

## ADVANCED VEHICLE SEPARATION APPARATUS

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### ABSTRACT

An advanced Vehicle Separation Apparatus is presented as a method of obtaining test data from two independent models or bodies in a conventional wind tunnel. The system makes efficient use of wind tunnel test time with computer control performing complex coordinate transformations necessary for model positioning. The new apparatus is designed to be used in any of the three Unitary Wind Tunnels at NASA-Ames Research Center. This paper will present mechanical design details and a brief description of the control system for the new separation apparatus.

### INTRODUCTION

Within NASA there is a strong interest in wind tunnel studies involving separation of aerodynamic shapes in flight including vehicle-from-vehicle, stores-from-vehicle, pilot escape capsules and staging of large vehicles. A model support apparatus designed to perform such testing could be extended for use in many other important areas. Component interference studies to provide optimum location of nacelles, canards, tail surfaces and ventral fins could be accomplished quickly and efficiently. In addition, rake surveys could be performed on engine inlets, wing wakes and boundary layers. An effort was directed at the NASA-Ames Research Center into the design of an Advanced Vehicle Separation Apparatus which would enable aerodynamic data to be obtained from two computer controlled model supports operating simultaneously in close proximity within the same wind tunnel test section.

### BASIC OPERATION

Figure 1 shows the Advanced Vehicle Separation Apparatus in the Ames Research Center 11-by 11-Foot Wind Tunnel. This is a closed return, variable density tunnel capable of continuously varying Mach numbers from .4 to 1.4. Maximum Reynolds number for this facility is  $9.4 \times 10^6$  per foot. The new apparatus will be capable of automatically positioning a pair of models at pre-selected locations and orientations for specified time periods. This will provide efficient force or pressure data sampling at a large number of sample points. For maximum positioning capability, independent pitch, roll and yaw are required at each model while relative translation in all three directions is required between the models. The new system will provide X and Y translations between models in addition to three rotations of the secondary model. Z translation and rotations of the primary model are provided by the existing main centerbody/strut and a separate roll mechanism. The Axial Extender Mechanism is to be mounted in front of the existing main centerbody to provide 30 inch relative X translation between the models along the tunnel centerline. The Secondary Centerbody Mechanism is mounted cantilever fashion from a new blade entering through the tunnel side wall. The blade bearings and horizontal Y translation drive motor are mounted outside the test section wall and provide 30 inches of

secondary model movement across the test section while the Secondary Centerbody provides all rotations of the model.

The servo control system will be responsible for model path selection to reach desired individual points as well as collision prevention between models and support systems. Coordinate transformation equations will be used by a mini-computer to convert desired model movements into a proper combination of motor rotation outputs. Analog signals from precision multi-speed resolvers will be digitized and sent to the computer for position feedback.

The user will be able to select an automatic or manual control mode. Automatic control will cause the computer to step through preselected model positions. Manual control will allow the user the freedom of selecting random positions and time steps subject only to limit stop and collision prevention restraints imposed by the computer.

Axial Extender Mechanism. The axial or X-direction translation is provided by an Axial Extender Mechanism shown in Figure 2. The design requirements for X-direction movement include a 30 inch minimum relative translation between models at a rate of 2 inches per second. Positioning accuracy is  $\pm .03$  inches with readout at  $\pm .005$  inches. Design loads are 2,000 pounds normal force, 500 pounds side force and 2,000 inch-pounds rolling moment at the model added to a maximum 300 pounds per square foot starting load on the entire assembly (model, stinger and axial extender mechanism) in the supersonic tunnels.

This mechanism was conceived as an addition to the existing wind tunnel centerbody and strut. In this manner, the primary model would be capable of existing motion in pitch, yaw and Z-translation with a new capability to translate up to 30 inches in the X direction. The concept of giving the X translation to the primary model is good for two reasons. First, tunnel blockage is not increased by the relatively large diameter (14 inches O.D.) of the new mechanism because the existing centerbody is larger. Second, the primary model is pushed forward in the test section by the length of the new mechanism to a point which coincides with possible secondary model placements.

