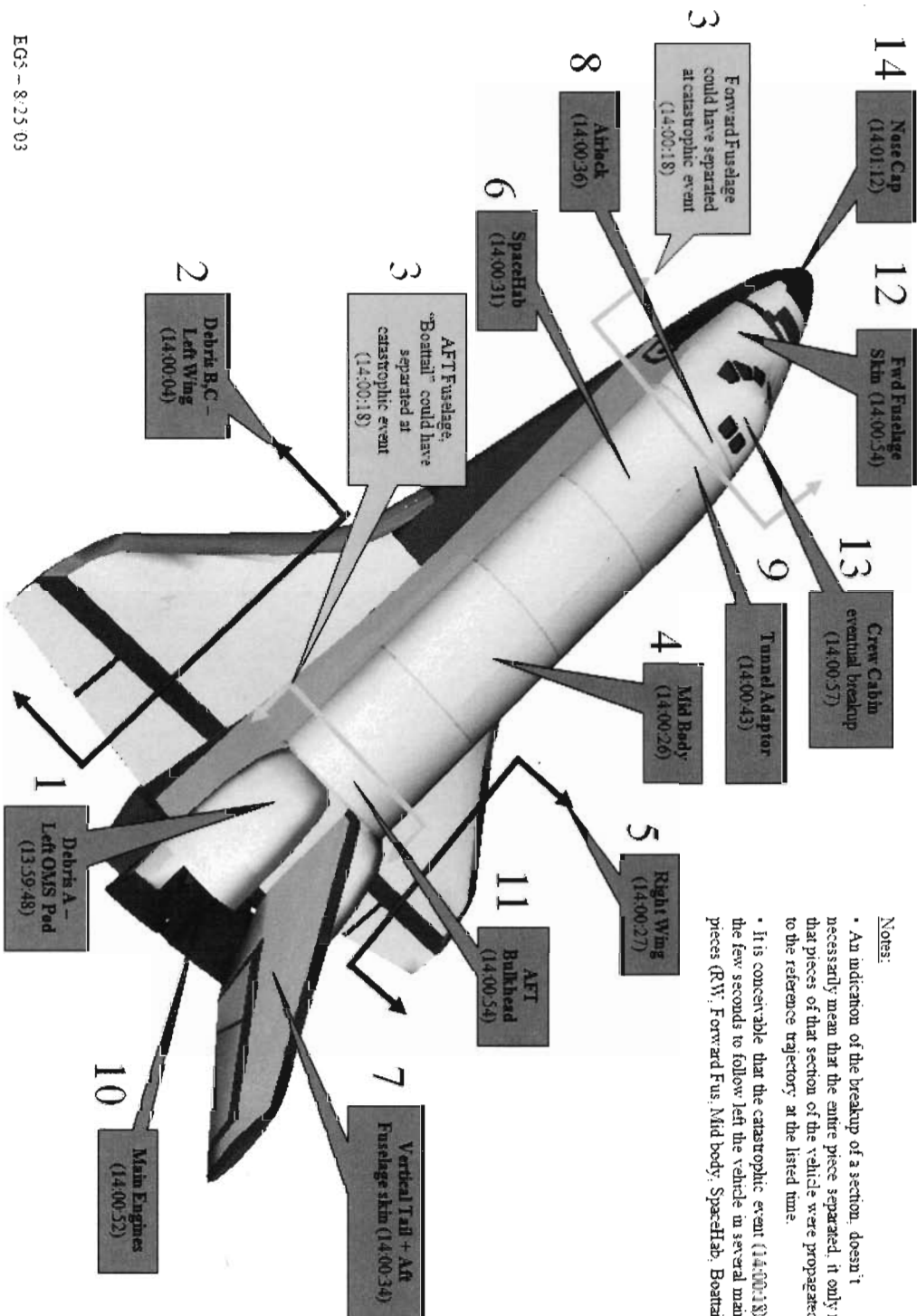
# Summary Scenario





# Columbia Breakup Scenario

## Columbia Breakup Data



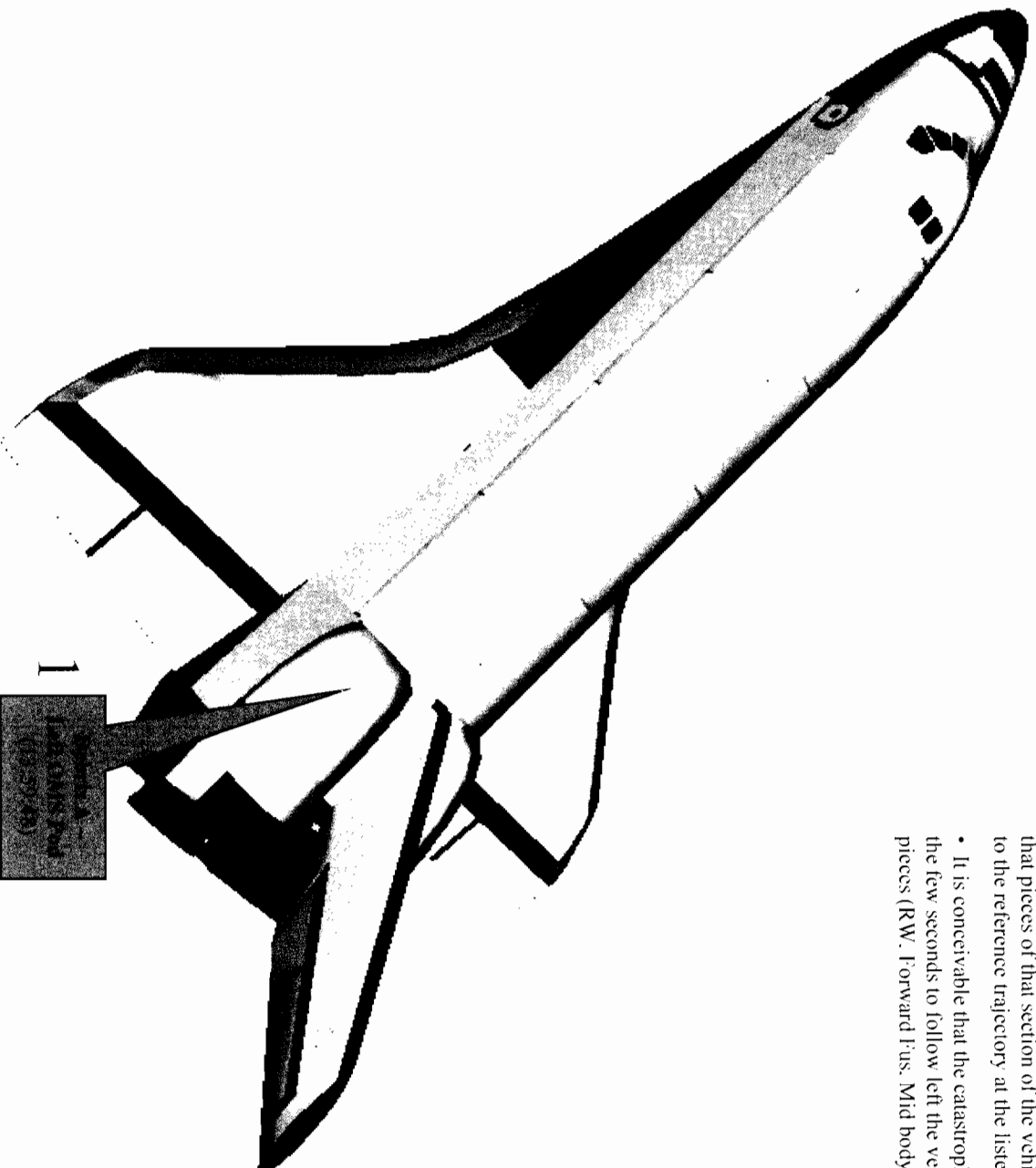
- Notes:
- An indication of the breakup of a section doesn't necessarily mean that the entire piece separated, it only means that pieces of that section of the vehicle were propagated back to the reference trajectory at the listed time.
  - It is conceivable that the catastrophic event (14:00:18) and the few seconds to follow left the vehicle in several main pieces (RV, Forward Fus, Mid body, SpaceHab, Boattail).

