- **Einstein Elevator Experiment via Balloon Launch**

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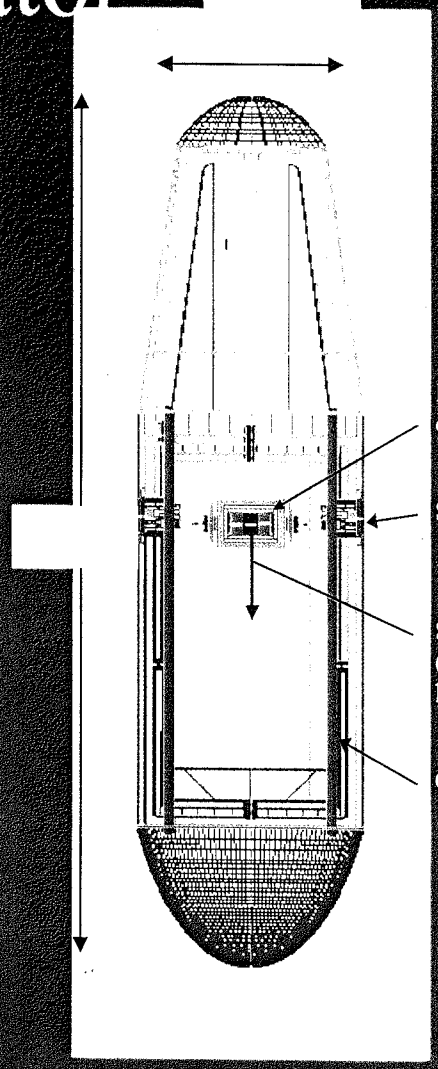
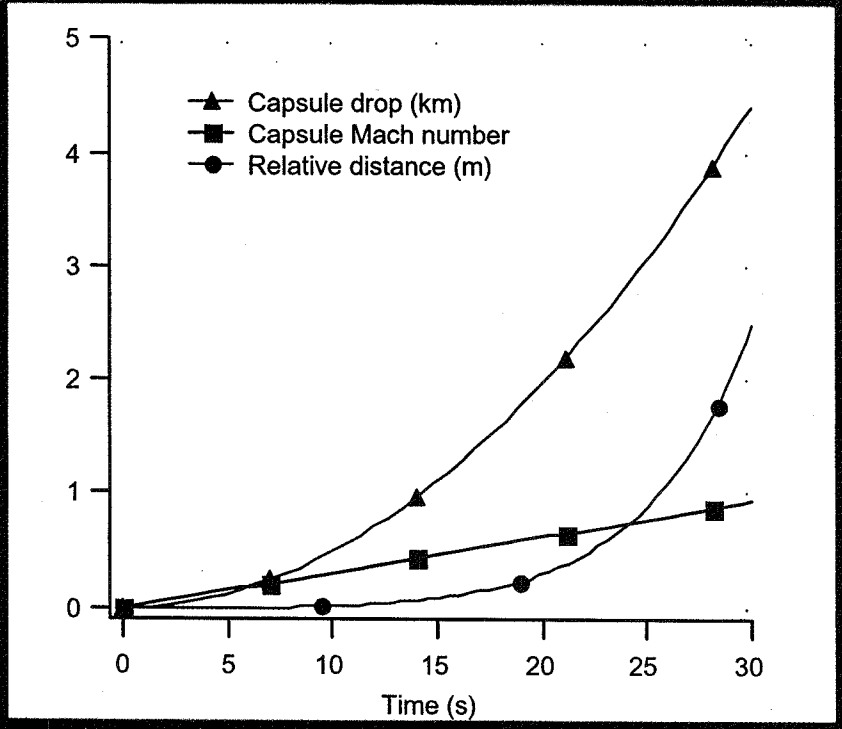
  - Basic Idea
  - Schematics of Equipment
  - Key Design Features:
    - Detector
      - (Packaging Proof Masses, Torque Sensitivity, and Frequency Discrimination)
    - Release Mechanism
      - (Rapid Damping of Transients)
  - Error Analysis and Accuracy Goal
  - Status:
    - Detailed Component Design
    - Funding Issues