Translation is accomplished using a direct current motor coupled to a ball screw. Ball bearings support the ball screw at each end of the stationary housing. The ball nut pushes a collar connected to the moving housing. 1/4 inch lead on the ball screw requires only 480 rpm at the motor for a 2 inch/second rate of translation. Sliding is done on linear bearings and roll is carried between housings with cam followers. A feedback resolver is mounted at the rear of the motor. This design provides infinite positioning capability with near zero backlash and low friction.

Secondary Centerbody Mechanism. Pitch, yaw and roll rotations for the secondary model are provided by a Secondary Centerbody Mechanism shown in Figure 3. The design requirements for these rotations include a maximum of 20 degrees pitch or yaw (not simultaneously) and  $\pm 180$  degrees roll. Angle change rates are 5 degrees per second on all rotations. Angle positioning requirements are  $\pm .05$  degrees with readout accuracy at  $\pm .01$  degrees. Design loads on the Secondary Centerbody are 750 pounds normal force, 500 pounds side force and 1,000 in-pounds rolling moment at the model added to a maximum

300 pounds per square foot starting load on the model and centerbody assembly. Overall size of the centerbody was to be kept at an absolute minimum to reduce tunnel blockage.

The new centerbody was conceived from spacesuit technology and operates in exactly the same fashion as an elbow joint in a hard spacesuit. Figure 4 shows the four basic cylindrical housings of the mechanism. The fixed housing is grounded to the blade and the three forward housings are free to rotate independently. The middle rotating housing actually revolves on an axis offset by 10 degrees (called the bisector angle) from the centerbody centerline. With this geometry, the model is capable of sweeping out a cone with a 10 degree half-angle by rotation of this housing alone. Rotation of the rear rotating housing then moves the model anywhere within a  $\pm 20$  degree cone. Figure 5 illustrates some typical pitch and yaw combinations including the worst combined loading case for the drive motors.

The detail design of the secondary centerbody (reference Figure 3) includes three rotating housings driven by direct current motors with varying horse-powers of .25, .75 and 1.25 from front to rear. Each motor contains a tachometer and fail-safe brake capable of resisting all motion due to aerodynamic loading in the event of power loss. The motors are custom designed units only 4.5 inches in diameter to keep overall centerbody diameter as low as possible. In order to keep centerbody length down, harmonic drive units with 200 to 1 reduction are used behind each motor. This 200 to 1 reduction coupled with a maximum motor speed of 1400 rpm gives a housing rotation speed of 7 rpm, necessary to achieve the design requirements of 5 degrees/second rate change of model angle. Feedback resolvers are referenced to harmonic drive output so that motor and brake backlash do not affect position readout. Motor, resolver and model wires pass through hollow motor shafts and finally exit at the rear. Protective tubes surround the wires inside of each motor and are fixed to motor housings to prevent contact with the high speed shaft. Needle roller bearings are used at each housing to resist high moment loads while small section thrust bearings are used to hold the housings together and resist axial loads.

In a pure pitch or yaw mode, the Secondary Centerbody Mechanism is capable of the desired 5 degrees/second rate change of model angle only up to around 15 degrees. This is because the model rate change of pitching or yawing angle approaches zero near 180 degrees of bisector rotation. In order to provide a unique set of model positions, all housings are mechanically restrained to  $\pm 178$  degrees. This limits actual maximum pitch and yaw to  $\pm 19.95$  degrees.

This centerbody design gives maximum versatility in the minimum size possible.

Support Structure for Secondary Centerbody. Y translation for the secondary model is provided by the support structure shown in Figure 6. Design requirements of travel, rate and accuracy are identical to those previously listed for the Axial Extender Mechanism.

The cantilever blade concept is used to provide greater mobility between models and reduce tunnel blockage. Translation is provided by a direct current

motor operating a ball screw as before in the Axial Extender Mechanism. Linear bearings are used to resist moments in all directions and force loads in X and Z directions. Forces in the Y direction are reacted by large thrust bearings at the end of the ball screw.

Wall penetration into the test section at the Ames 11-Foot Wind Tunnel is through an existing window frame with the glass removed. Figure 7 shows a different mounting scheme used at the Ames 9- by 7-Foot Supersonic Wind Tunnel with blade penetration through the roof for the secondary model. A new pressure can is shown which houses the extended blade, motor and bearing assembly.

