





**Determination of Selected Material  
Properties of Castable Thin Film Polyimides  
for Applications in  
Solar Thermal Propulsion**

**By**

**James Patrick Paxton**

**Undergraduate  
Senior Year**

**Mechanical and Aerospace Engineering Department  
University of Alabama in Huntsville  
Huntsville, Alabama**

**Presented to**

**The AIAA Southeastern Regional Student Conference  
April 7 - 8, 1994  
Huntsville, Alabama**



## **This Study Will...**

- **Provide an Introduction to Typical Applications of Thin Film Polyimides**
- **Introduce 6FDA + APB Polyimides as an Important Component in Solar Thermal Propulsion**
- **Show Unique Methods in the Determination of Selected Material Properties of 6FDA + APB Polyimides**
- **Provide Modulus of Elasticity and Coefficient of Thermal Expansion Data for 6FDA + APB Polyimides**



## What is a Thin Film?

- Thin Sheet of a Polymer Material
- Typically .0005 - .002 Inches Thick
- Used for Stretched Membrane Mirrors and Parabolic Concentrators
- Examples of Thin Film Materials
  - Mylar™ Polyester Film
  - Kapton™ Polyimide Film
  - 6FDA + APB Polyimide Film

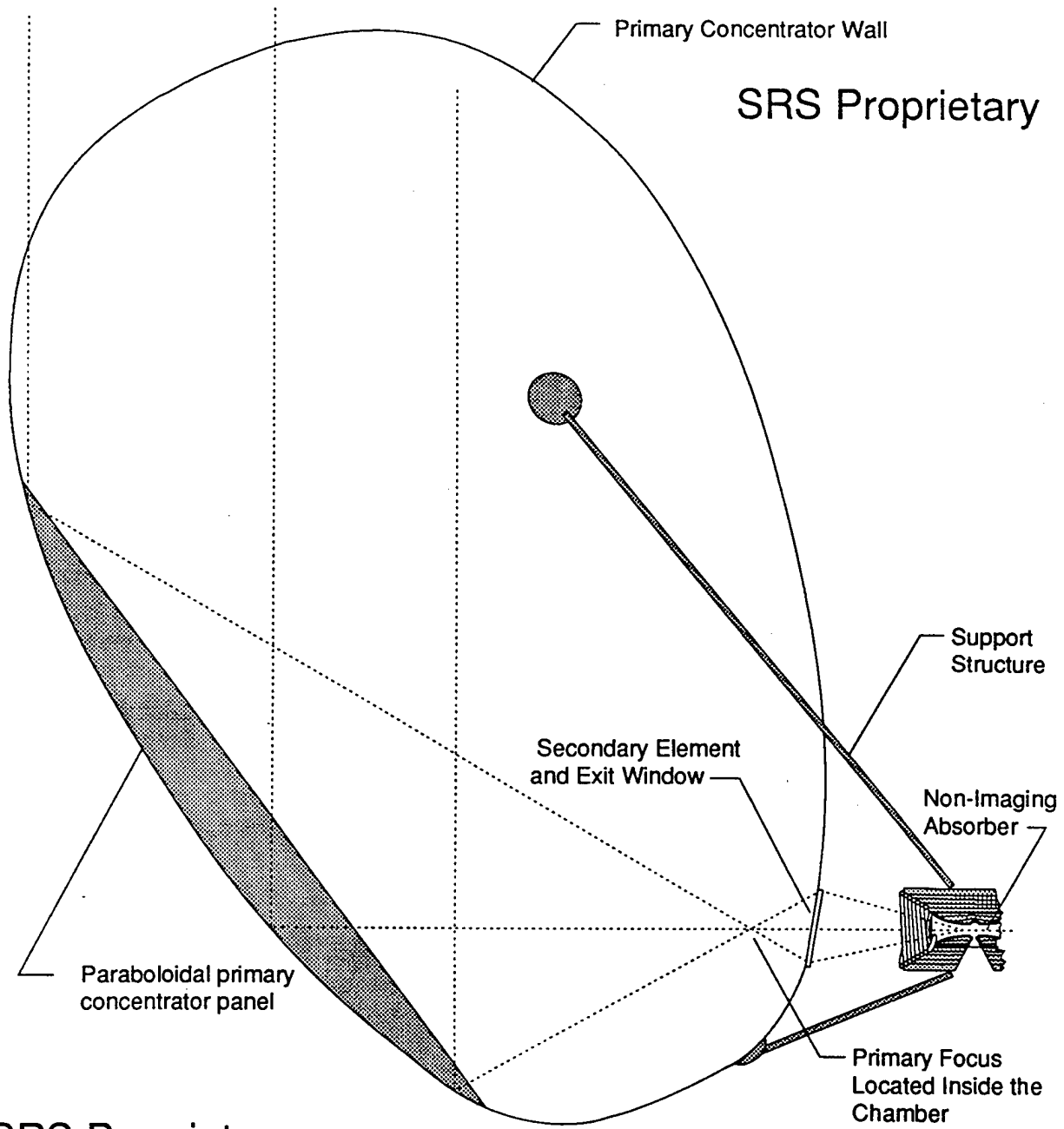