Planned Test of EP in an Einstein Elevator

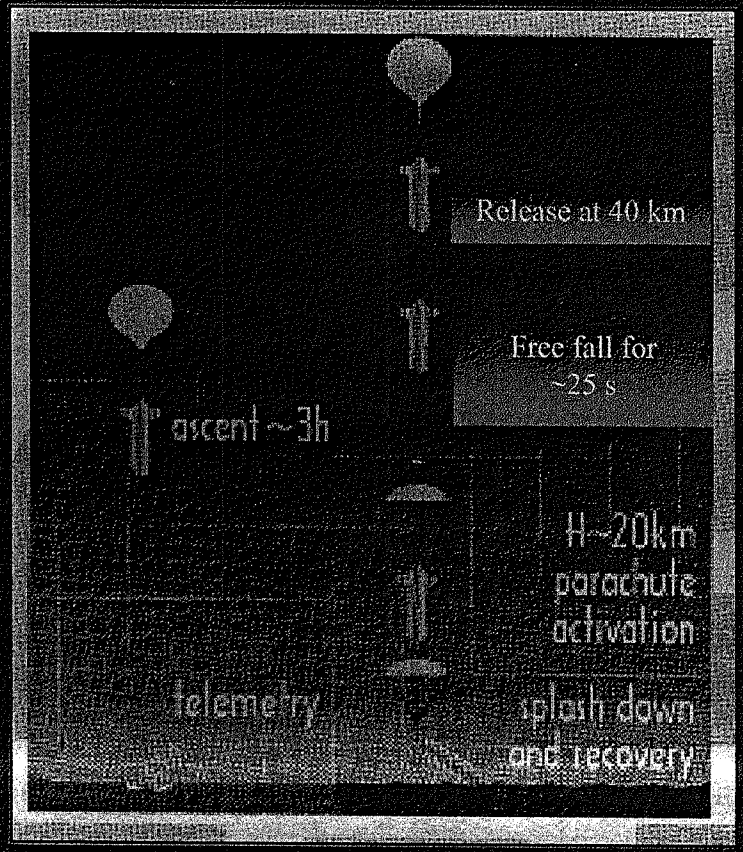
- Use differential accelerometer with two proof masses of different materials
- Capsule released first from balloon at an altitude of 40 km
- Detector released from top of capsule to free fall for ~25 s inside the evacuated capsule
- Detector rotates (at 0.5 Hz) during free fall to modulate violation signal
- Vacuum isolates detector from external noise sources
- Estimated accuracy in testing the EP is 5 parts in 10^{15} at 95% confidence level
- Experiment is repeatable at intervals of a few weeks



