

***Multiple-Degree-of-Freedom
Pyrotechnic Shock
Simulation***

by

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and a

Host of Contributors, Kibitzers, and Doubting Souls

October 22, 1992

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Lockheed Palo Alto Research Laboratory

Outline

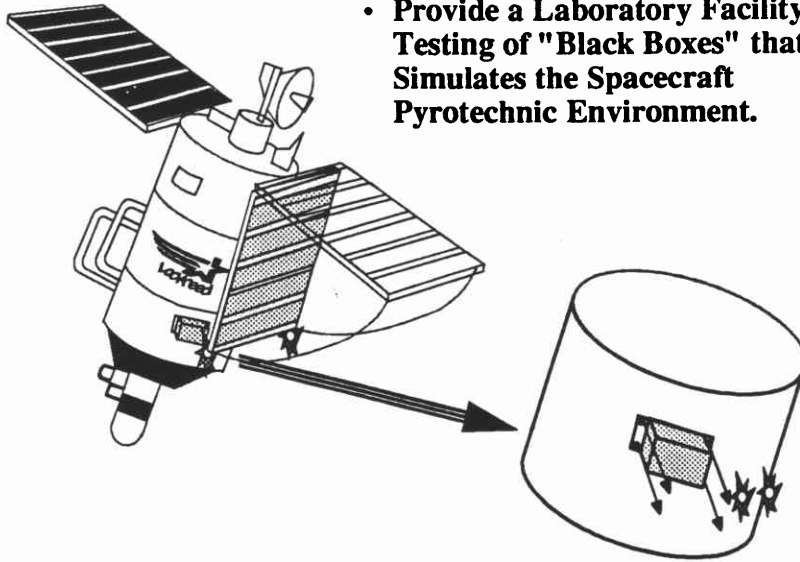
- **Explain the Problem**
- **Discuss the Goals**
- **Describe Some Methods In Use**
- **Discuss the Simulation**
- **Discuss Some New Ideas**
- **Solicit Your Comments**

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The Problem

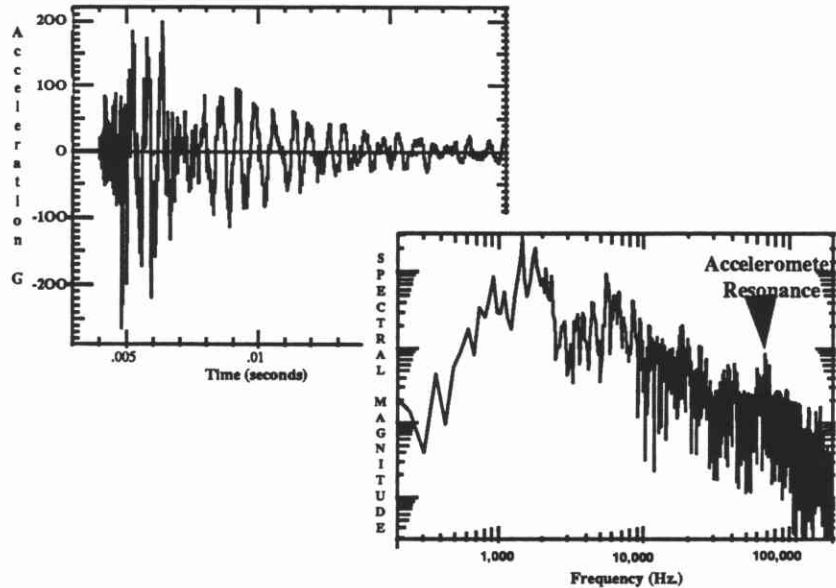
- Provide a Laboratory Facility for Testing of "Black Boxes" that Simulates the Spacecraft Pyrotechnic Environment.



