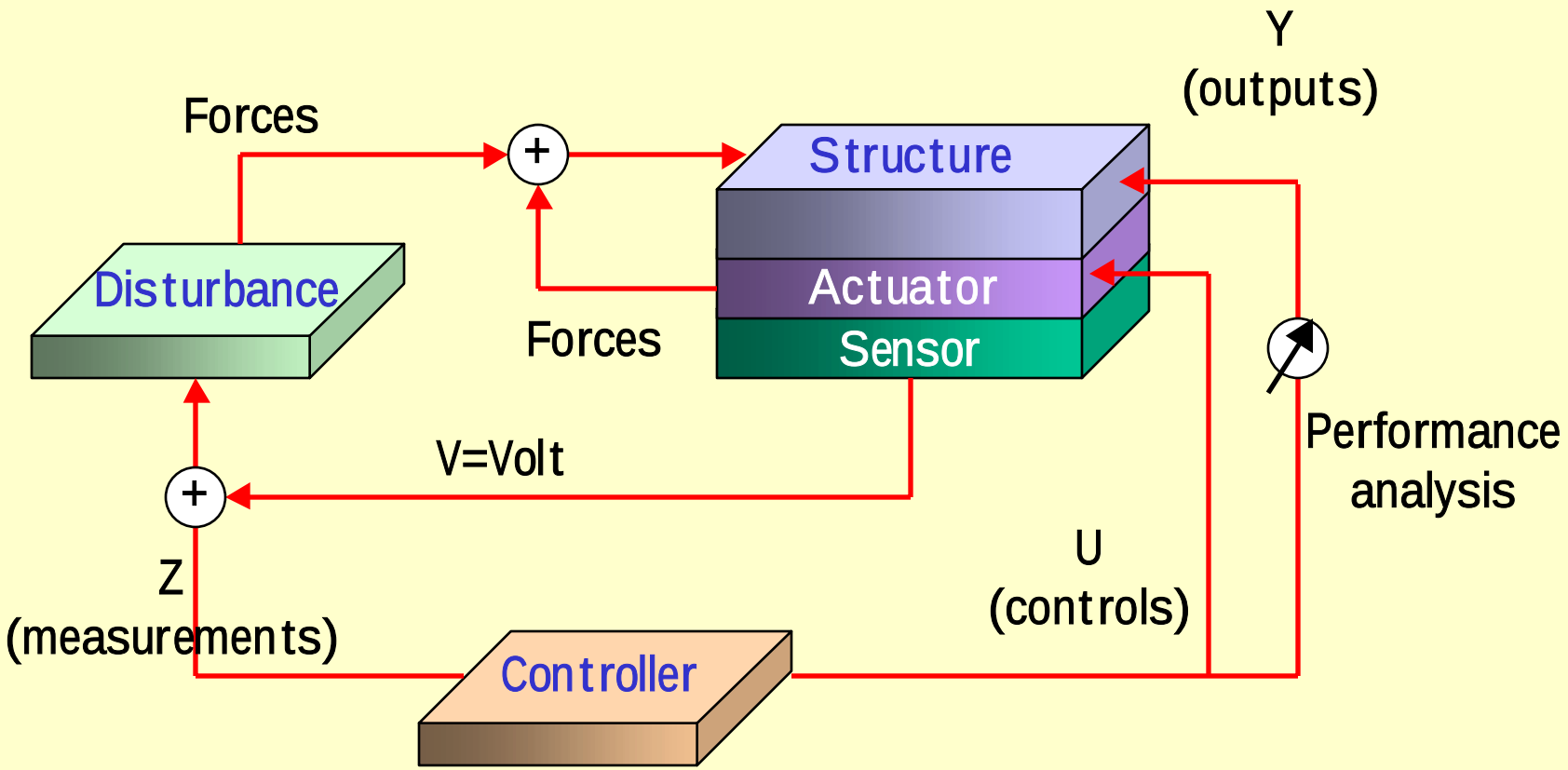
Smart Structure Applications

- Smart Structure Applications
- Emerging Themes
- Smart Structure Sub-systems
- Application Examples
  - Space Antennas
  - SHAPECONS
  - Deformable Mirror
- Conclusions