Flight sequence



Expected free-fall characteristics of experiment for a capsule mass of 1700 kg



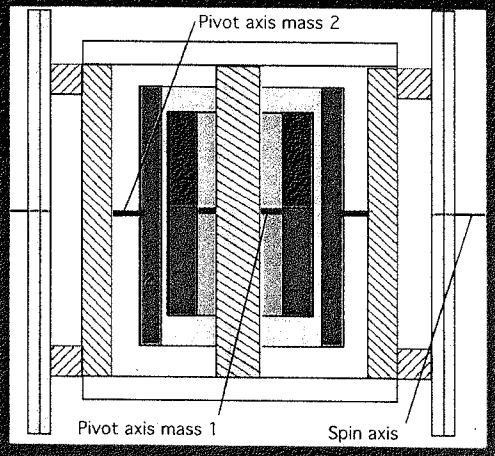
Rotational detector configuration

- **Purely-rotational detector configuration**

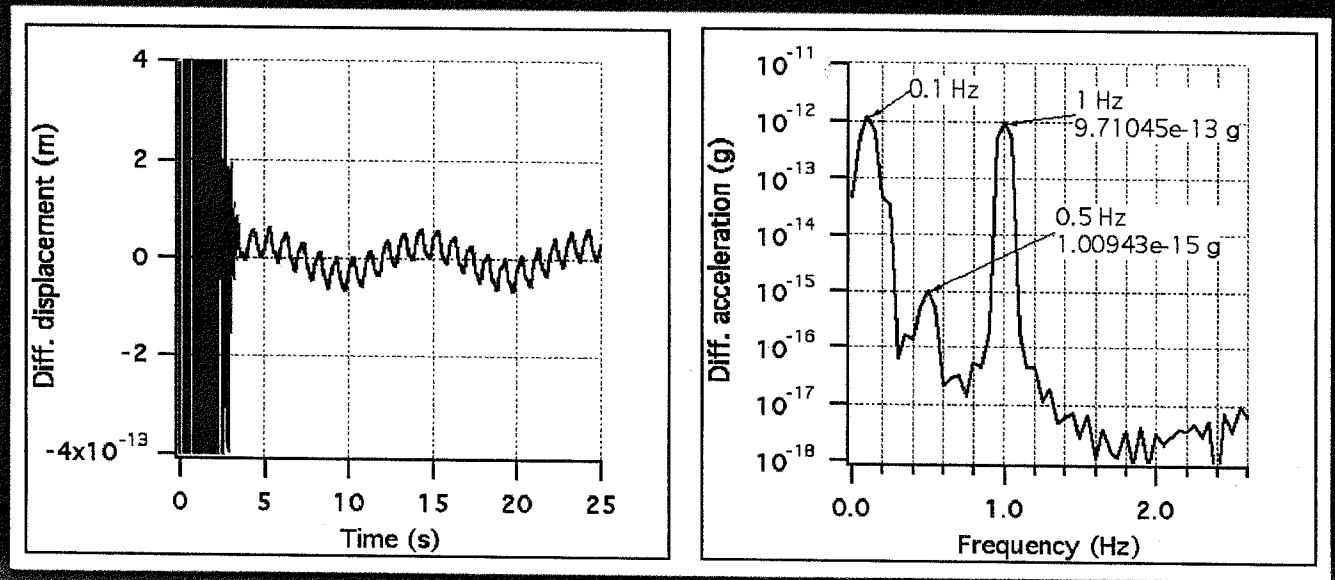
  - Spin axis *coincident with* pivot axes of proof masses

  - Gravity gradient torque about pivot axis modulated *at twice signal frequency*

  - EP violation torque modulated *at the spin frequency*



Simulation results



Simulation results for realistic error at release and construction imperfections

Advantages of purely-rotational detectors

- Comparatively low sensitivity to motion of instrument package
- Low sensitivity to effects of gravity gradient forces and torques and hence relaxed requirements on orientation of detector with respect to local gravity vector and axial symmetry of proof masses
- EP violation torque (with an arm length of a few cm) is strong when compared to (inertial and gravitational) differential torques consistent with realistic errors and imperfections

Estimated Error Budget

Noise Source	Max. differential acceleration	Frequency content
Brownian noise	$1\times10^{-14}\ g\sqrt{Hz}$	white
Amplifier noise	$4\times10^{-15}\ g\sqrt{Hz}$	white
Capsule's vibrations	$10^{-17}\ g\sqrt{Hz}$	white
Drag in capsule	$6\times10^{-17}\ g$	$1/t_{fall}$
Capsule-equipment ferromagnetism	$5\times10^{-16}\ g$	f_S
Radiometer effect	$2\times10^{-16}\ g$	f_S
Earth's gravity gradient torques (for realistic construction and orientation errors of detector)	$10^{-16}\ g$ $10^{-12}\ g$	f_S $2f_S$
Higher-order gravitational coupling to capsule mass	$10^{-16}\ g$	$f_S, 2f_S, 3f_S,...$
Others	$< 10^{-17}\ g$	various
Error sum (rms) for a 20-s integration time	$2.4\times10^{-15}\ g$	at f_S

t_{fall} = free-fall time, f_S = signal frequency

Estimated accuracy in 20-s integration time is 5 parts in 10^{15} at 95% confidence level.

Conclusions

- Selection of appropriate configuration for detector and inertia characteristics of package makes experiment in vertical free fall rather insensitive to dynamics of the instrument package and gravity gradients
- As a result, test accuracy is not limited by effects related to dynamics, proof mass centering, and orientation of the detector with respect to gravity vector but rather by the intrinsic noise of the differential accelerometer
- Vertical free fall from a balloon could make possible EP tests about two orders of magnitude more accurate than presently achieved with torsion balances