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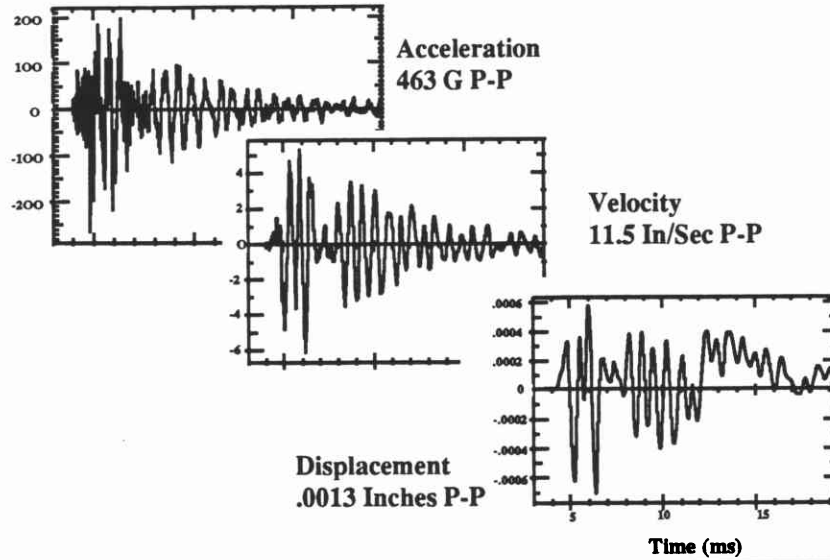
Typical Broadband Spacecraft Pyro-Shock Measurement



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PyroShock Acceleration, Velocity, Displacement Histories



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10000 P. ...
... & ...

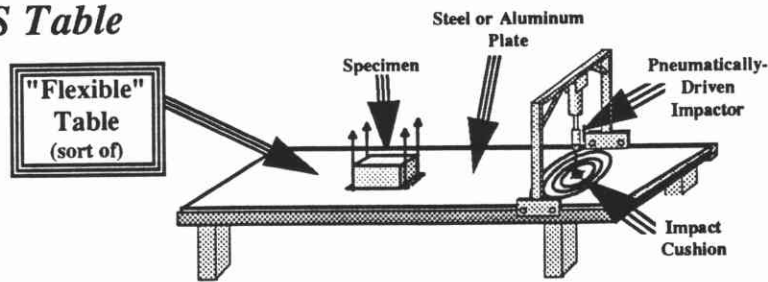
Available Methods

- **Mipps Table**
- **Motorola Air Gun/Longitudinal Beam**
- **Sandia Bending Beam**
- **Electrodynamic Shakers**
- **HDL 3-DOF Machine**

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... & ...

MIPPS Table



Shape of Shock Spectrum Controlled by:

- Plate Resonant Frequencies
- Specimen Position on Plate
- Impact Cushion Characteristics
- Plate Suspension

Level Controlled by:

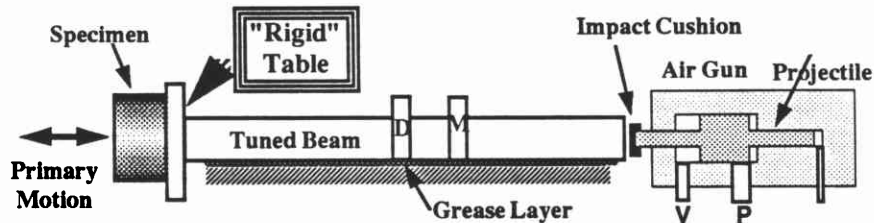
- Air Gun Pressure
- Projectile Mass
- Specimen-to-Impactor Distance

Good Repeatability
Trial & Error Tuning
Poor Simulation
"High" Art

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Motorola Air Gun/Longitudinal Beam



Shape of Shock Spectrum Controlled by:

- Tuned-Beam Resonant Frequencies
 - » Tuning Includes Moveable Masses and Dampers
- Impact Cushion Characteristics
- Grease-Layer Characteristics

Level Controlled by:

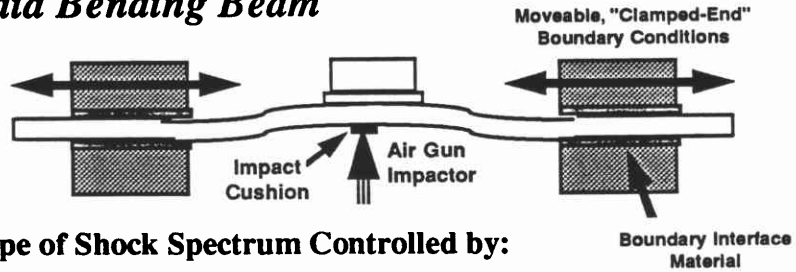
- Air Gun Pressure
- Projectile Mass

Excellent Repeatability
Trial & Error Tuning
1-DOF Simulation
"Moderate" Art
Some Science

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Sandia Bending Beam



Shape of Shock Spectrum Controlled by:

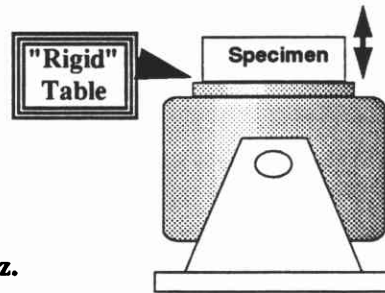
- Adjusting Resonant Frequencies by Moving Boundary Conditions
- Changing Interface Materials for Damping
- Modifying Impact Cushion
- Level Controlled by:
 - Impact Velocity

Excellent Repeatability
Analytically-Aided
Trial & Error Tuning
"Low" Art
Moderate Science

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Electrodynamic Shaker



Shock Spectrum Controlled by:

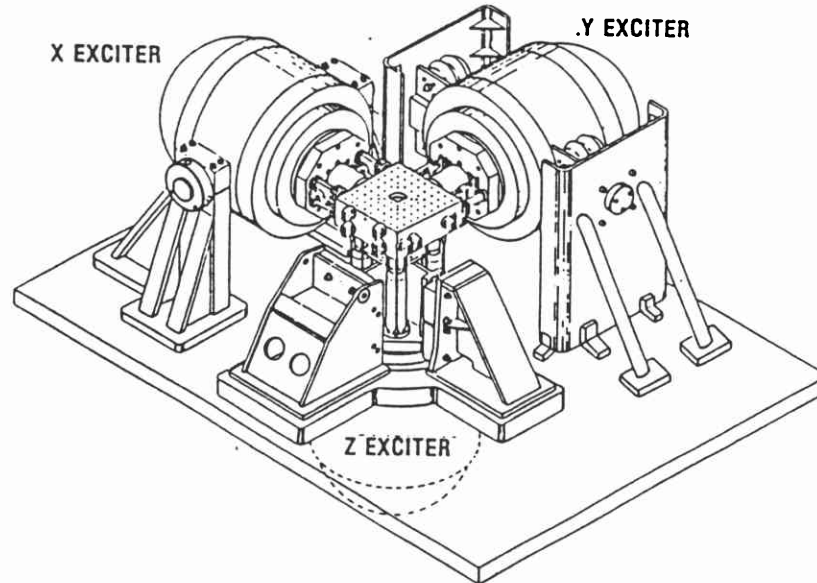
- Time-History Reproduction or Other Shock Generation Method
- Frequency Range: 10 Hz. to 3 KHz.
 - Limited by Armature Mass/Stiffness
 - Not High Enough for Pyro