System Component Schematic



Smart Structure Applications

- Aerospace
  - Damage detection
  - Vibration control
  - Shape control
  - Adaptive structures
- Defence
  - Firing accuracy of weapons
  - Vibration and noise reduction in submarines
  - Adaptive wings for aircraft and missiles

Smart Structure Applications

- Automotive
  - Passenger comfort (noise control in cabin)
  - Vibration control (active engine mounts)
  - Health monitoring (smart sensors)
- Industrial
  - manufacturing (machine tool chatter control)
  - Air conditioning and ventilation (noise control)
  - Mining machinery (vibration control)

Smart Structure Applications

- Medical
  - Smart sensors (tele-medicine)
  - Micro robotics
  - Surgical tools
- Civil
  - Bridges
  - Earthquake protection

Emerging Themes

- The emerging themes are:
  - Active Vibration Control (AVC)
  - Active Noise Control (ANC)
  - Active Shape Control (ASC)
  - Active Health Monitoring (AHM)

Technology Development

Based on the emerging themes for smart structure research the work at Sensor Technology Limited has been focused on three smart structure sub-systems (modules).

- Smart Strut Member
- Smart Structural Panel
- Smart Control System

Smart Structure Sub-systems

- Smart Strut Member
  - It will be used in applications involving load-bearing applications and will replace standard struts. The Smart Structure Member will consist of an actuator and motion and acceleration sensors integrated into a single strut structure. Typical applications include active shape and vibration control and pointing accuracy control applications such as antennas.

Smart Structure Sub-systems

- Smart Structural Panel
  - Smart Structural Panels will be used in lightweight and low-force applications. It will consist of typically a carbon fibre-reinforced plastic (CFRP) panel element with embedded actuators and strain and temperature sensors. Applications for Smart Structural Panels include fibre optic instruments and vibration and surface-shape control applications such as antennas and deformable mirrors.

Smart Structure Sub-systems

- Smart Control System
  - Smart Control Systems will provide feedback control for the above sub-systems. Low-cost, configurable control systems with special interfaces for the Smart Strut and Smart Panel will be required.

Smart Strut Member Component Selection

The actuators considered for possible incorporation into the Smart Strut Member include:

- Shape memory alloys
- Magnetostrictive materials
- Piezoelectric materials (includes electrostrictive materials).

Smart Strut Member Component Selection

The sensors considered for possible incorporation into the Smart Strut Member include:

- Potentiometers
- Linear voltage differential transformers
- Accelerometers

SSM Features

The Smart Strut Member (SSM) was designed to replace some of the conventional strut members that are components of current passive support structures, with the goal of providing a degree of active control in critical truss systems. The SSM has the ability to vary its length depending on the requirements of the truss structure.