EGS - 8:25:03

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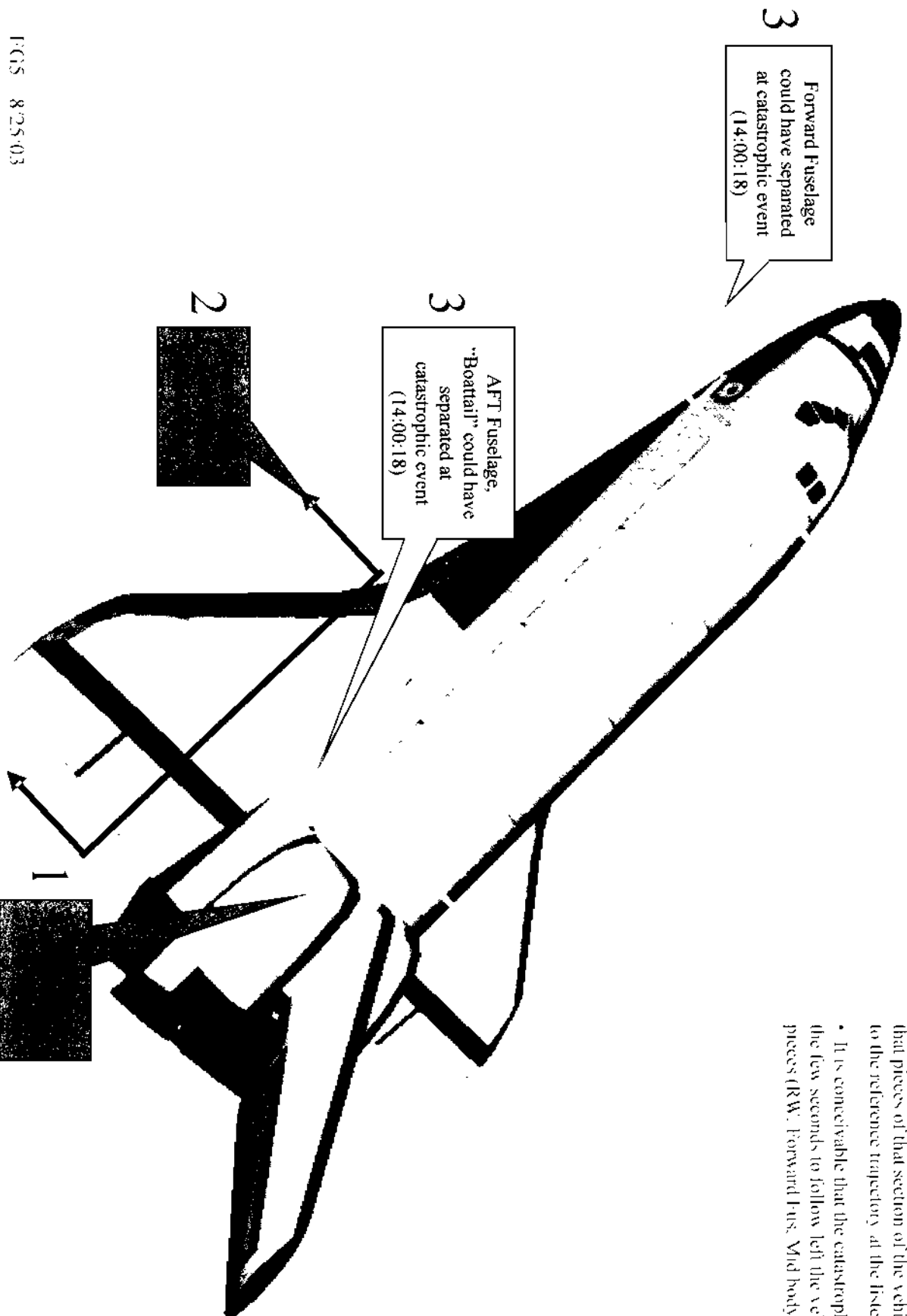
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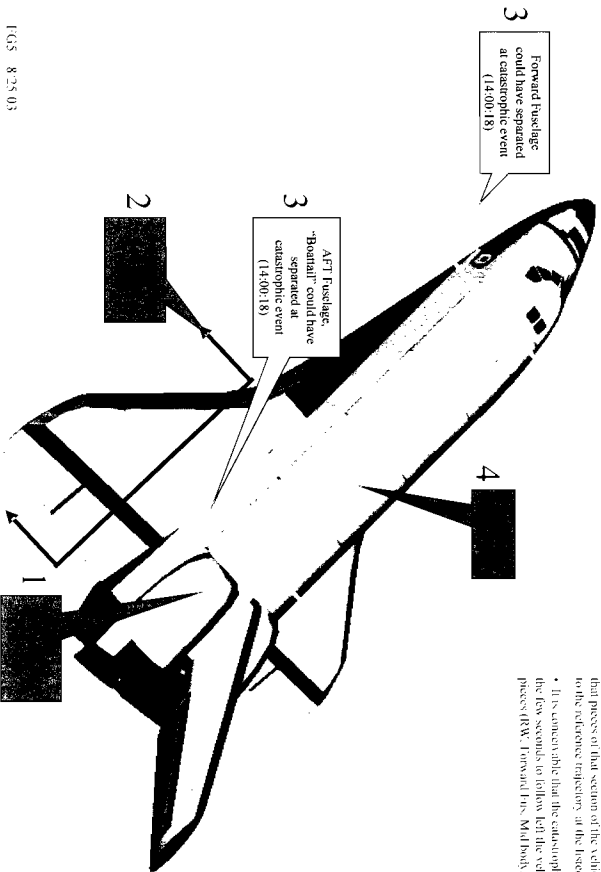
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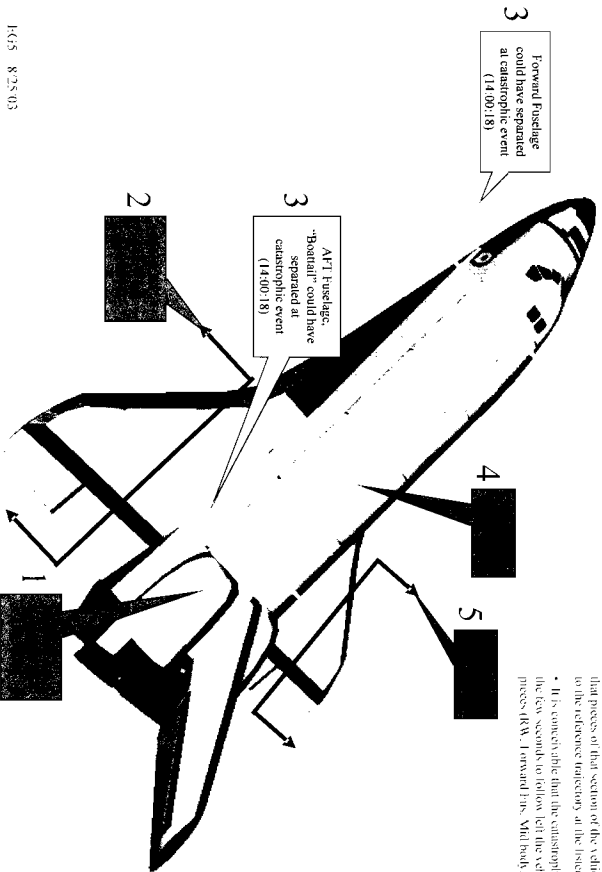




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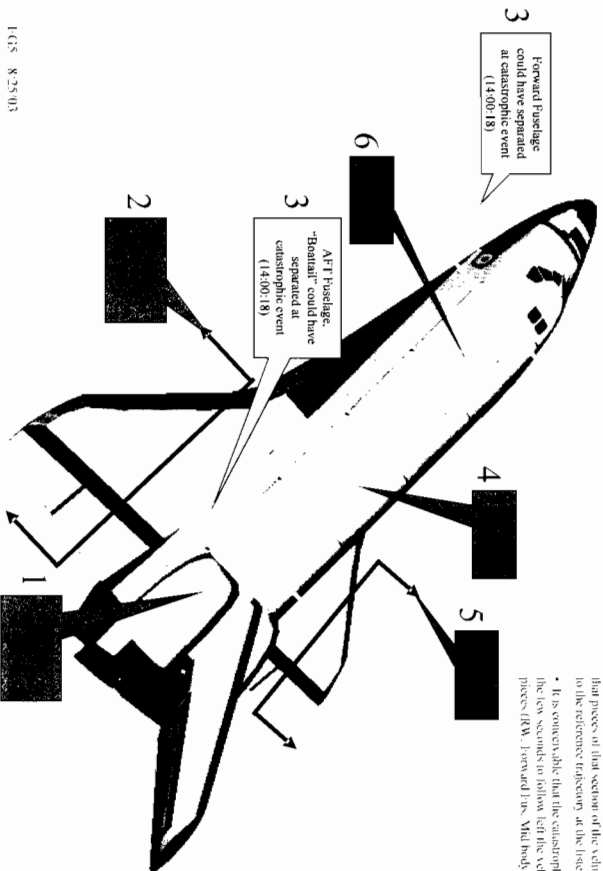
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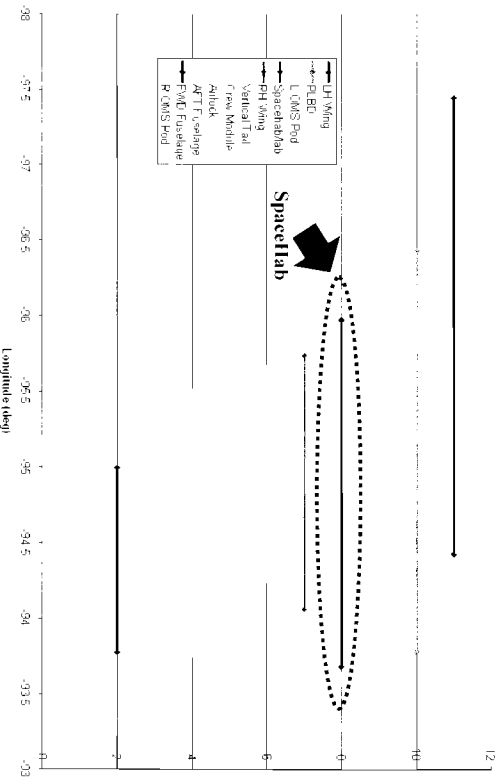
# Columbia Breakup Timeline

Time	Piece	Notes	Justification
13:59:48	Left Orms Pod		Orms pod Fragment 76899 (13:59:48); 85446 (13:59:57); 84132 (16:41)
14:00:04	L Wing		RCC 7039112 2; Skin 8133114 9; 1152516 3;
14:00:18		Loss of OEX (LOX) & Catastrophic Event (CE)	
14:00:26	Mid Body PLBD	In between 04 and 23 could be losing pieces of PLBD (doors, internal Mem's, etc.)	Homemade heel piece(15); 82427 (20 1); 82172 (33 5); 36315 (35)
14:00:27	Right Wing	Could be after effect of vehicle split	RCC 49833(30 1); 81721(27 9); skin 58702(24 2); 24509(25 6)
14:00:31	Space Hab		22900(57 2); outlier 55045(29 3); 7641(32 7);