Excellent Repeatability
Deterministic Tuning
"Very Low" Art
High Science

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HDL 3-DOF Machine



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The Goals

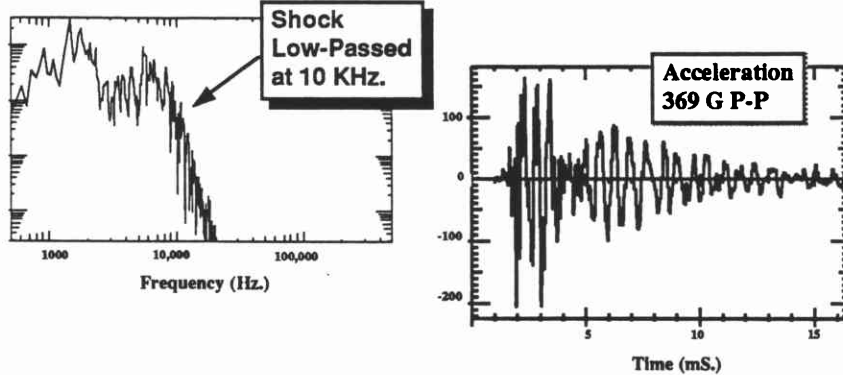
- **Realistic Wave Form**
 - Matches Recorded Time History?
 - Meets Shock Response Spectra (SRS) Requirements?
- **Programmable**
 - Linear System
- **Reproducible Excitation**
 - From Facility-to-Facility
- **Little or No Specimen-Dependent Tuning**
 - Art Not Required
- **Safe..Can be Used in A Structural Testing Lab Environment**

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Frequency Range of Interest

- **Conventional Wisdom Suggests That Energy Above 10 KHz Does Not Cause Mechanical Damage.**
 - **Items That Are Susceptible To Wavelengths Below 1 Inch Are Well Isolated From The Excitation**



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Payload/Motion/Force Requirements

- **Payload: 100 lb.**
- **Acceleration: ± 500 G**
- **Velocity: ± 20 In/Sec**
- **Displacement: $\pm .010$ Inches**

*At the Real Specimen Measurement Points
or Closest Possible Simulation*

**If the Mounting Plate/Specimen is Rigid,
the required force is 50,000 lb.**

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Candidate Specimen Interfaces

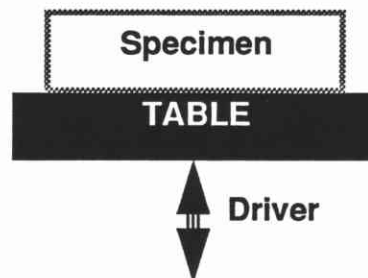
- **"Rigid" Table**
- **"Flexible Fixture"**

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Model 2000 Series
— Force & Displacement, Inc.

"Rigid" Fixture Concept

- **Heavy Fixture**
 - Requires Excessive Drive Forces
 - Expensive
 - Poor Emulation of "Box" Mounting Surface
- **Can't Be Truly Rigid in the Required Frequency Range!**
- **Produces an Over Test**
 - Conservative.
 - Good?