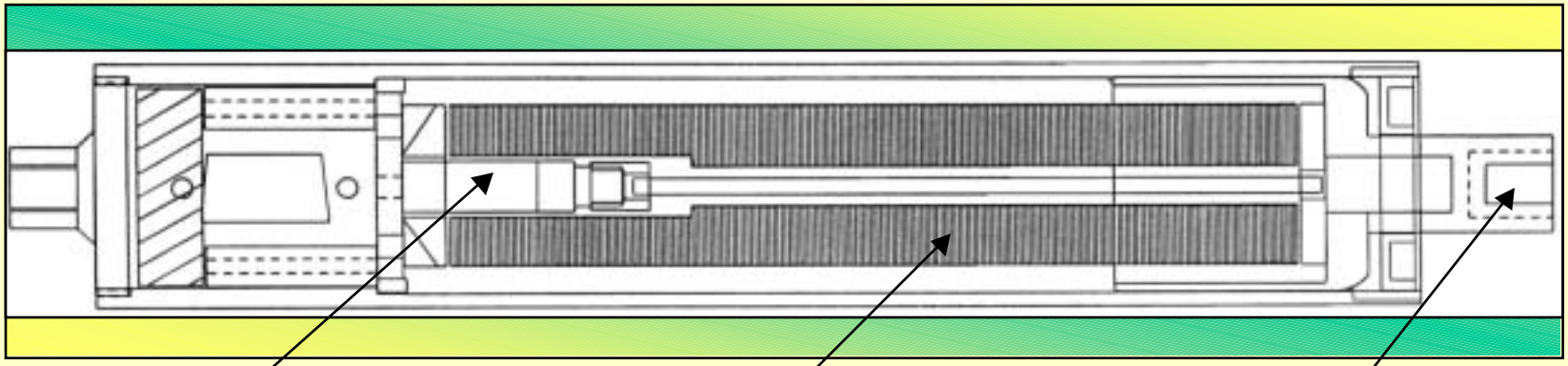
SSM Features

The SSM consists of a cylindrical structural housing with an actuator and a position sensor, with the related sensor drive and signal conditioning electronics. A piezoelectric stack generates the necessary forces and movements in order to displace large loads. A linear displacement sensor will measure the length of the stack actuator in order to provide positional feedback to an active control system. An optional accelerometer can also be integrated into the SSM.

SSM Features

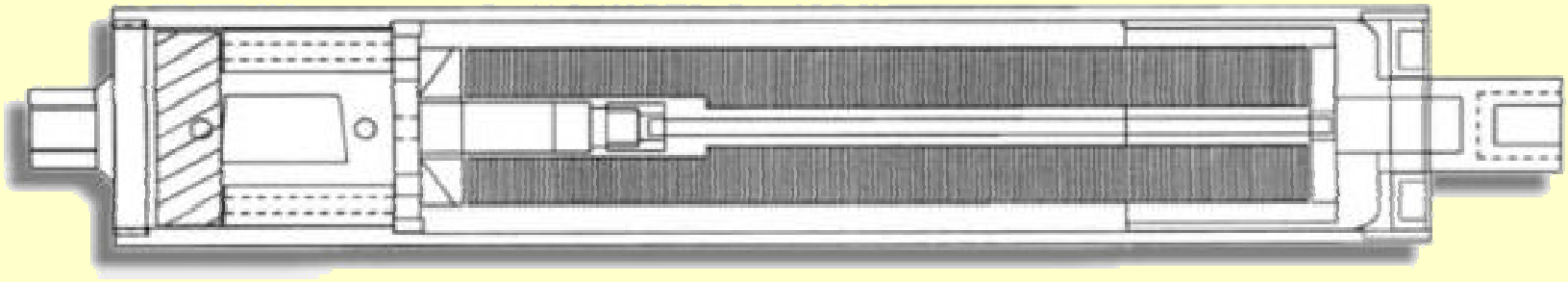
The output of the sensor can be configured for different data acquisition systems. Because of the modular nature of the SSM design, the actuator and sensor components can be replaced for application-specific properties.

Smart Strut Member (SSM)



SSM Cutaway Drawing

SSM Specifications



Features:

- High stiffness
- Wide area actuators
- Mechanical pre-load

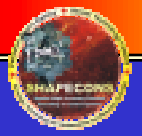
Applications:

- Heavy load positioning and handling
- Smart structure research
- Dynamic loading
- Instrumentation
- Robotics
- Civil engineering

Smart Strut Member Specifications

• PERFORMANCE:	
• Displacement (mm)	±40
• Maximum pull force (N)	1,000
• Maximum push force (N)	10,000
• Hysteresis	8-12%
• Position Resolution (nm)	±50
• Stiffness (N/mm ±10%)	2,000
• Capacitance (nF)	250
• Resonance frequency (kHz)	5.0

Smart Strut Member Specifications



MECHANICAL:

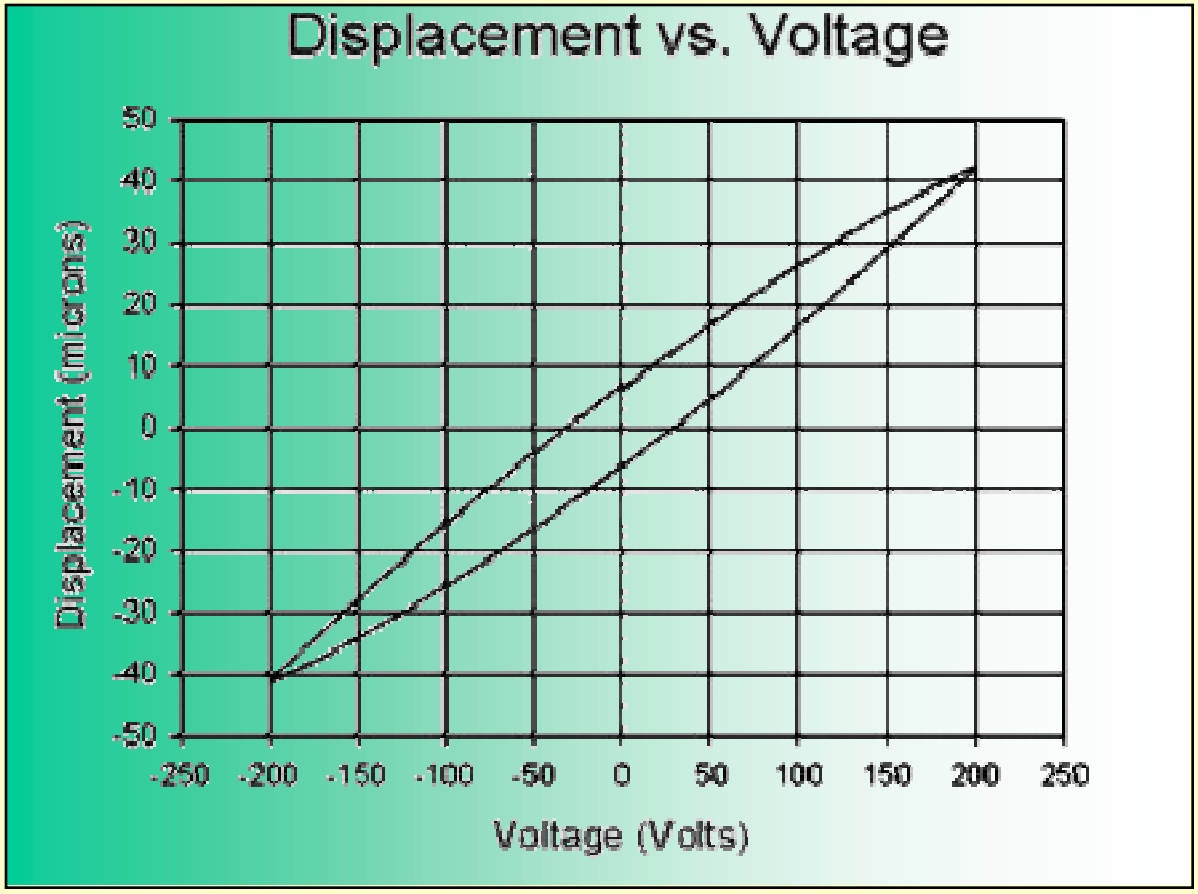
• Length (mm)	230
• Width (mm)	38
• Housing	stainless steel
• End caps	thread-mount (1/4”- 20 tapped)
• Weight (g)	1,186.5

Smart Strut Member Specifications

ELECTRICAL:

- Voltage (V max) ±300
- Connector 9-pin D-SUB

Smart Strut Member Hysteresis



Smart Structural Panel

The Smart Structural Panel will be used in lightweight and low-force applications.

The Smart Structural Panel will consist of the following:

- Reinforced plastic (CRFP) panel element
- Embedded piezoelectric actuators
- Embedded strain and temperature sensors

Smart Structural Panel Component Selection

The actuators considered for possible incorporation into the Smart Structural Panel include:

- Shape memory alloys
- Magnetostrictive materials
- Piezoelectric materials (includes electrostrictive materials)

Smart Structural Panel Component Selection

The sensors considered for possible incorporation into the Smart Structural Panel include:

- Strain gauges
- Optical fibres
- Piezoelectric sensors
- Thermistors
- Thermocouples

SSP Features

Consists of two ceramic elements formed into a flexure mode element, which generates a controlled amount of actuator displacement and force. When a voltage is applied to the ASP, one element expands while the other contracts, thus providing a bending motion and force. These actuators are provided with a base for cantilever operation and two electrical pins for connection to external circuitry.