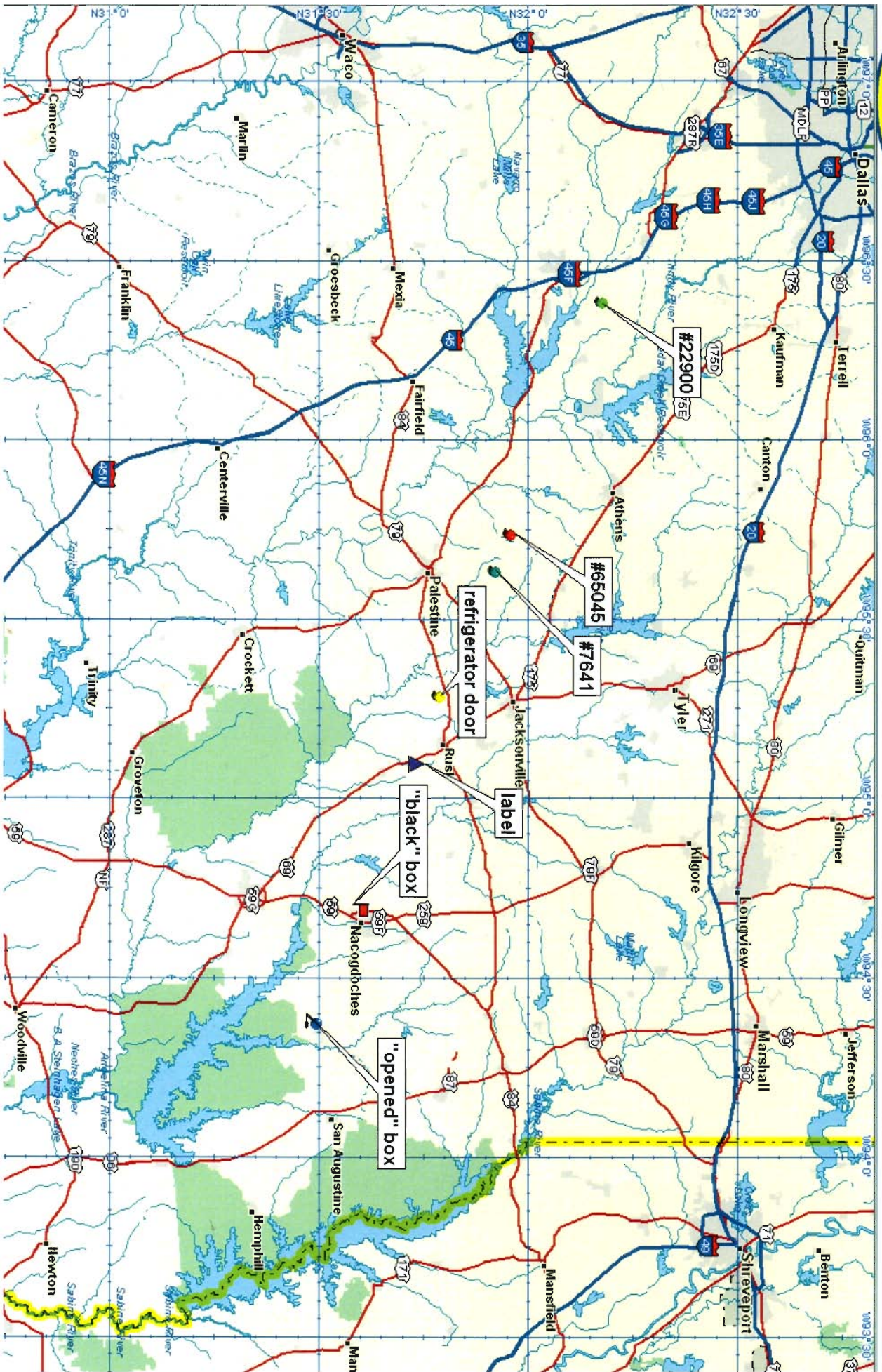
# Debris Footprints

## STS-107 Debris Impact Footprints





# Location of Recovered Debris





# Ballistics

- Limitations
  - Only “facts” are location and mass properties of recovered debris
  - All else is assumed using engineering judgment and experience
- Assumptions
  - Recovered debris were released in the same state as which they were recovered
    - Cannot account for cascading breakups
  - Trajectory from which the debris were released propagated forward in time from the last known position and velocity, using estimated mass properties
  - Debris did not experience lift
  - Debris did not experience cross-track acceleration
  - Limited analysis to objects with simple geometries (spheres, flat plates)



# Ballistic Analysis Steps

- Tool used is SORT (Simulation and Optimization of Rocket Trajectories)
- The inputs are the debris object's mass, area, recovered longitude, and aerodynamic drag coefficients
- SORT iterates on the release time until the recovered longitude is achieved
- Outputs include release time, loads, and the object's trajectory to the ground



# “Black” BOX

Debris item #15561

Recovered location, 31.58°N, 94.71°W

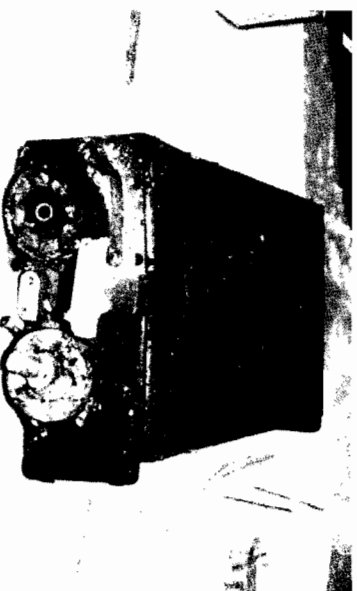






# “Black” Box Observations

- Blacken outer appearance
  - A picture indicates that the box had a metallic surface before the accident
  - Could this be melted material deposited on the box?
- No signs the box achieved a trimmed attitude
- Damage to the box upon impact





# “Opened” Box

Debris item #44087

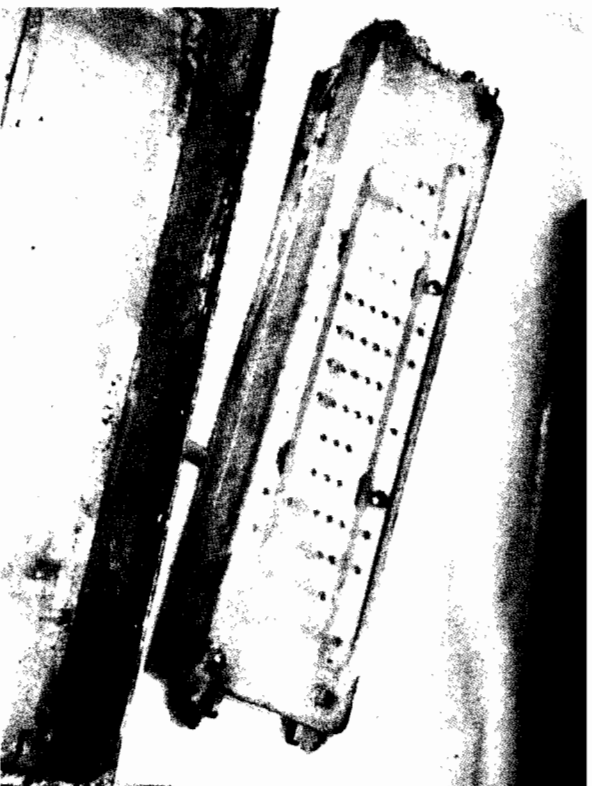
Recovered location, 31.47°N, 94.40°W





# “Opened” Box Observations

- No signs the box achieved a trimmed attitude
- Damage to the box upon impact
- Evidence of heating on material inside the box





# BOX Aero

- Since there was no signs that the boxes achieved a trim attitude, 3 aerodynamic drag scenarios were examined
  - Maximum Drag Orientation
    - The largest box face was normal to the wind
  - Tumbling Drag Orientation
    - Box was tumbling randomly
  - Minimum Drag Orientation
    - The smallest box face was normal to the wind



# Release Times

	Minimum Drag	Tumbling Drag	Maximum Drag
"Black" box	13:59:46.44	14:00:13.4	14:00:32.69
"Opened" Box	13:59:46.44	13:59:49.53	14:00:18.89

<u>Time</u>	<u>Piece</u>	<u>Notes</u>
13:59:32		Loss of Continuous Signal from GPCs (LOS)
13:59:46		Loss of Control (LOC)
13:59:46	"Black" and "Opened" Box	Minimum Drag
13:59:48	Left Oms Pod	
13:59:50	"Opened" Box	Tumbling Drag
14:00:03 to 14:00:05		Reconstructed GPC Data (RGPC)
14:00:04	Payload Bay Doors were still intact	Freon loops and radiators (located in the doors) were intact; flow measurements and pressure measurements were nominal
14:00:04	L Wing	
14:00:13	"Black" Box	Tumbling Drag
14:00:18		Loss of OEX (LOX) & Catastrophic Event (CE)
14:00:19	"Opened" Box	Maximum Drag
14:00:26	Mid Body, PLBD	In between 04 and 23, could be losing pieces of PLBD (doors, internal items, etc.)
14:00:27	Right Wing	Could be after effect of vehicle split
14:00:31	Space Hab	
14:00:33	"Black" Box	Maximum Drag



# Release Times

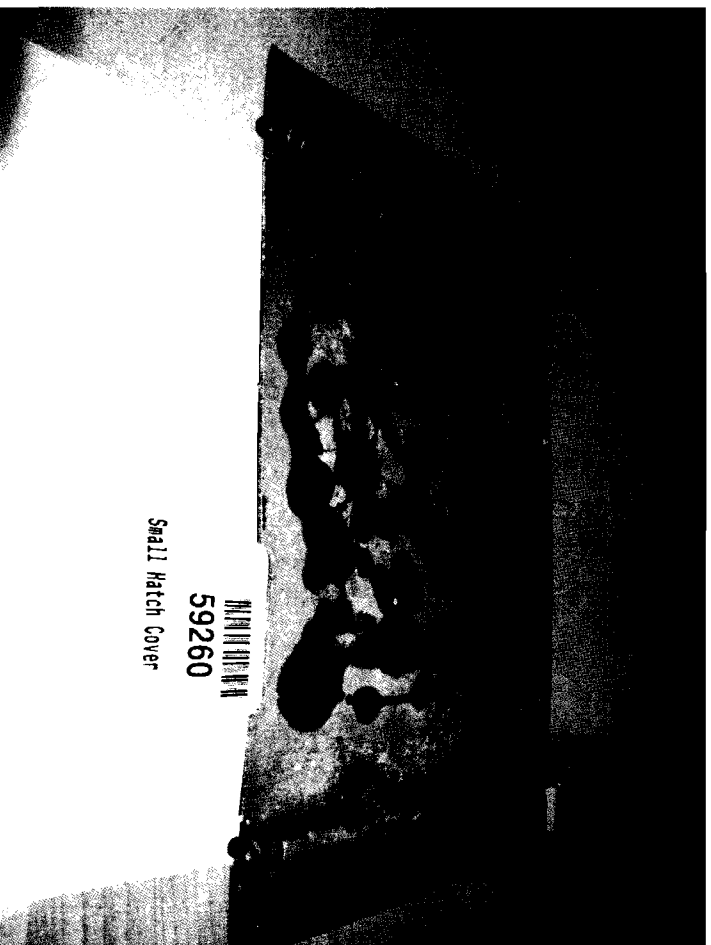
- Three of the release times are too early in the breakup scenario
- The boxes probably remained inside the refrigerator for some period of time before becoming free-flyers
- Ballistics on the recovered refrigerator door may help narrow down the release times