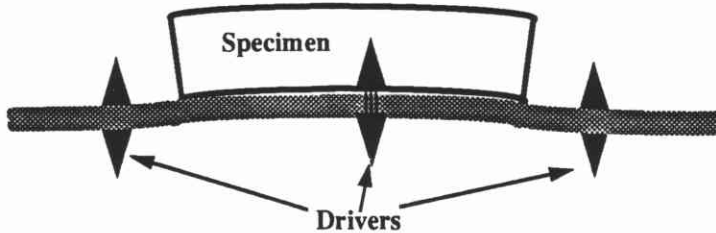


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Flexible Fixture Concept

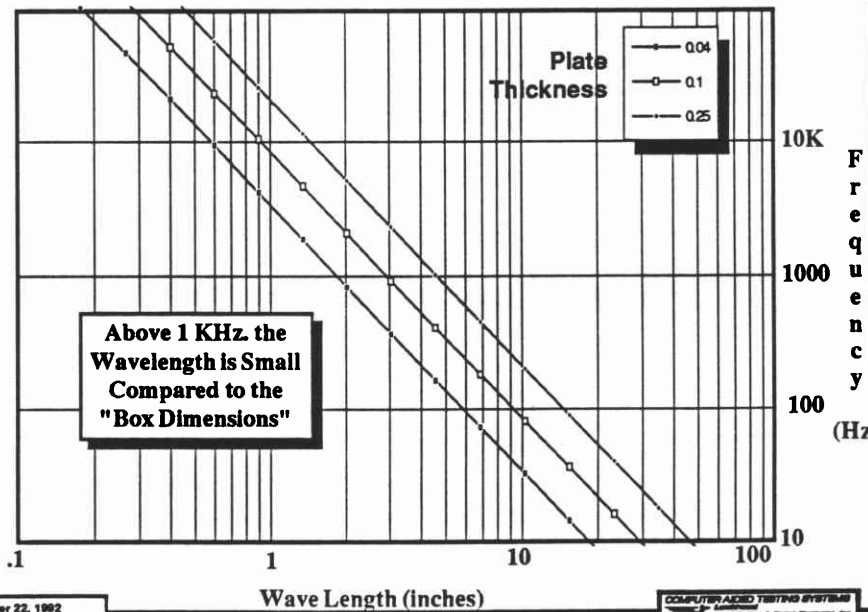
- Emulates the Structure
 - to "some extent"
- Multiple Actuators
 - and Multi-Axis Control System
are Required
- Forces Required are Relatively Small



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Wave Length vs Frequency



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Emulation Considerations

- **"Box" is Stiff Compared to it's Mounting Surface.**
 - Fixture Should Be Soft.
- **We want to Emulate the Motion at the "Box Boundary Conditions"**
 - Need to Measure the Correct Motions.
 - Need to Drive at the Measurement Points.

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Candidate Actuator Technologies

- **Pyrotechnic**
- **Hammer**
- **Electrodynamic**
- **Piezoelectric**
- **Magnetostrictive**
- **Hydraulic**
- **Hybrid**

Recall that the Actuation Time
is Very Short (0.1 Seconds) so
some "Preconceived Notions"
will not hold!

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Hybrid and Compound Machines

- **Hybrid**

- **Piezoelectric-Hydraulic or Magnetostrictive-Hydraulic**
 - » Use Hydraulics as a "Lever Arm" to Multiply Motion.

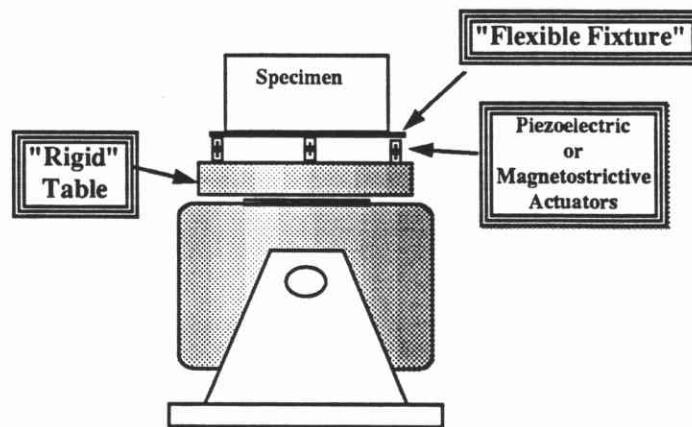
- **Compound**

- **Piezoelectric or Magnetostrictive Actuators Mounted on Rigid-Table Electrodynamic**
 - » **Electrodynamic handles 10Hz to 1 KHz.**
 - High displacement, Low Acceleration.
 - » **High Frequency Actuators Drive Flexible Fixture**
 - Low Displacement, High Acceleration.
 - Mass of the Rigid Table Reacts the High-Frequency Forces.

