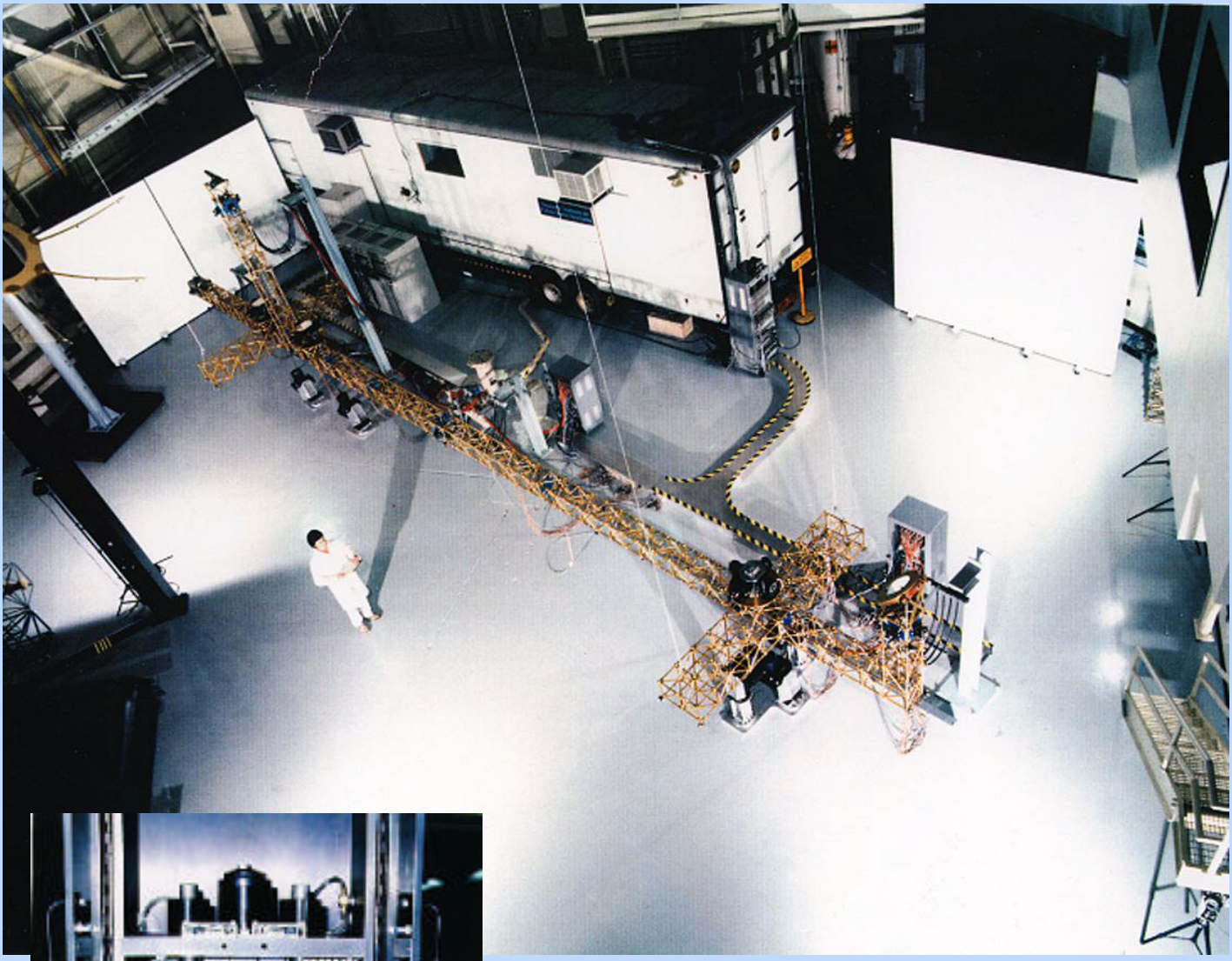
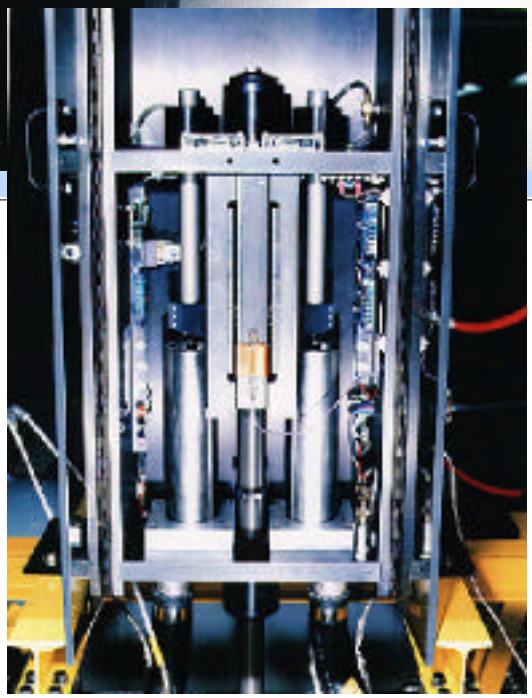
CSA Engineering, Inc.