#### CONCLUDING REMARKS

The Advanced Vehicle Separation Apparatus is designed to simultaneously position two aerodynamic models or bodies in a single wind tunnel test section through use of a computer control system. Separation testing will be used to optimize location of aircraft components and investigate flow patterns and problems associated with two aerodynamic shapes in close proximity. This paper has described the design of a system to be used for efficient wind tunnel testing in this area.

# ADVANCED VEHICLE SEPARATION APPARATUS ELEVEN FOOT WIND TUNNEL INSTALLATION

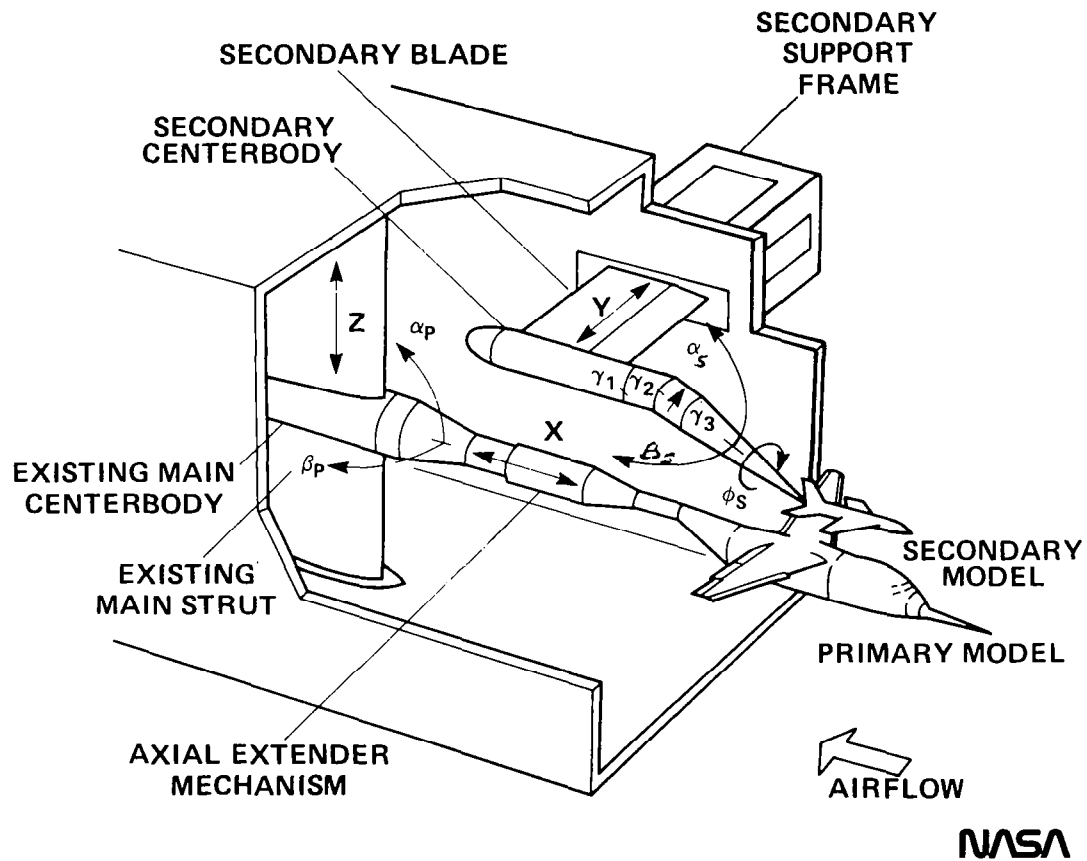


Figure 1

# ADVANCED VEHICLE SEPARATION APPARATUS AXIAL EXTENDER MECHANISM

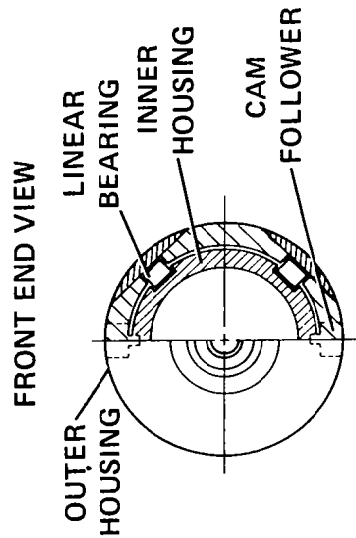
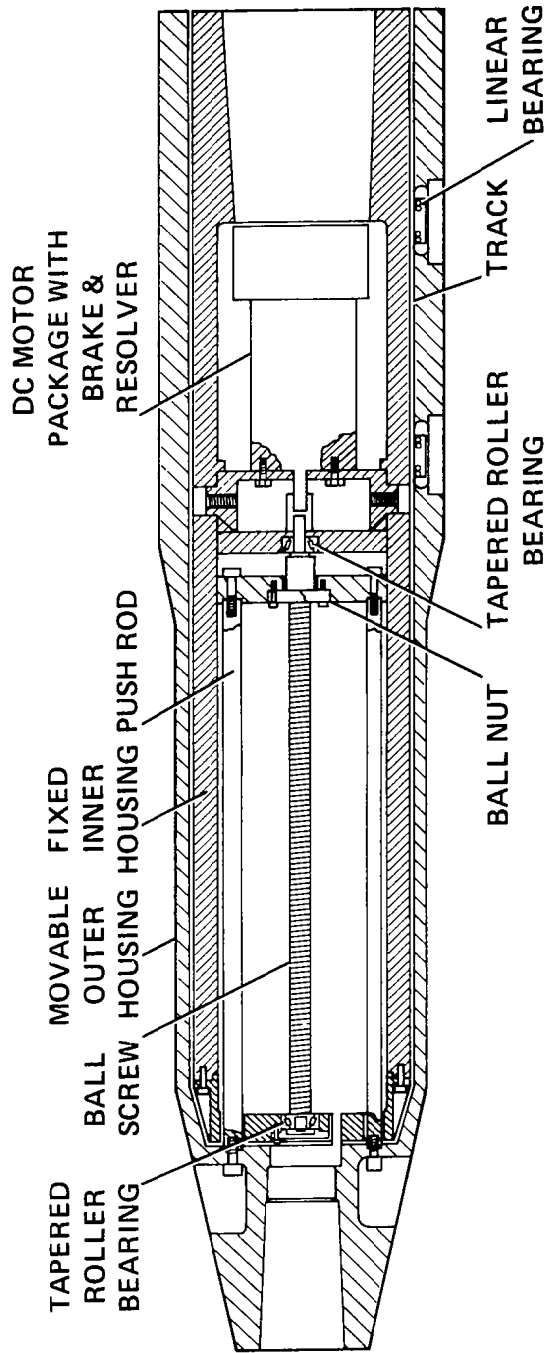
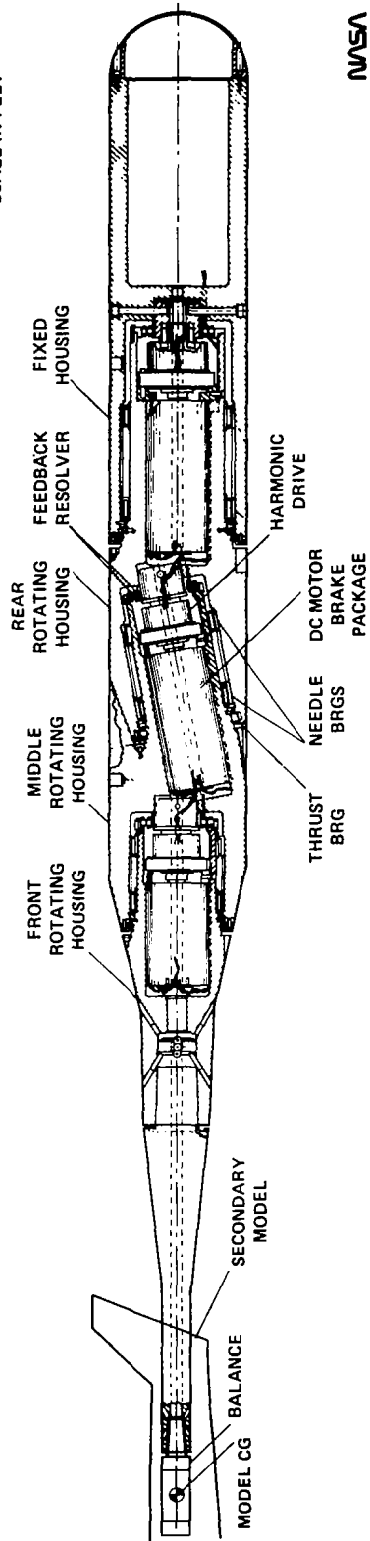