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Model 1000 Series

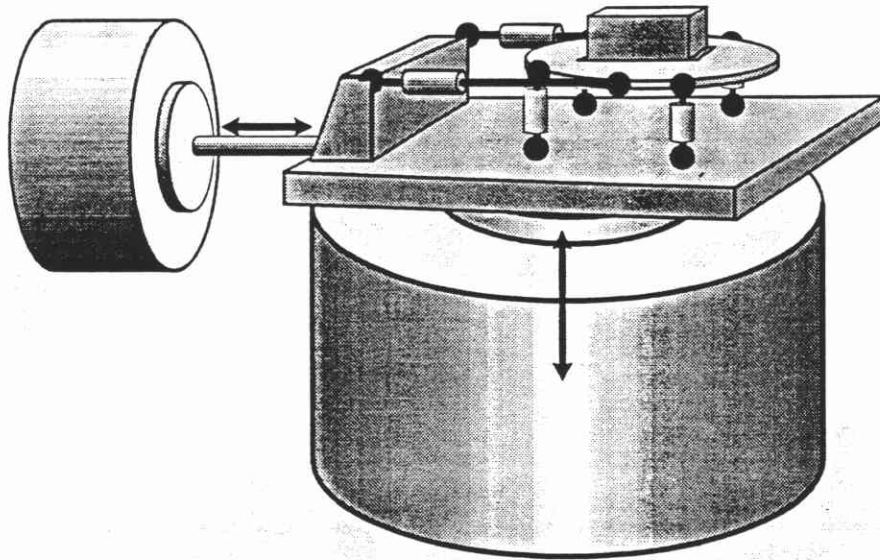
Piezoelectric or Magnetostrictive/Flexible Fixture Mounted on Rigid-Table Electrodynamic



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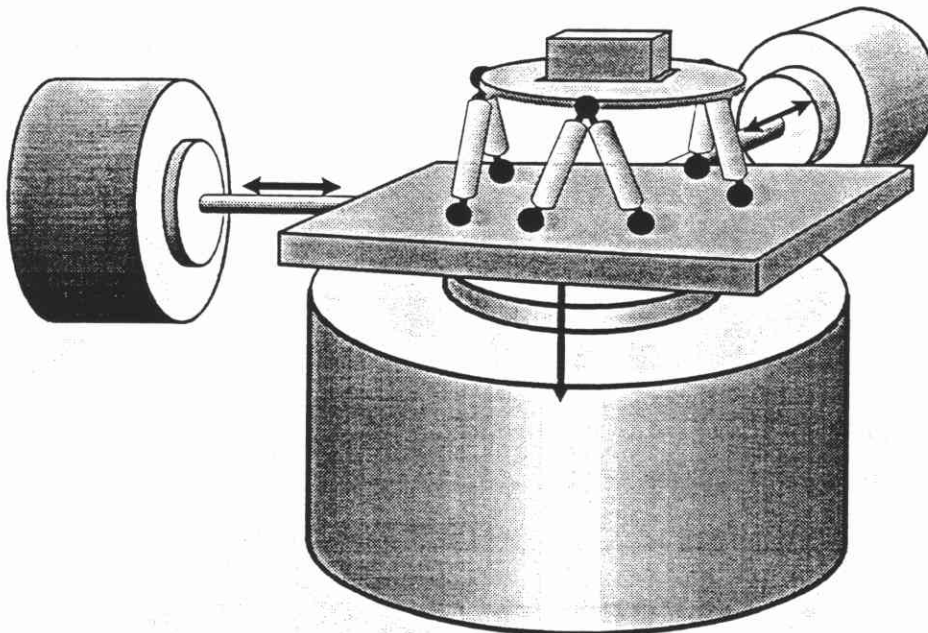
Two (+) Degree-of-Freedom Concept



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Extension to HDL Machine..Concept



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Lynchburg & Boston, Virginia, Inc.

Conclusions

- **The Methods In Use Today Do Not Provide Accurate Simulation.**
 - They are also Difficult and Expensive.
- **The Flexible Fixture Concept Should Be Investigated.**
 - Is it a Better Simulation?
- **For the Excitation Requirements Discussed, it Appears that a Compound Machine Might be Appropriate.**
 - Needs Further Study!!

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