Photos courtesy of NASA Langley Research Center, Spacecraft Dynamics Branch





60350-DA suspension device

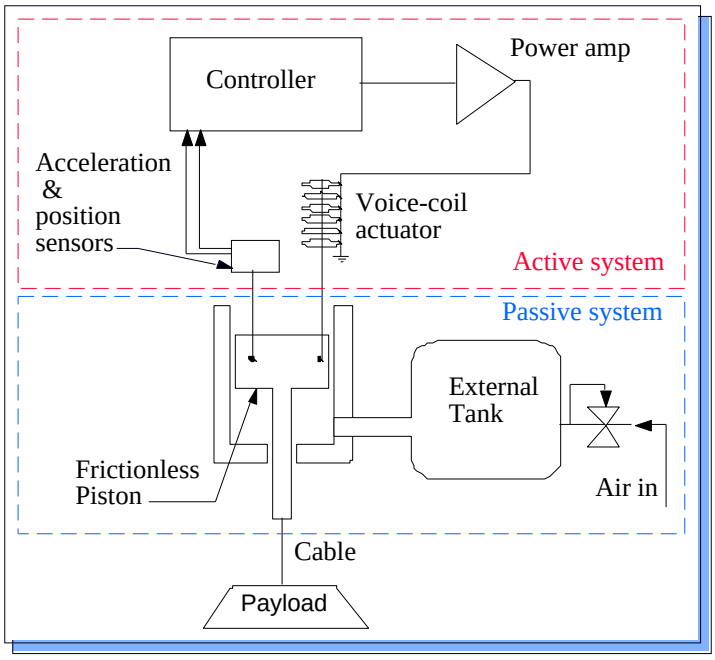
CSA Suspension System for Zero-Gravity Simulation

Modal or other ground vibration testing of space structures often requires a suspension system that can accurately simulate the unconstrained (free-free) boundary conditions of orbit. Obtaining high fidelity in tests involving rigid-body modes or flexural modes below a few Hz imposes extreme demands on the suspension system. CSA Engineering has developed a practical solution for this classic problem.

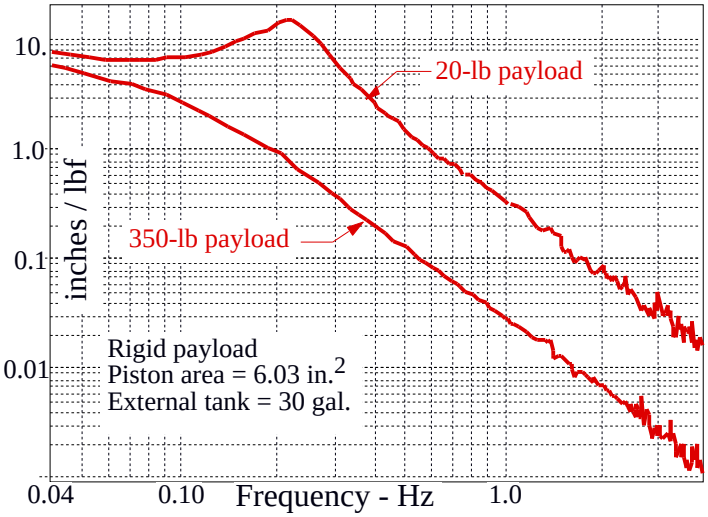
Shown above is a simulated large space structure supported by a system of four CSA pneumatic-magnetic (pneu-mag) suspension devices, one at the upper end of each support cable. At left is a close-up view of a single device.