# Refrigerator Door

Debris item #59260

Recovered location, 31.78°N, 95.28°W





# Future Work and Questions

- Future Work
  - Run ballistic analyses on refrigerator door (max, min, and tumbling drag)
- Questions
  - Was the “black” box initially black?
  - Are there any pictures or drawings that show how the boxes were arranged inside the refrigerator?
  - What are the materials and their melting points inside the “opened” box?
    - JSC Materials and Processes Branch (ES4) can evaluate the melted material found in the “opened” box by :
      - Inspection, to estimate what the material is and a melting point range
      - Testing, by taking a sample of material to determine what it is and its melting point
  - Are there any other recovered debris?

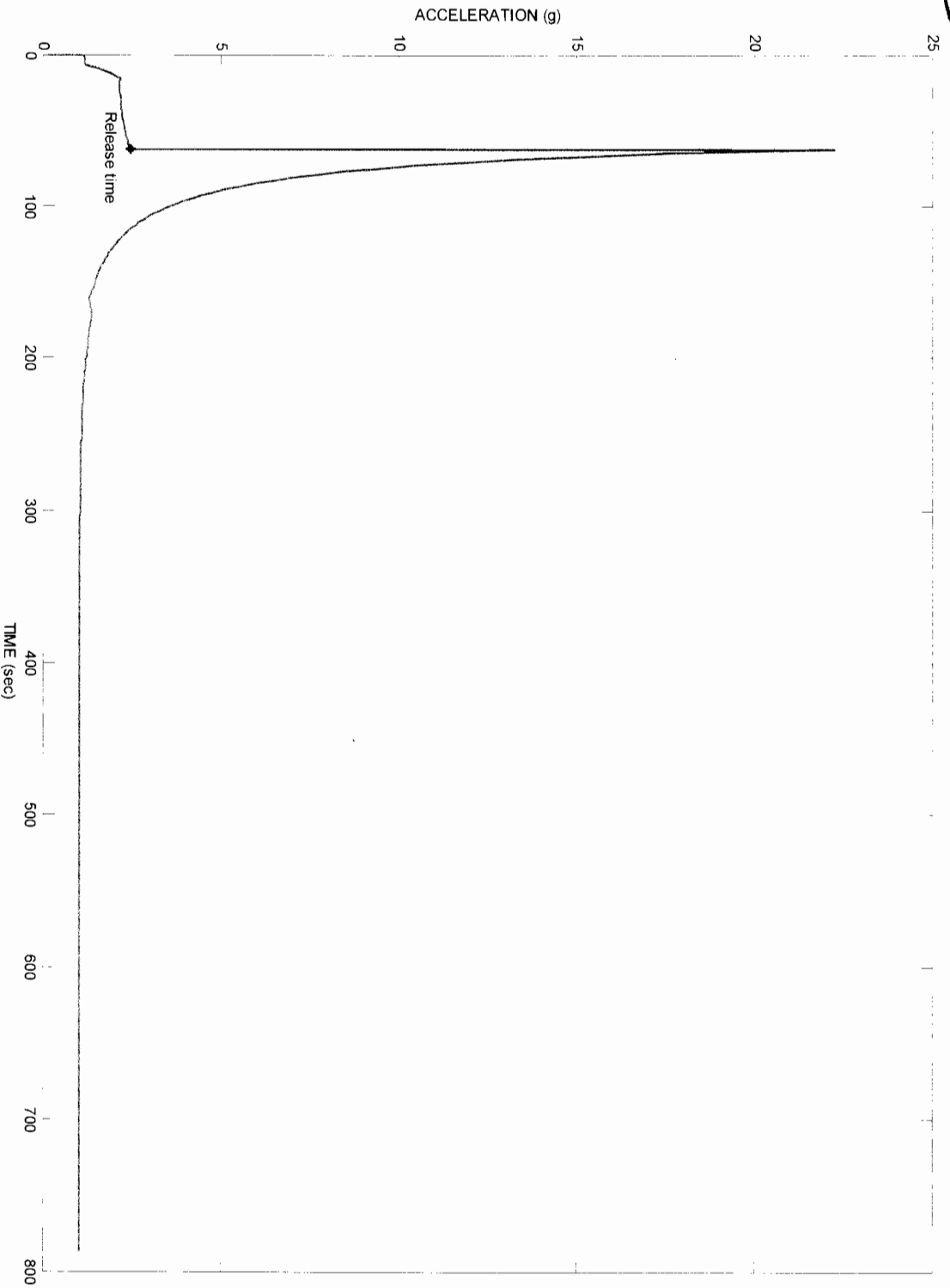




# Backup

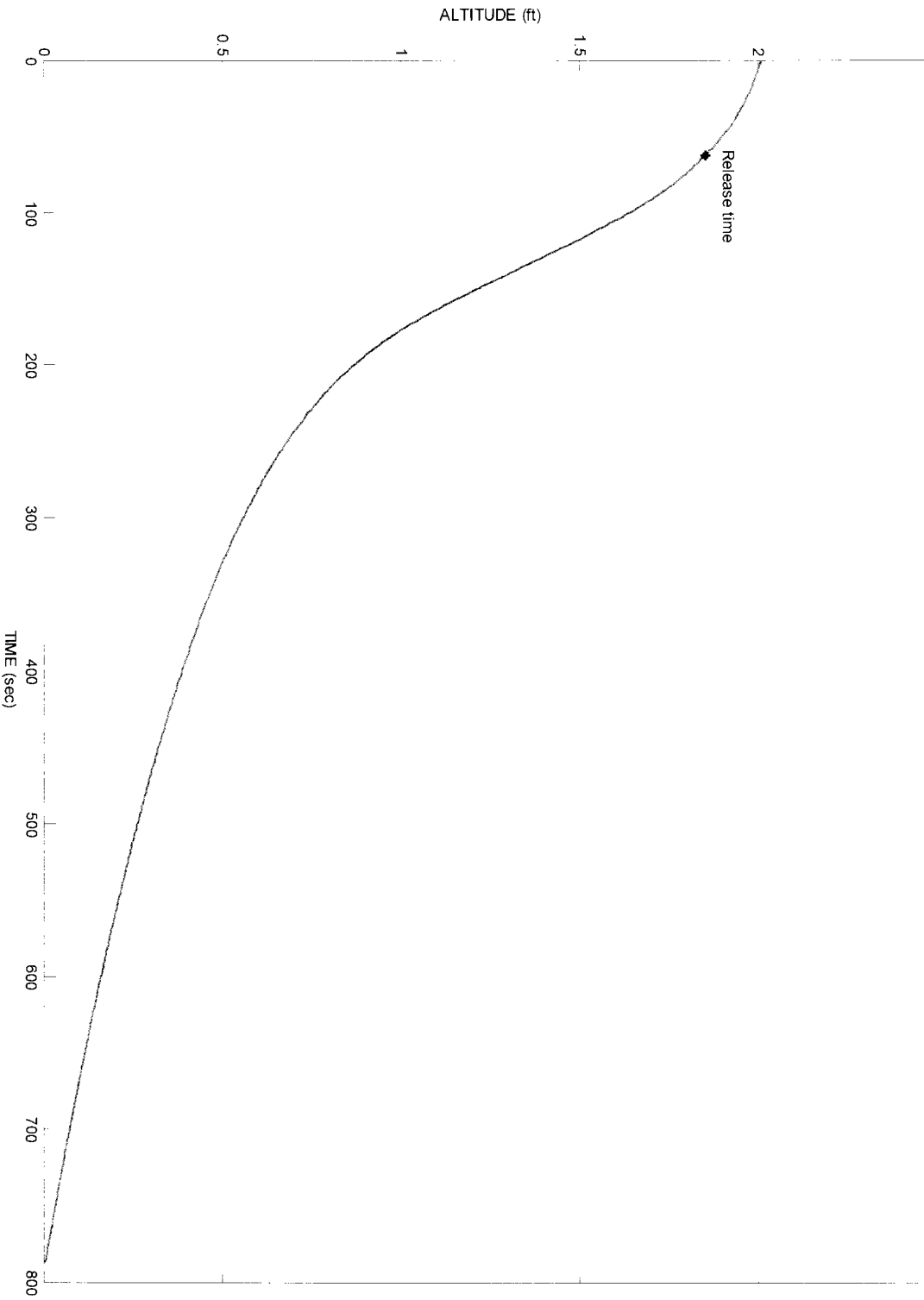


# GLOADS "Black" Box, Maximum Aero



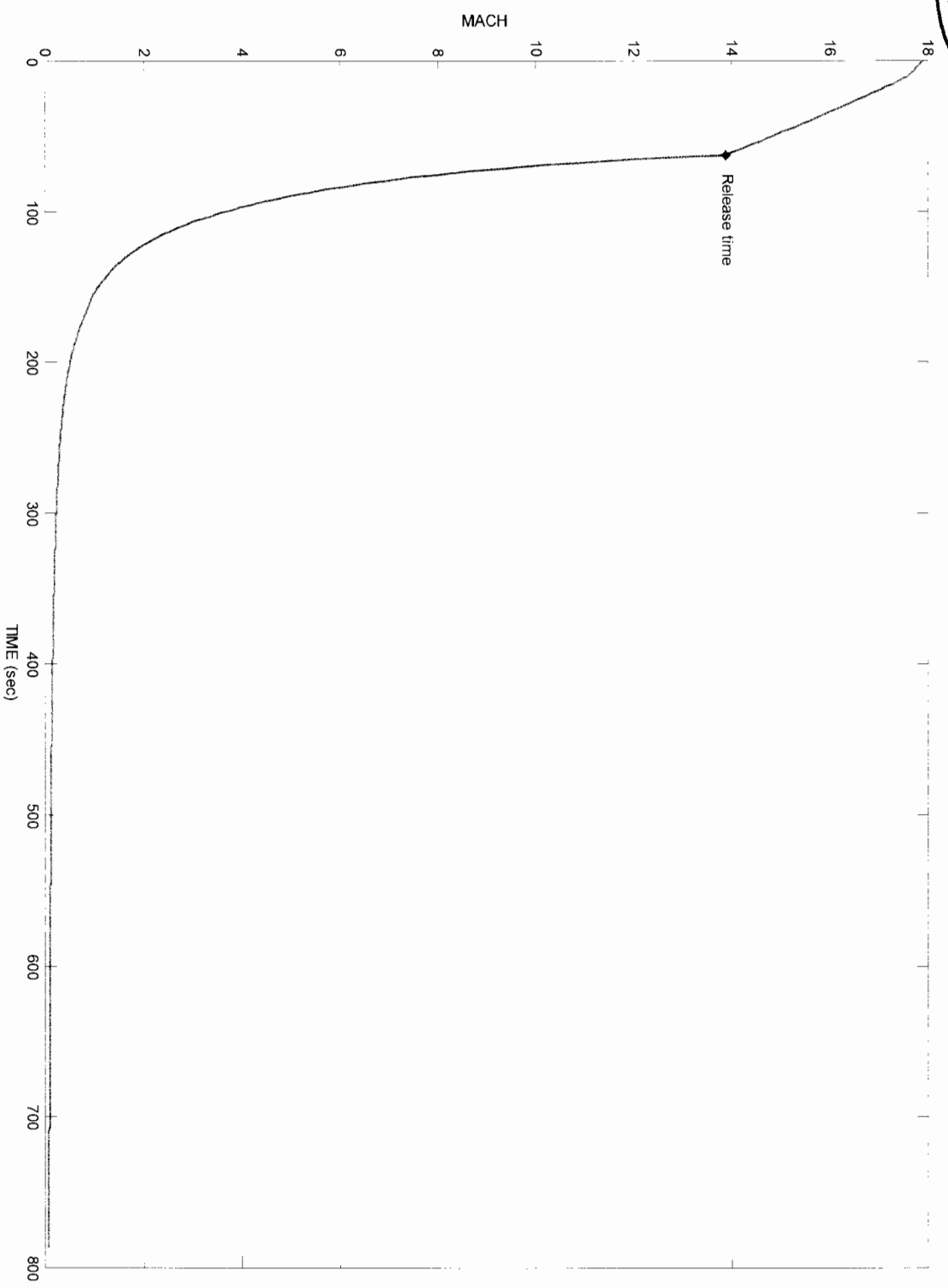


# ALTITUDE "Black" Box, Maximum Aero



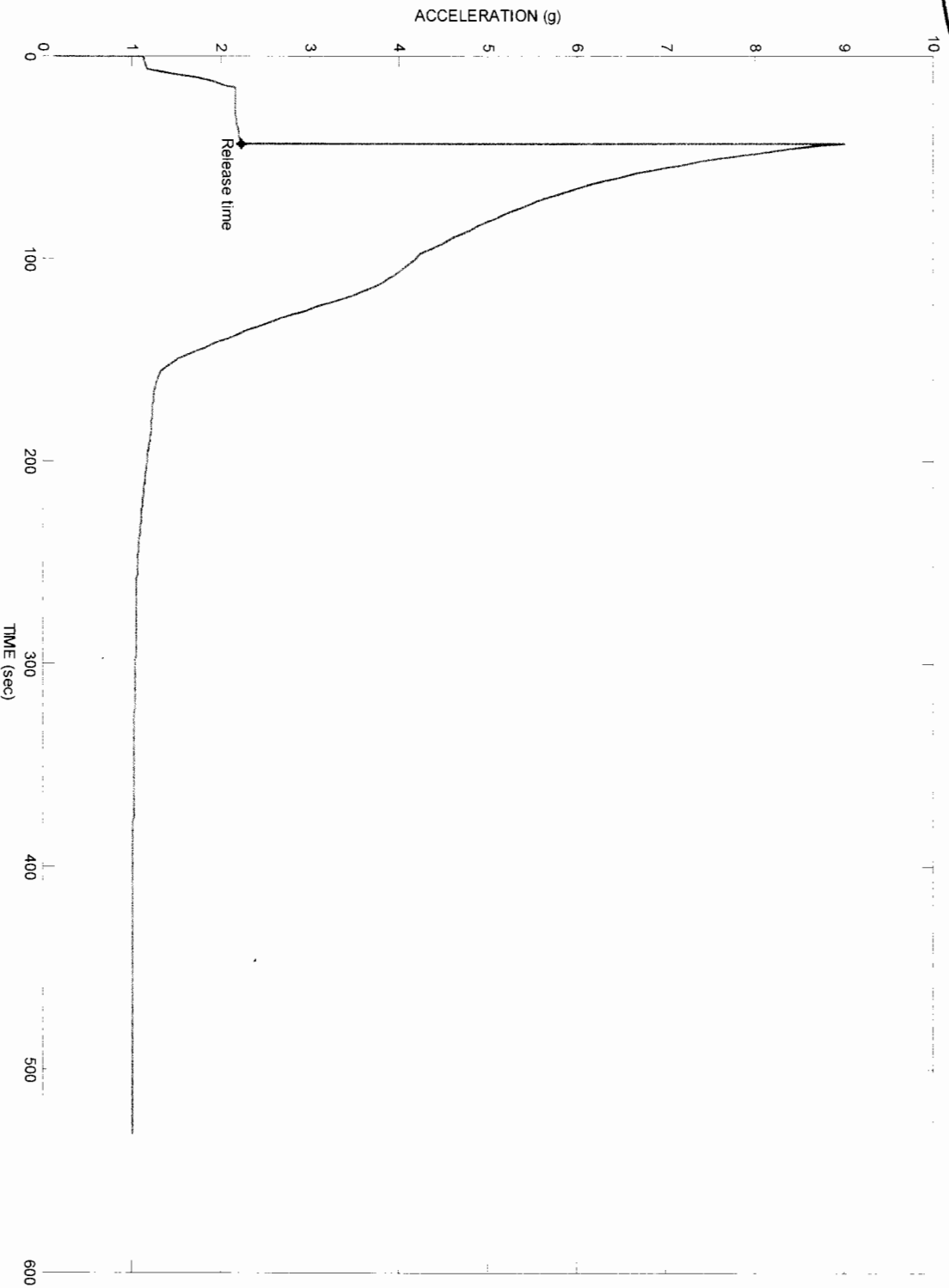


# MACH “Black” Box, Maximum Aero



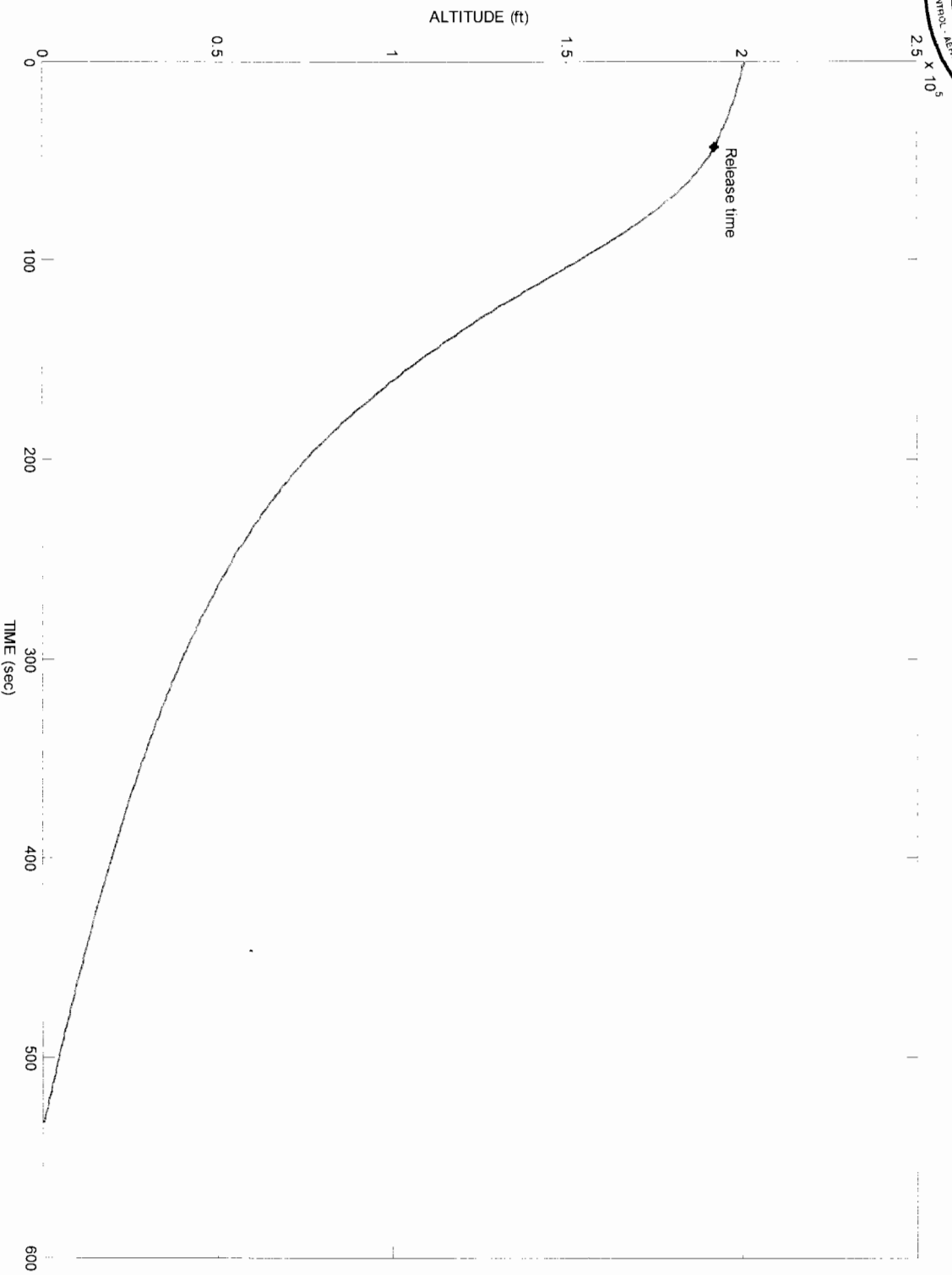


# GLOADS “Black” Box, Tumbling Aero



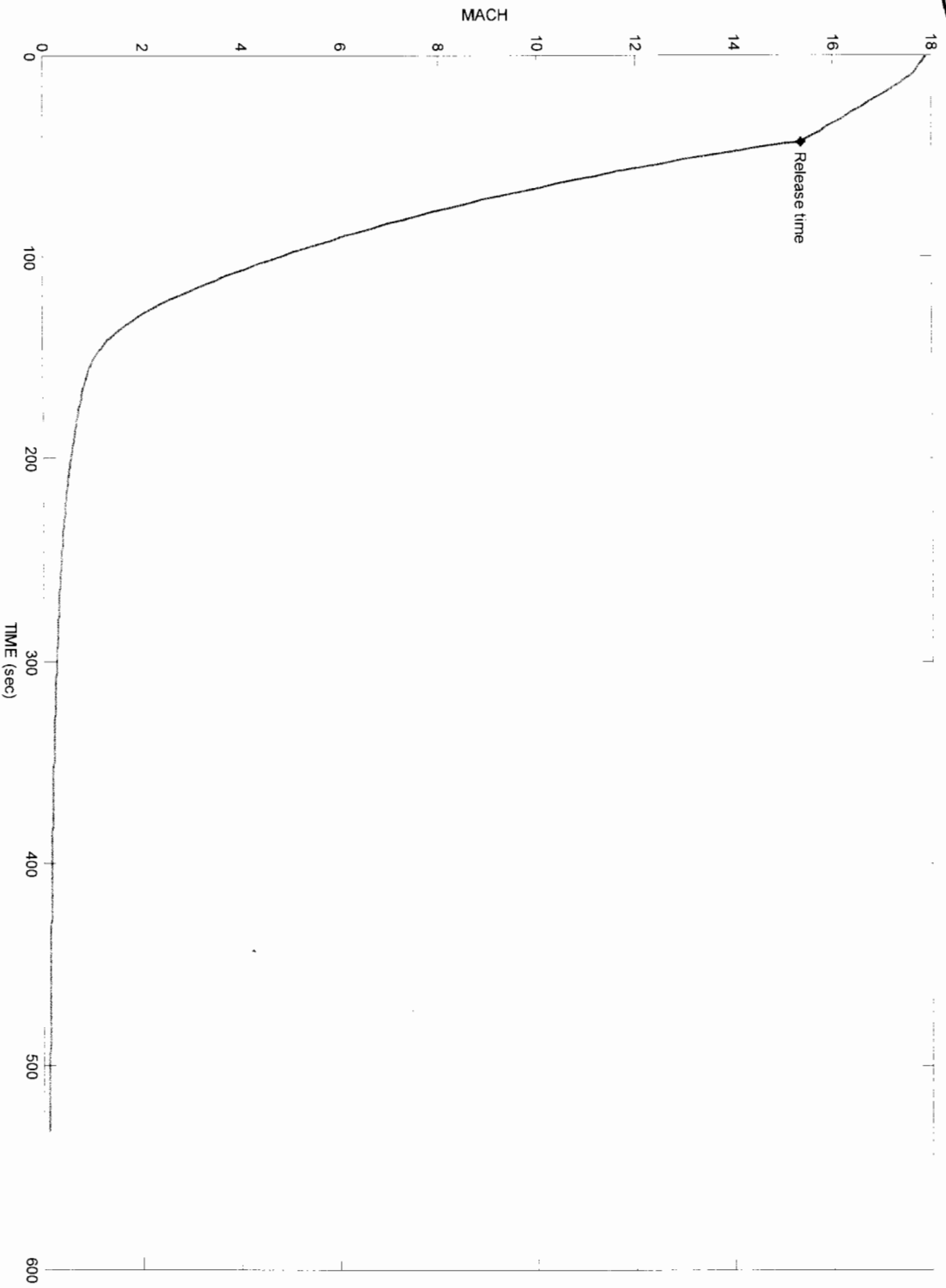