## **An Application of Thin Film Polyimides**

- **Solar Thermal Propulsion is Fast Becoming an Attractive Option  
for On-orbit Satellite Maneuvers**
  - LEO to GEO Orbit
  - High Performance (Typical Isp – 600 - 1000 sec.)
  - Lightweight
- **The Components of a Solar Powered Rocket Include...**



# Typical Solar Thermal Rocket Configuration



SRS Proprietary



## **Benefits of 6FDA + APB Thin Films**

- **Lightweight**
- **Optically Transparent**
- **Stowable / Deployable**
- **Superior Material Properties**
- **Wide Temperature Range (-450 – 750°F)**
- **Castable on Curved Surfaces**



## Design Parameters for Articles Constructed with Thin Film Polyimides

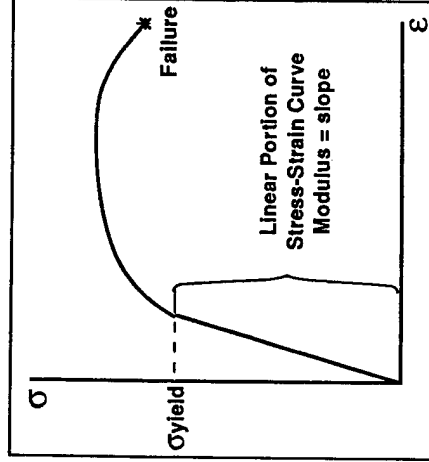
- External Loads / Pressures
- Environmental Conditions
- Transparency
- Material Properties
  - Modulus of Elasticity
  - Coefficient of Thermal Expansion
  - Coefficient of Moisture Expansion
  - Poisson's Ratio



# Theory

- Modulus of Elasticity (Young's Modulus) is given by Hooke's Law

$$\sigma = E\epsilon \quad (\text{psi})$$



- Coefficient of Thermal Expansion is given by

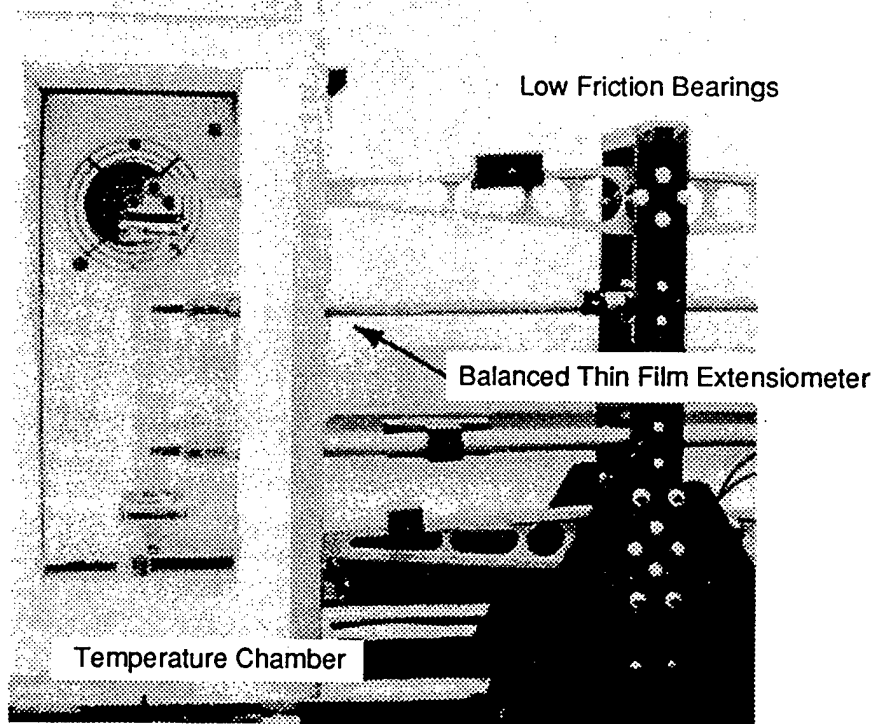
$$\text{CTE} = \frac{\Delta L}{L\Delta T} \quad (\text{in}/(\text{in}^\circ\text{F}))$$