Operating Principle

The CSA suspension device uses two parallel subsystems: one pneumatic and one electromagnetic. Special frictionless air pistons support the entire weight of the test article. By porting the cylinders to an external volume through large-diameter lines, the stiffness of the air spring can be made very small while retaining a large payload capacity. A precision regulator maintains the mean cylinder pressure and supplies makeup air. The active subsystem uses a long-stroke, noncontacting voice coil actuator designed for linearity. A displacement feedback loop with adjustable DC offset provides fine-trim control and a small, user-set centering stiffness to keep the piston near the center of the vertical working stroke. The device carriage, its only moving part, transmits piston force to the load cable. Supported by non-contact air bearings, the lightweight carriage moves vertically without friction, following the motion of the payload hard point to which it is attached by the load cable. An optional acceleration feedback loop allows active cancellation of the mass added by the carriage. Full six-degree-of-freedom suspension is obtained by using three or more devices to support a single payload at its hard points and near the tips of any flexible appendages such as solar arrays.



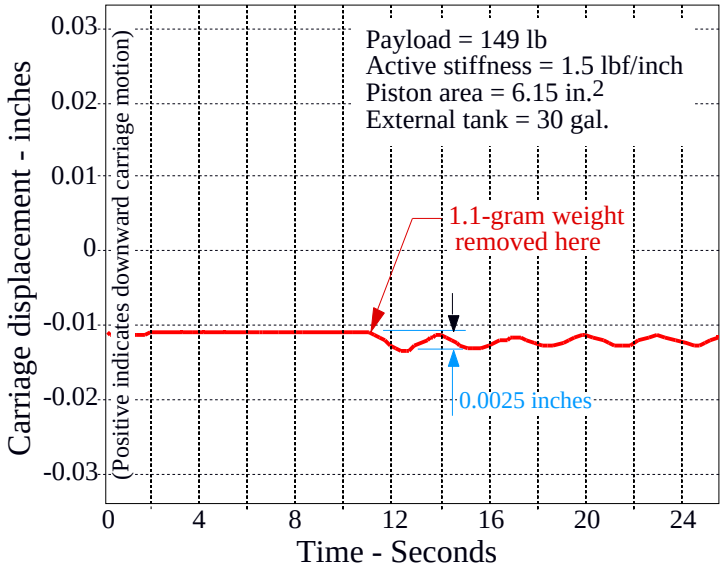