# ALTITUDE “Black” Box, Tumbling Aero



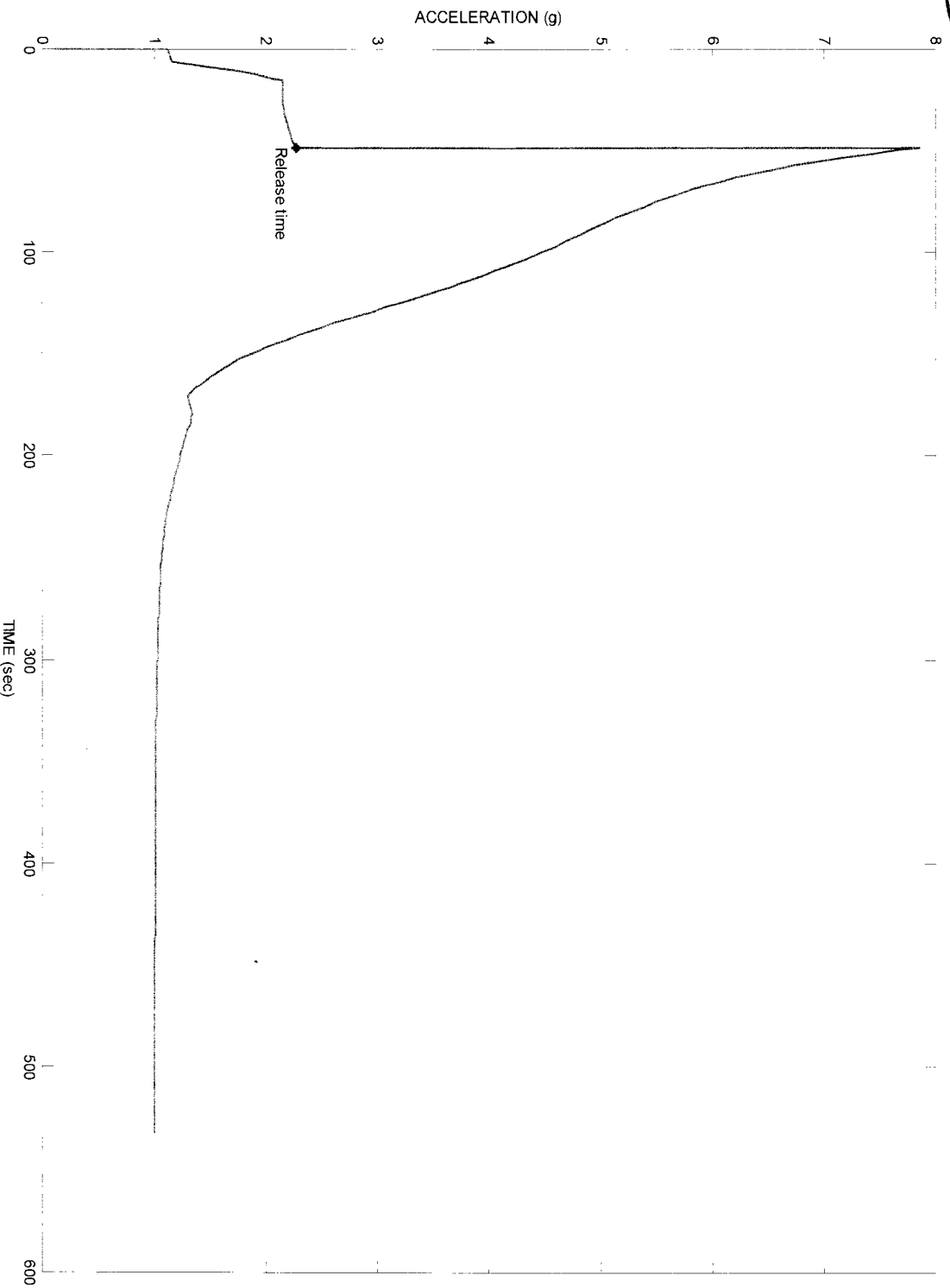


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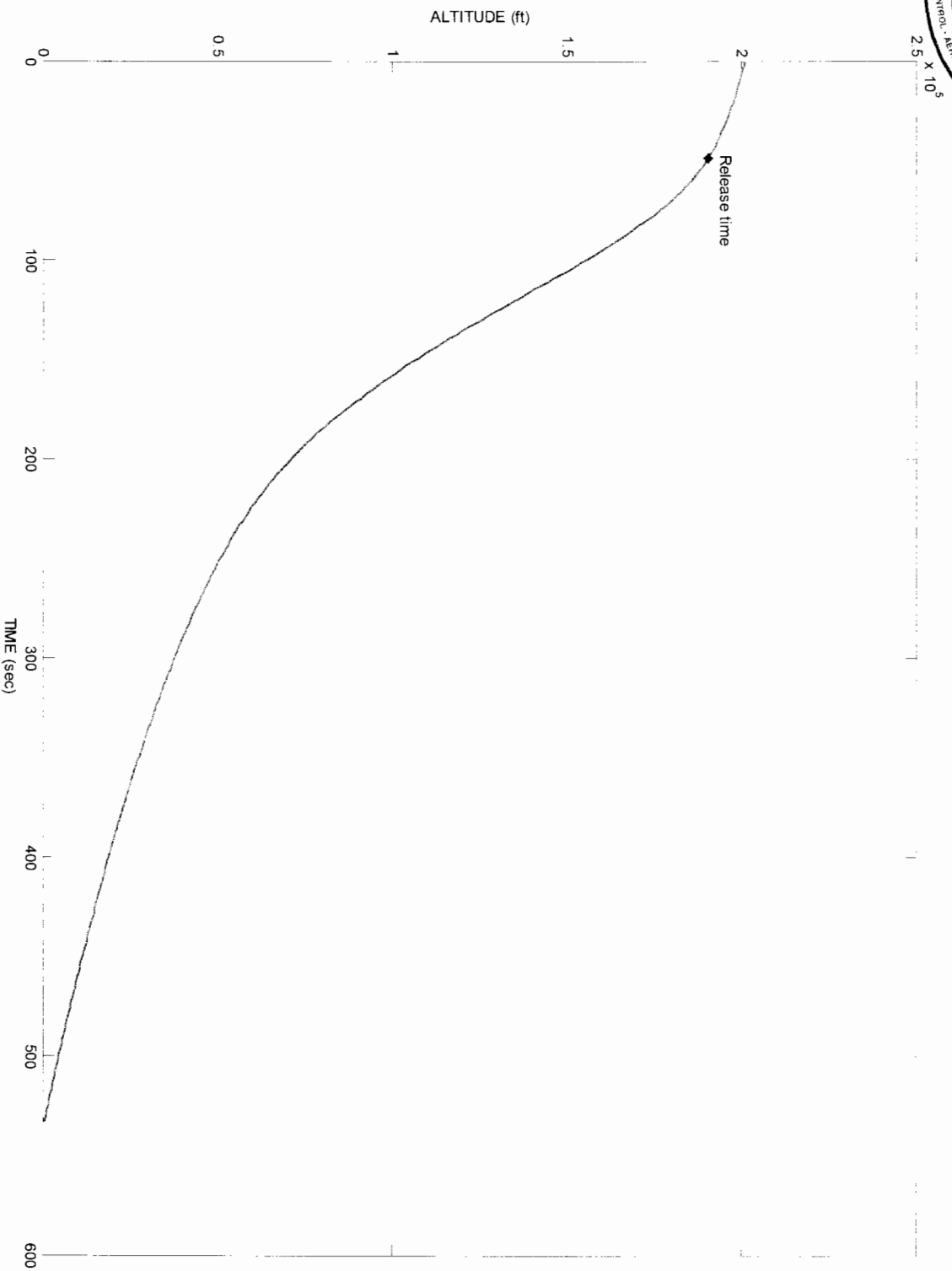
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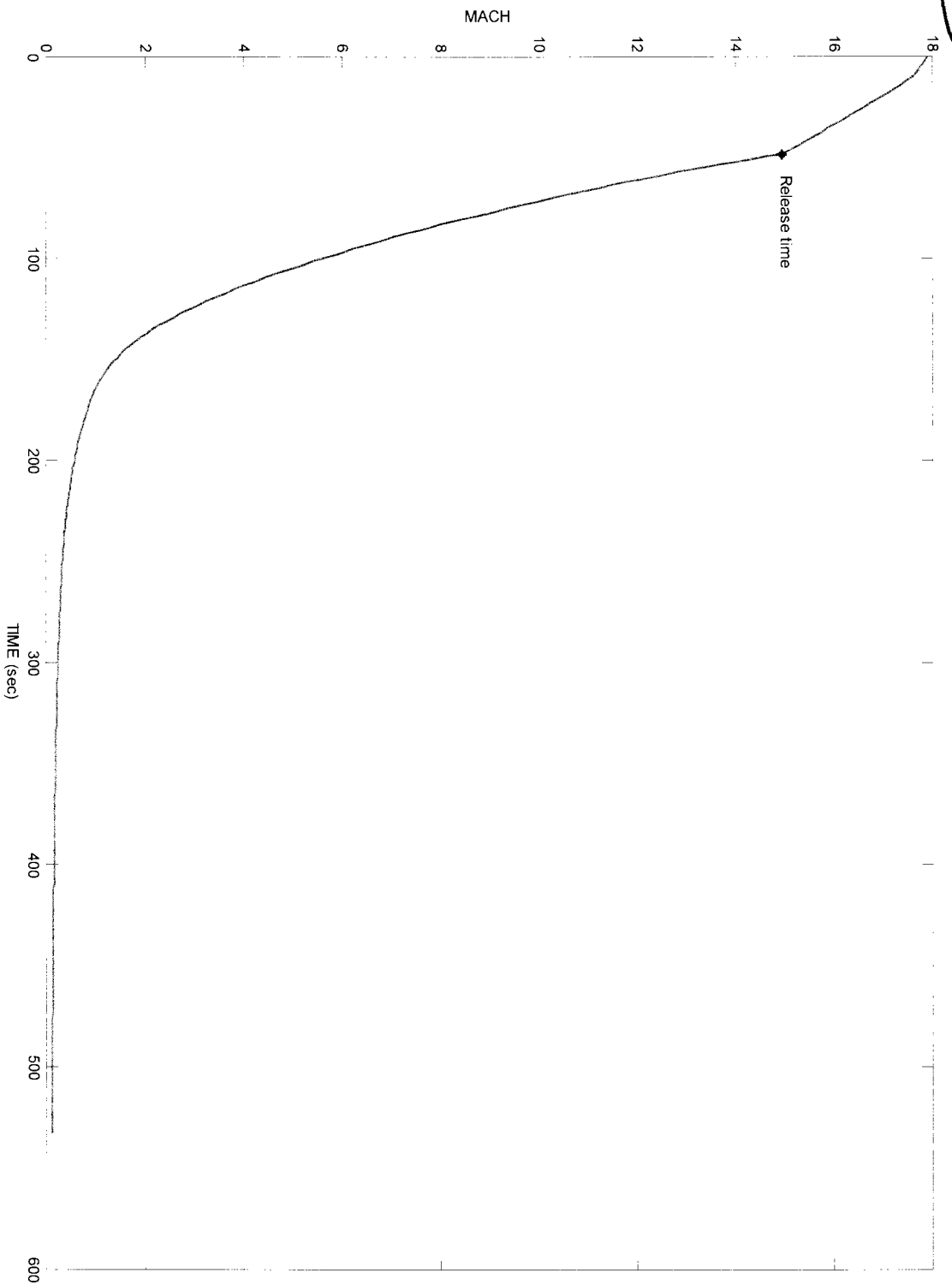


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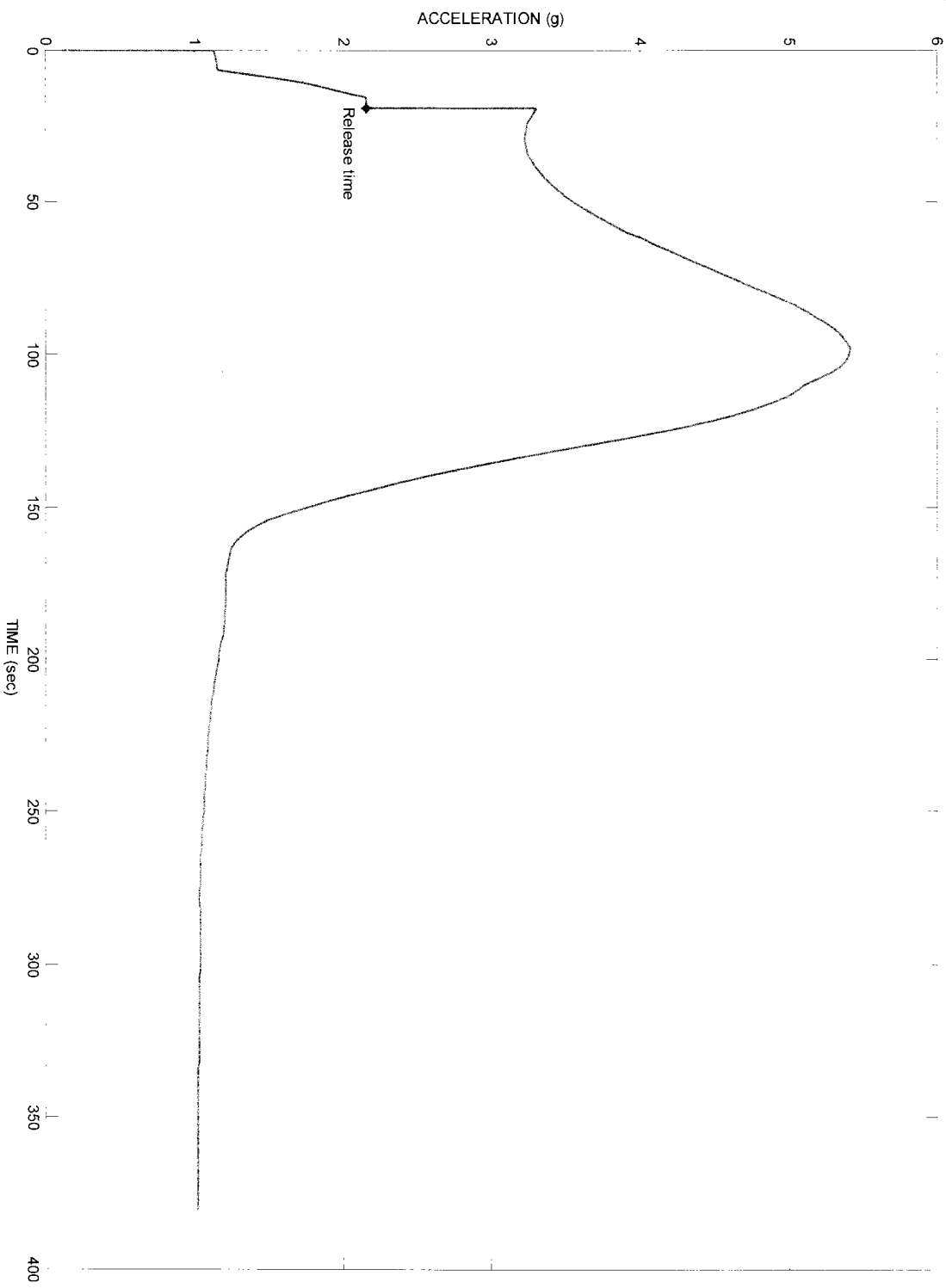