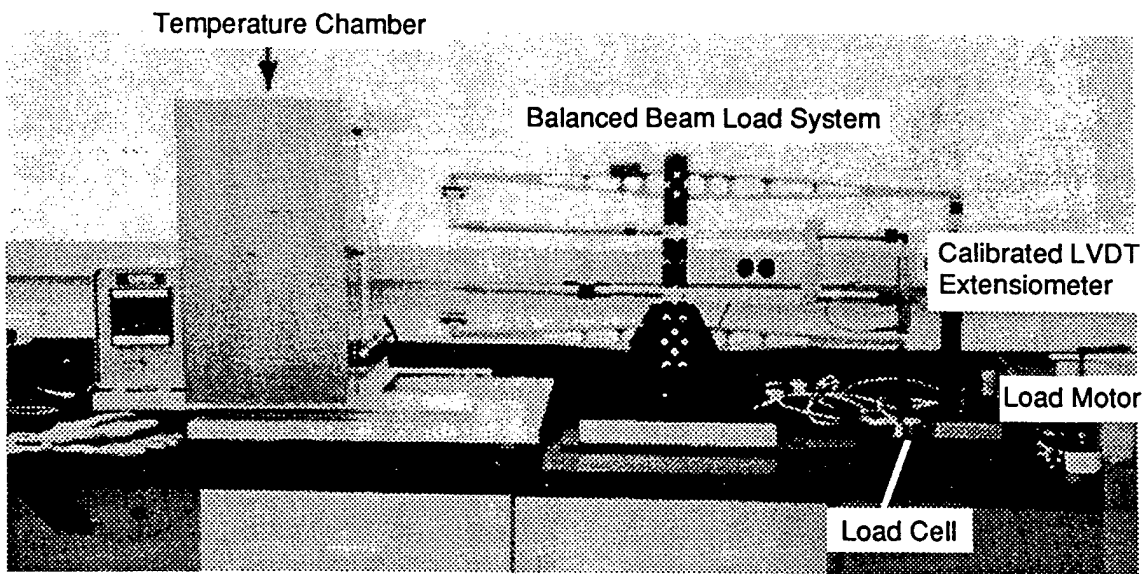
## **Thin Film Test Apparatus**

- **Conforms to ASTM Standards**
- **Includes Temperature Chamber**
- **Provides Constant Uniform Loading**
- **Incorporates Unique Toggle Grip Design**
- **Computer Data Acquisition System**