Frequency Response



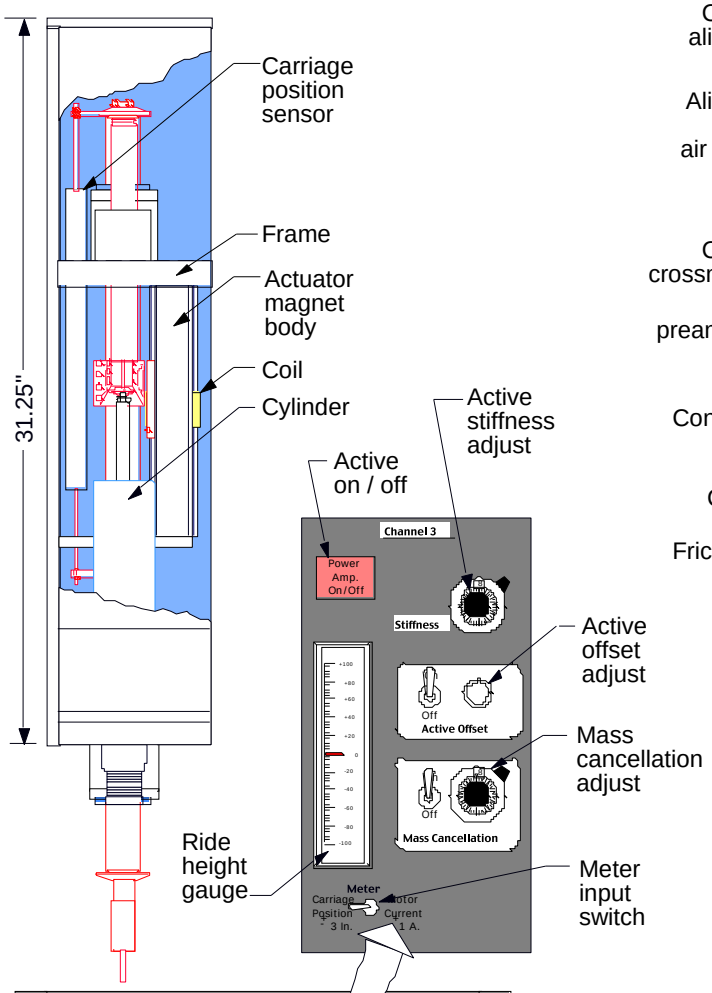
The extremely low stiffness of the suspension device is evident in the measured frequency response of vertical displacement / force as shown above. At light loads, vertical suspension frequencies of 0.1 - 0.2 Hz are typical. At loads near the device capacity, the suspension frequency falls within the bandwidth of the air pressure regulator, and no suspension resonance appears at all; the payload behaves essentially as an unconstrained body, floating freely in space.

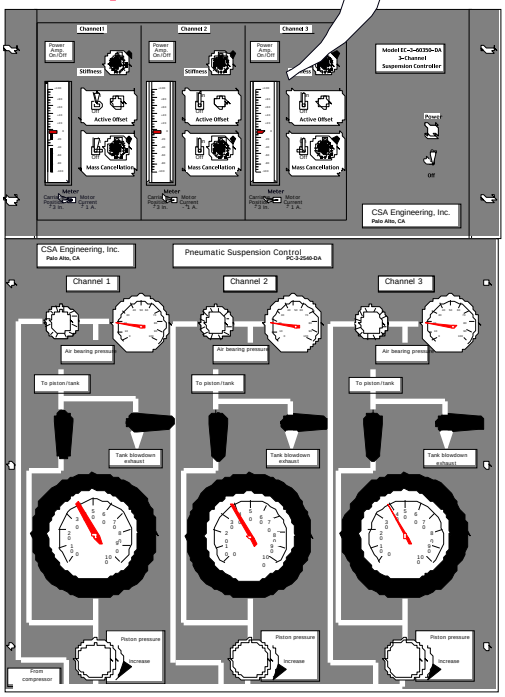
Zero Friction

Friction in the suspension system is intolerable in high-fidelity zero-gravity simulation. The combination of frictionless air pistons, carriage air bearings, and non- contact sensors and actuator render the CSA pneu-mag device virtually frictionless. The plot below shows the effect of reducing the payload by 1.1 grams from an initial value of 67,700 grams. The resulting oscillation is only a few mils in amplitude but is clearly visible against the quiescent background. It shows that even this tiny load step is more than sufficient to cause motion. Tests of this type are performed on every device shipped to assure that friction is less than 0.005% of payload. In actual testing use, it is virtually impossible to detect any friction effects.