Figure 2

ADVANCED VEHICLE SEPARATION APPARATUS  
SECONDARY CENTERBODY



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Figure 3

# ADVANCED VEHICLE SEPARATION APPARATUS SECONDARY CENTERBODY JOINT GEOMETRY

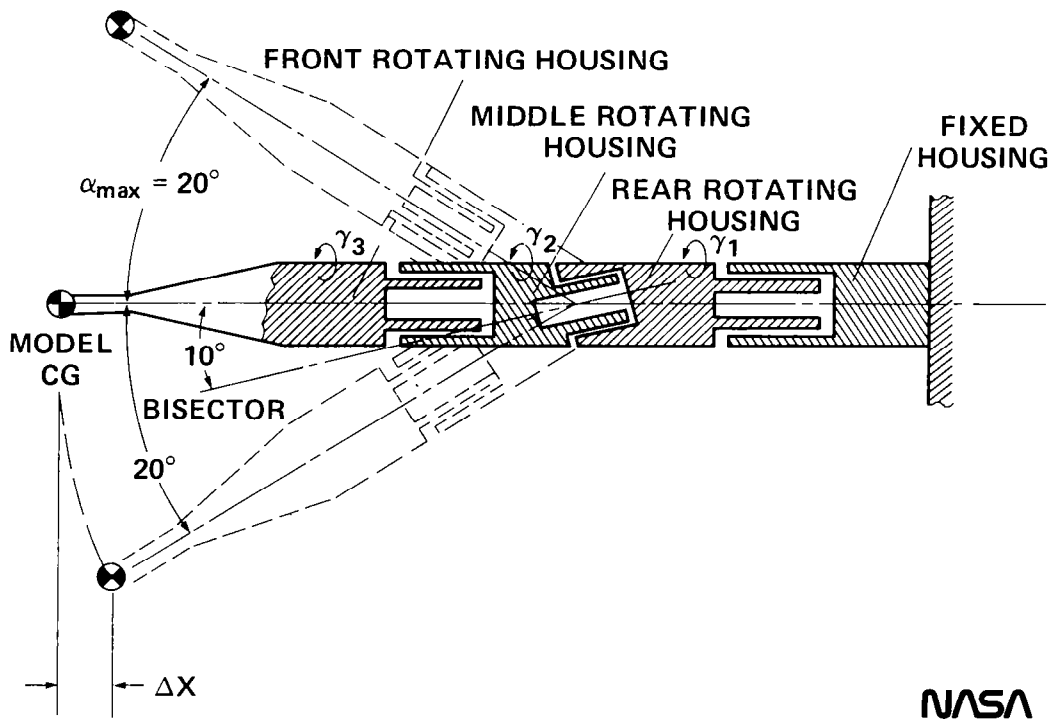


Figure 4



# ADVANCED VEHICLE SEPARATION APPARATUS SECONDARY MODEL POSITION ENVELOPE

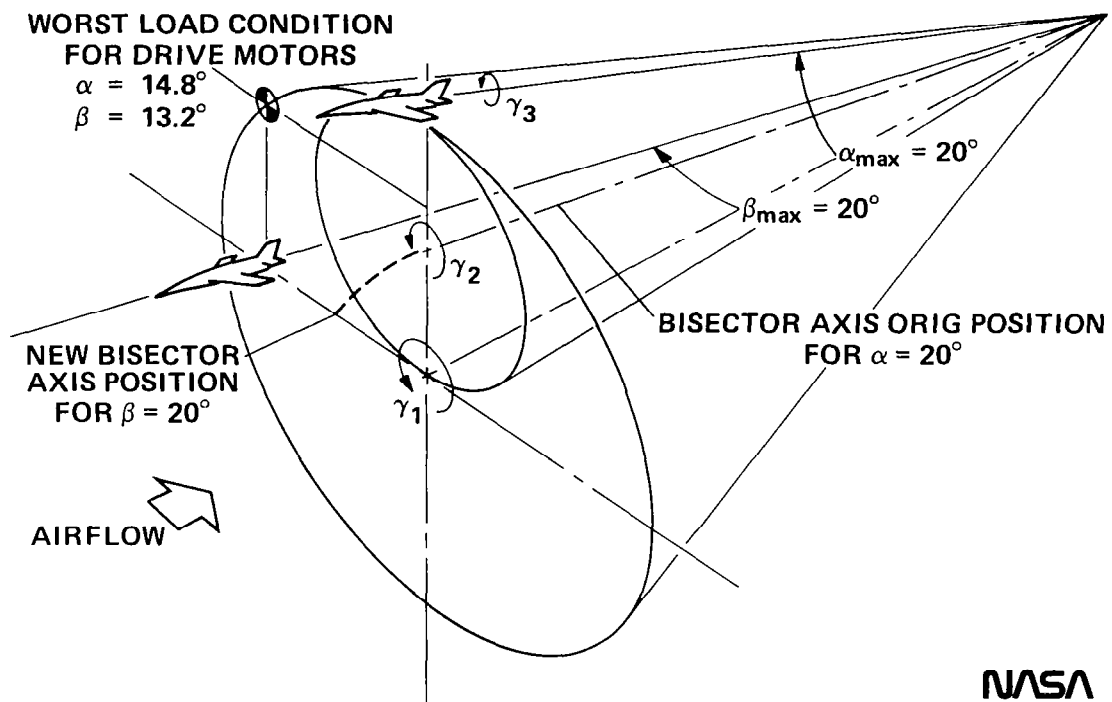


Figure 5

**ADVANCED VEHICLE SEPARATION APPARATUS  
BLADE