# Uniaxial Test Apparatus



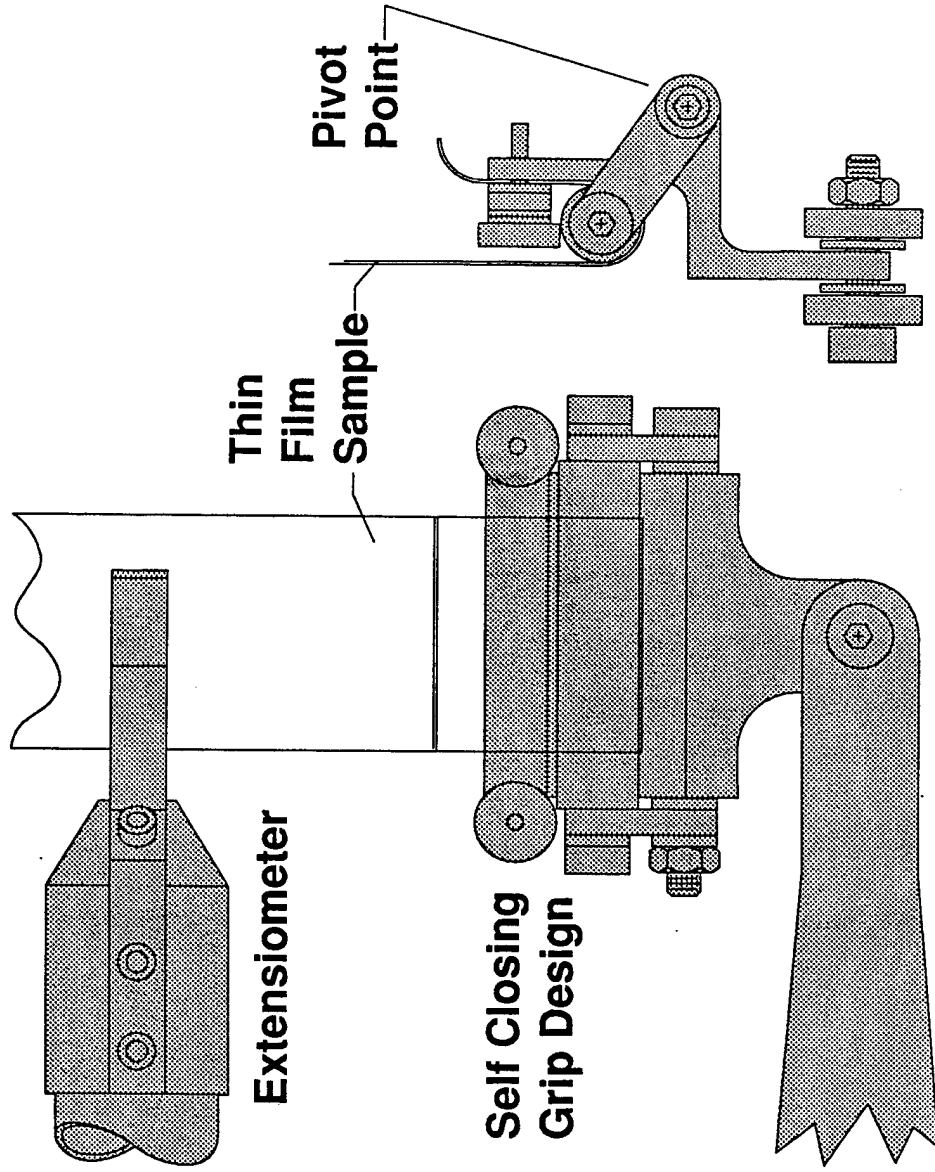
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# Toggle Grip Design



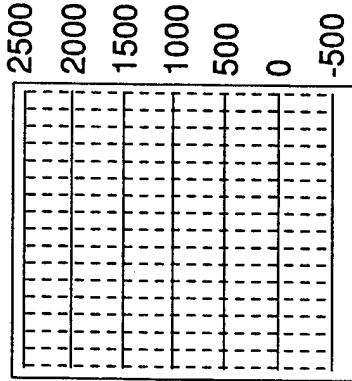
# Computer Test Panel

## CREEP TEST PANEL

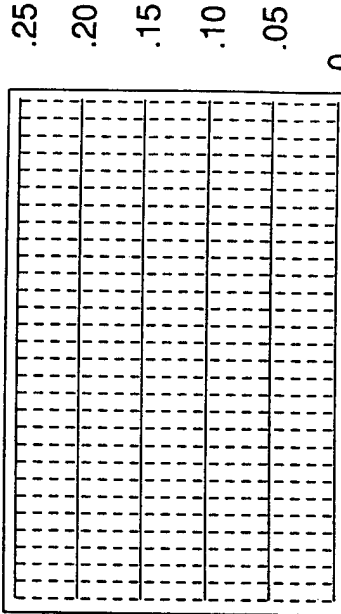
0

.0500

Load / Stress



Time Dependent Strain



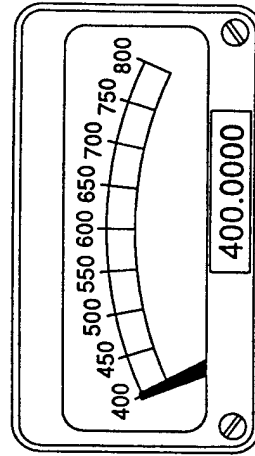
- 2.0 min
- 1.0 min
- 30 sec
- 10.0 sec
- 5.0 sec
- 2.0 sec
- .5 sec