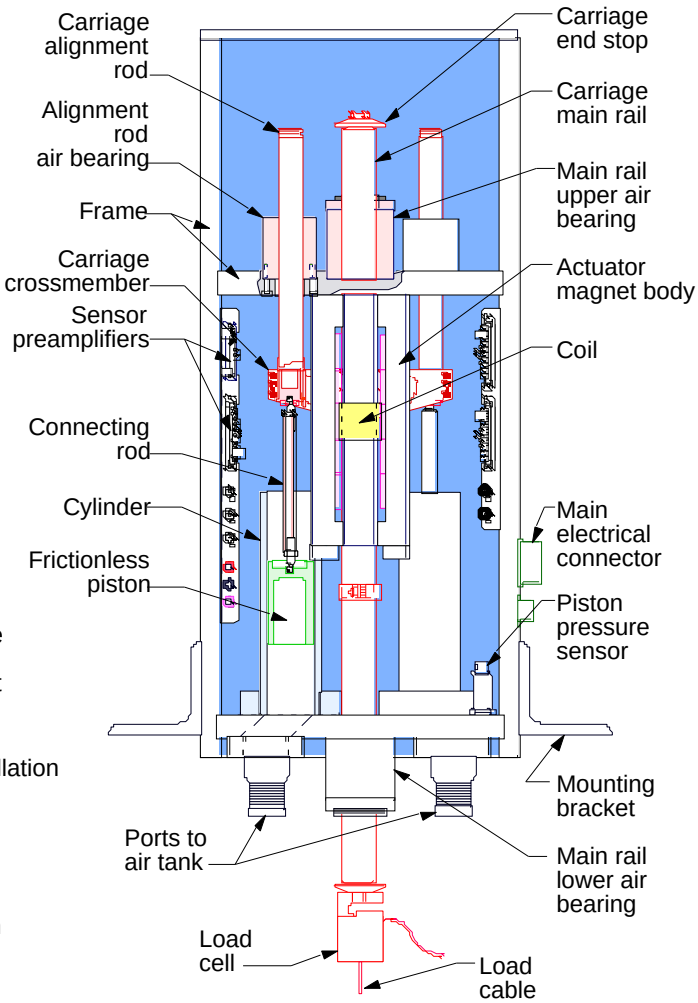
Side View





Electronic package and pneumatic control panel for three-device system

Suspension Device Front View



Ease of Use

The CSA suspension system is designed for ease of use in busy dynamic testing labs where availability of the test article itself is often limited and expensive. Electronics and pneumatic controls for a full three-device system are conveniently packaged for operation from a central panel. Ride height of each device is displayed on a front panel meter for easy adjustment. Height trim, active stiffness, and mass cancellation are set by front-panel knobs, the latter two with precision turns-counting dials. BNC jacks on the rear panel give easy access to sensor outputs and test points in the active system. Vertical displacement sensing is standard. Integral piston force, load-cable force, and carriage acceleration sensing are optional. In typical operation, the payload can be "floated" and adjusted to equilibrium in a few minutes. Operation thereafter requires only occasional retrimming of ride height.

CSA Engineering, Inc.

Specifications: CSA Pneumatic/ Magnetic Suspension Device

Model	25350-Dx	2540-Dx	60350-Dx
Piston area, in^2	6.16	1.49	6.28
Maximum payload, lb 60 psig 100 psig	 360. 607.	 80. ----	 370. 621.
Vertical supension frequency, Hz	0.1 - 0.2		
Vertical stroke, in.	2.5	2.5	6.0
Moving mass, lbm w/o mass cancelling w/mass cancelling	 9.0 1.4	 3.3 0.4	 6.0 1.3
Friction	less than 0.005% of payload		
Device outline H x W x D, in.	28.6 x 12.5 x 7.5	28.6 x 12.5 x 7.5	36 x 13.5 x 7.5
External air tank size, gal.	30 or 60	30	30 or 60

Specifications are nominal and subject to change without notice

Model 60350-DA

- mass cancelling (acceleration feedback)
- displacement feedback (standard)
- nominal payload in pounds at 55 psig
- nominal stroke in tenths of inches

These configurations are some typical examples. Numerous variations and options are possible and requests for custom versions are welcome. Typical systems use three to five identical devices although this number can be much greater for large, flexible test articles.

Several technical papers and application notes are available describing the CSA pneu-mag suspension system. For further information, contact

CSA Engineering, Inc.
Attn. David Kienholz
2565 Leghorn St.
Mountain View, CA 94043

Phone (650) 210-9000 FAX (650) 210-9001