SUPPORT STRUCTURE FOR 11 FT. WIND TUNNEL**

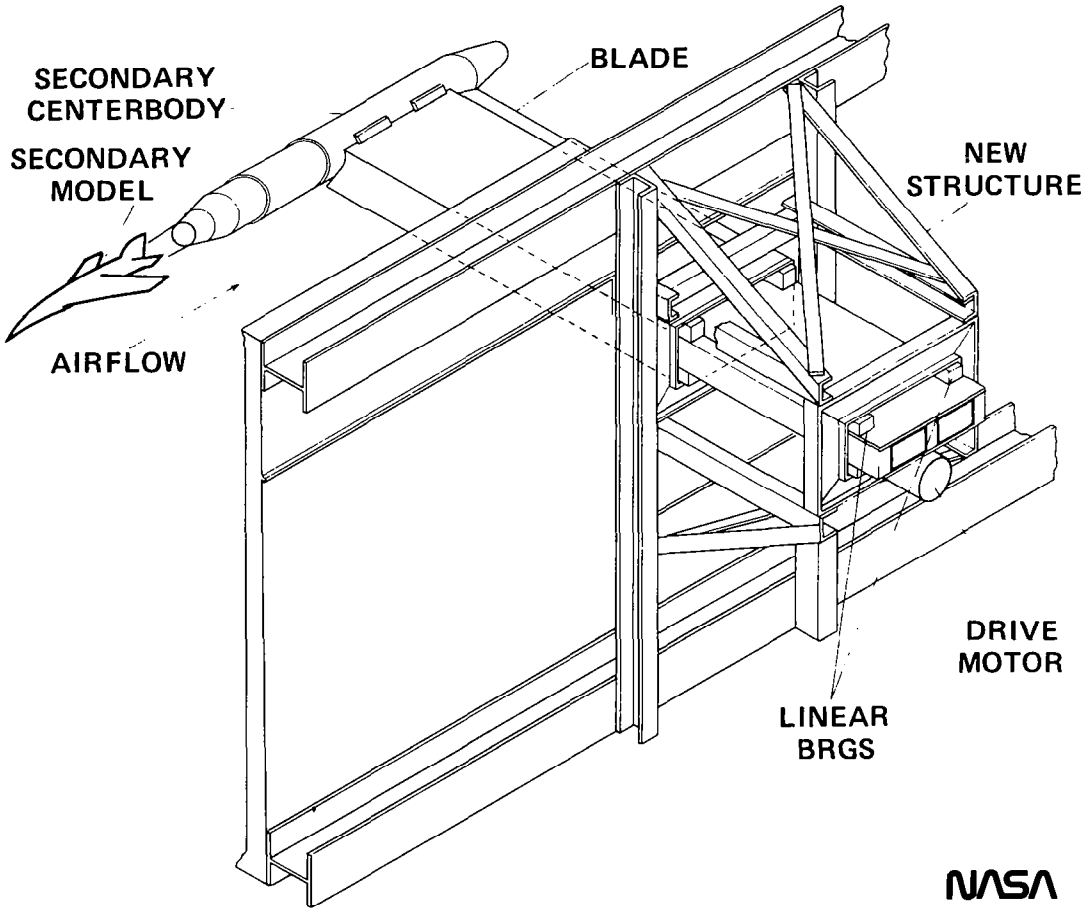


Figure 6

# ADVANCED VEHICLE SEPARATION APPARATUS 9 x 7 FOOT WIND TUNNEL INSTALLATION

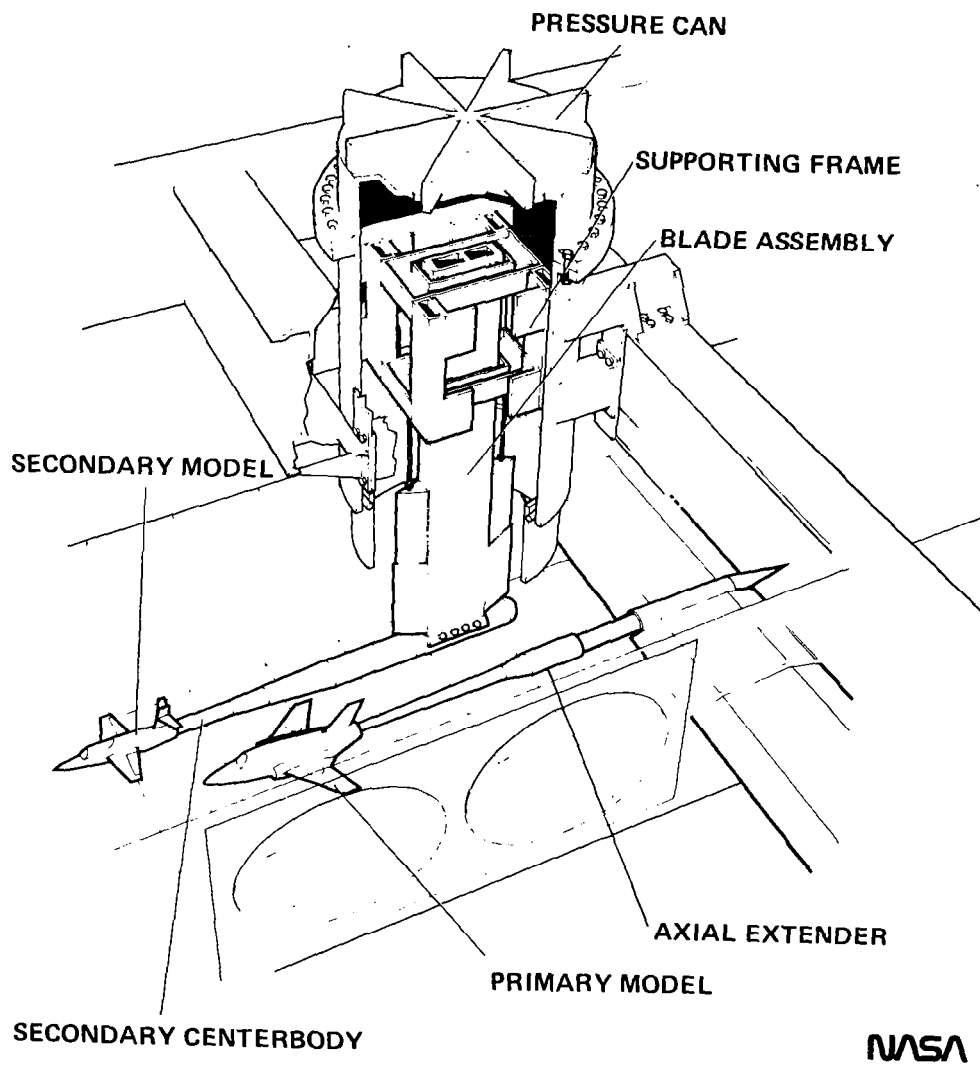


Figure 7