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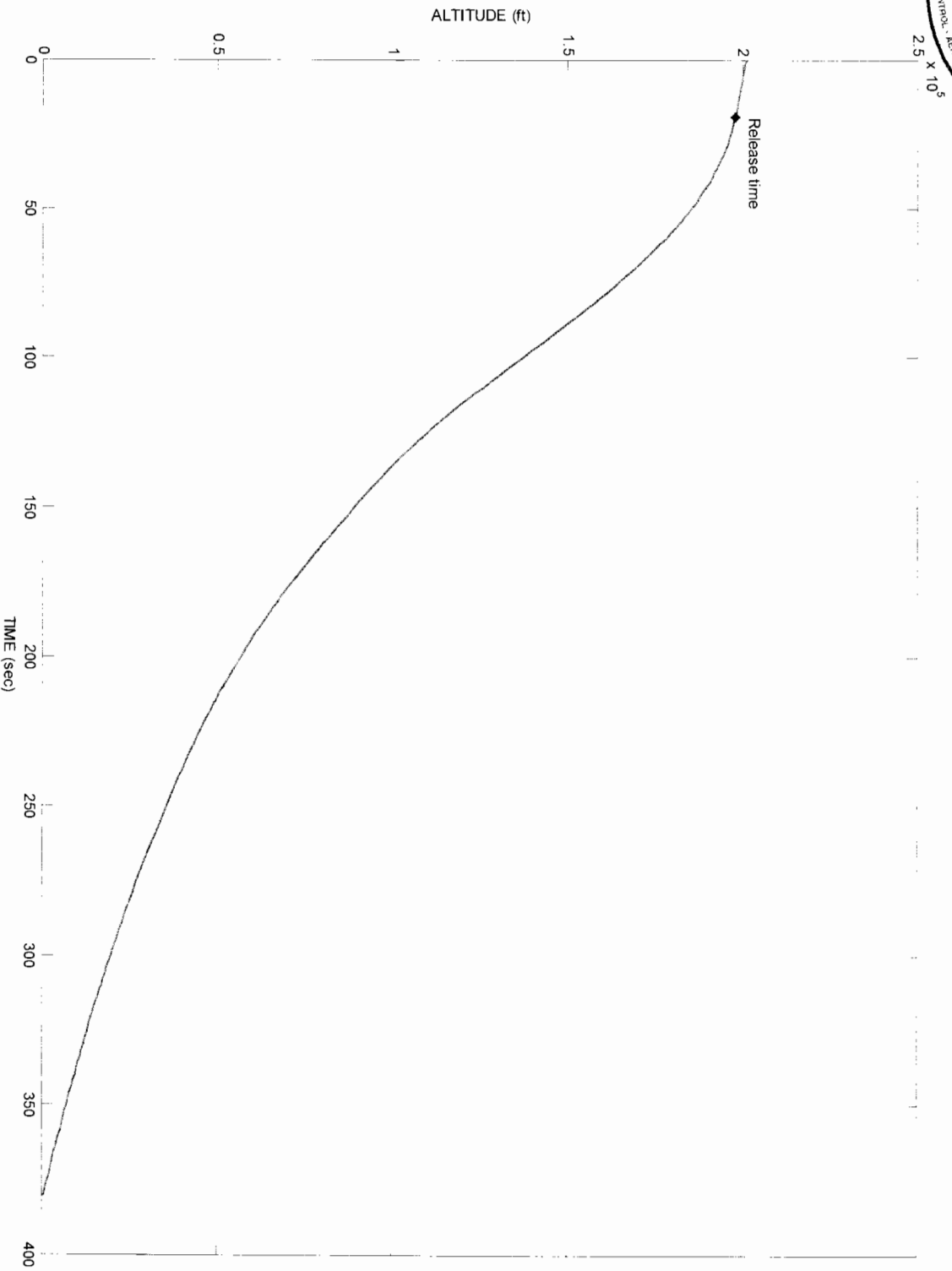


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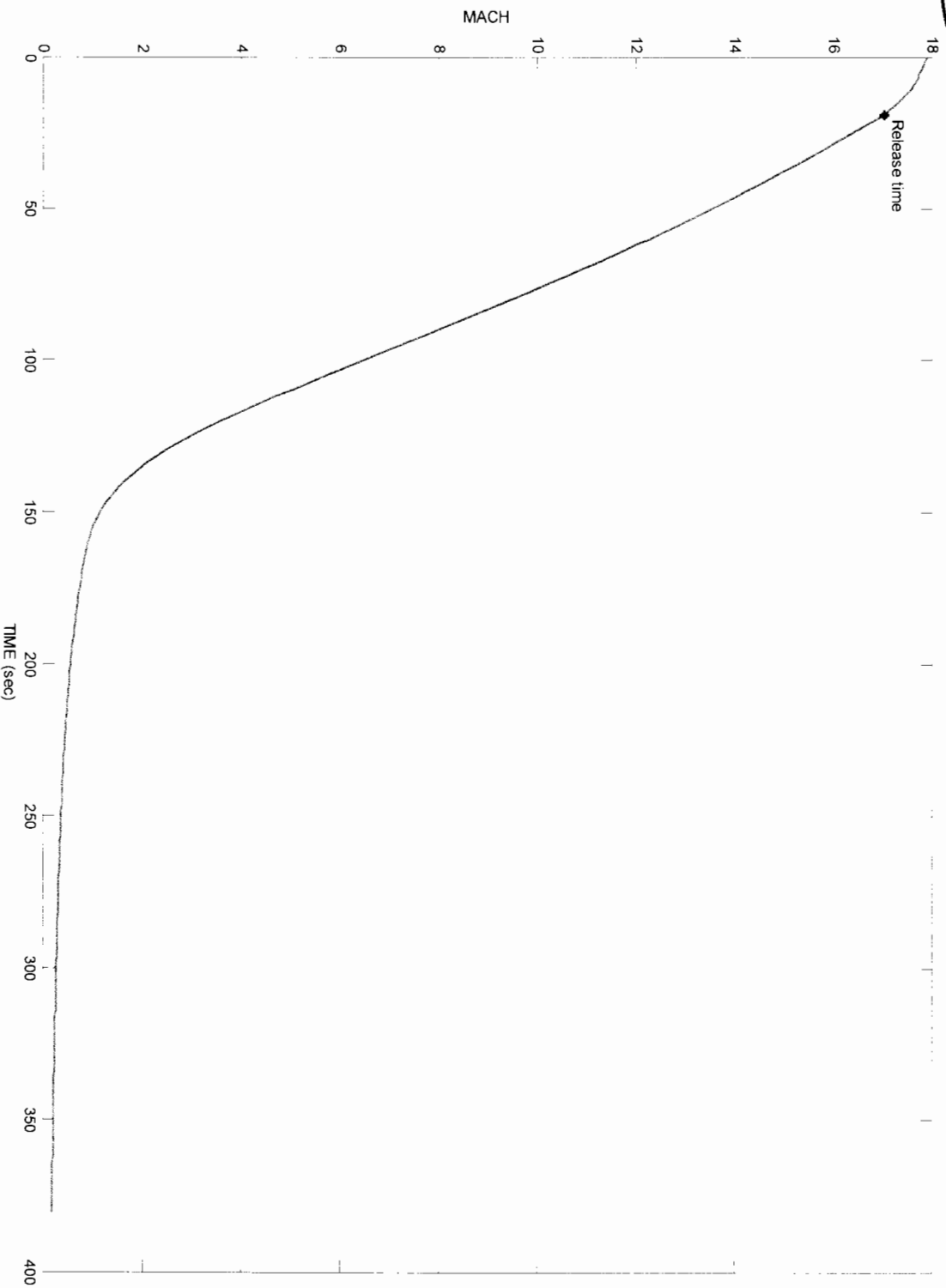


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# MACH “Opened” Box, Tumbling Aero





# SORT

The Simulation and Optimization of Rocket Trajectories (SORT) program is a general purpose three degree-of-freedom simulation of the flight dynamics of aerospace vehicles. SORT was used to generate the reference trajectories for the various configurations the orbiter went through during the accident. The aerodynamic forces experienced on the reference trajectories, the heating, and atmospheric conditions were also generated. SORT was also used to determine the approximate release times for selected debris items found on the ground. Because SORT is a verified flight dynamics tool (it was used to design the Shuttle Ascent) and because of the users familiarity with it, SORT was chosen for this task.

SORT divides the trajectory into user-defined discrete events. Events are points in the trajectory where vehicle, guidance/steering, or other parameters can be changed including weights and aerodynamics. Any math model output parameter (such as time, altitude, or mass) can be used to trigger new events that would alter the trajectory. SORT also contains several targeting and optimization algorithms which can be used to solve an unlimited number of trajectory design and performance optimization problems. SORT numerically models vehicle subsystems such as propulsion, guidance/steering, and moment control. It also models environmental effects such as atmosphere, gravity, and winds for a rotating oblate planet.