0

Rate



Data Rate



Temperature



Start Test

0

Time



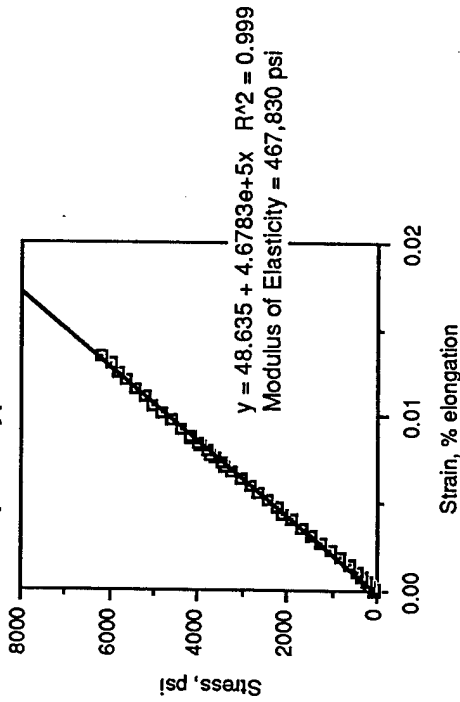
## Experimental Procedure

- **Cast, Cut and Measure Samples**
- **Material Tester Calibration**
- **Perform Modulus Tests on Kapton Polyimide**
- **Perform Modulus Tests on 6FDA + APB Polyimide**
- **Perform CTE Tests on 6FDA + APB Polyimide**
- **Tabulate and Graph Results**
- **Compare Results to Material Source Data**

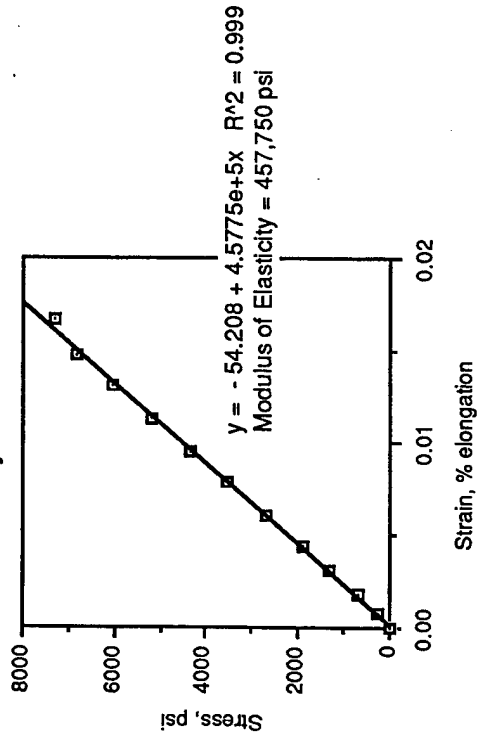


# Modulus of Elasticity Results

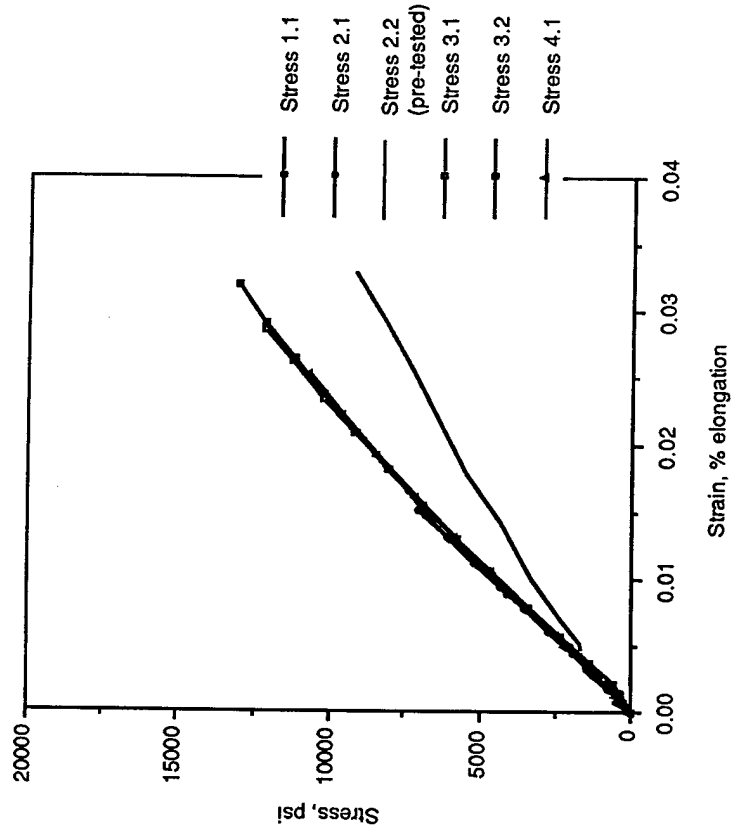
**.5 mil Kapton Type H Linear Curve Fit**



**6FDA+APB Polyimide Linear Curve Fit**



**Comparison of Stress vs. Strain Curves for the 6FDA+APB Polyimide**





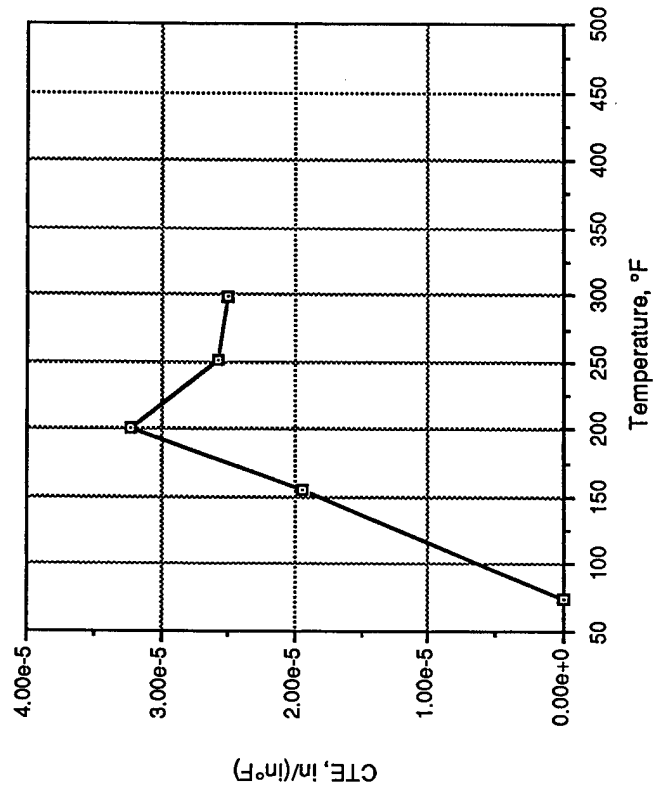
## Modulus of Elasticity Results cont.

	Manufacturer's Data	Harris / NASA	Results of Tests	% Difference
<b>Kapton Type H</b>	430,000 psi 1 mil at 25 °C		467,830 psi .5 mil at 23 °C	8.8 %
<b>6FDA + APB</b>		426,000 psi 452,000 psi	457,500 psi 457,500 psi	7.5 % 1.3 %



# Coefficient of Thermal Expansion Results

6FDA+APB Polyimide CTE





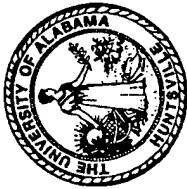
## Coefficient of Thermal Expansion Results cont.

	Harris Data	Results of Tests	% Difference
Average CTE	27.2E-6 in/(in°F)	25.7E-6 in/(in°F)	5.7%



## Conclusions and Recommendations

- All Tests Showed Good Repeatability
- Results Compared Favorably to Source Data
- Values Presented here may be used as Design Parameters for Applications of Thin Films in Solar Thermal Propulsion
- The Determination of other Material Properties is Recommended
- Further Investigation of the Non-linearity in the CTE Curve is Recommended



## Acknowledgements

- Phillips Laboratory, Edwards Air Force Base, California
  - Ms. Kristi K. Laug
- SRS Technologies, Huntsville, Alabama
  - Mr. Paul A. Gierow
- NASA LaRC, Langley, Virginia
  - Ms. Anne St. Clair