SSP Features

Typical applications include active control of vibration and noise, modal analysis of structures, smart structure research, and other applications requiring small and efficient sensors and actuators.

SSP Specifications

PERFORMANCE SPECIFICATIONS:

Type of actuator: Flexure mode element

Hysteresis (%)	8
Deflection (mm)	±1,500
Bandwidth (Hz)	30
Effective moment (N)	3
Electrical connection	two pins standard, three pins for strain gauge

SSP Specifications

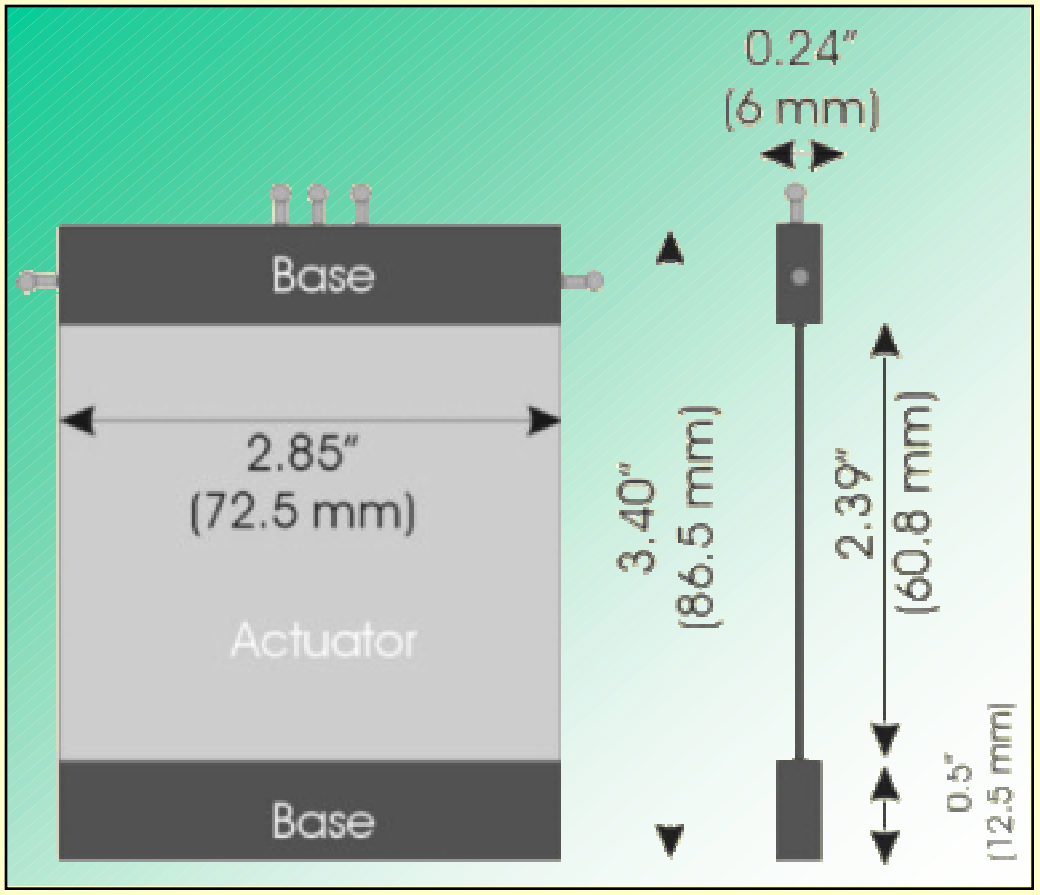
PIEZOELECTRIC SPECIFICATIONS:

Maximum voltage (V)	± 200
Temperature range (°C)	-60 to +60

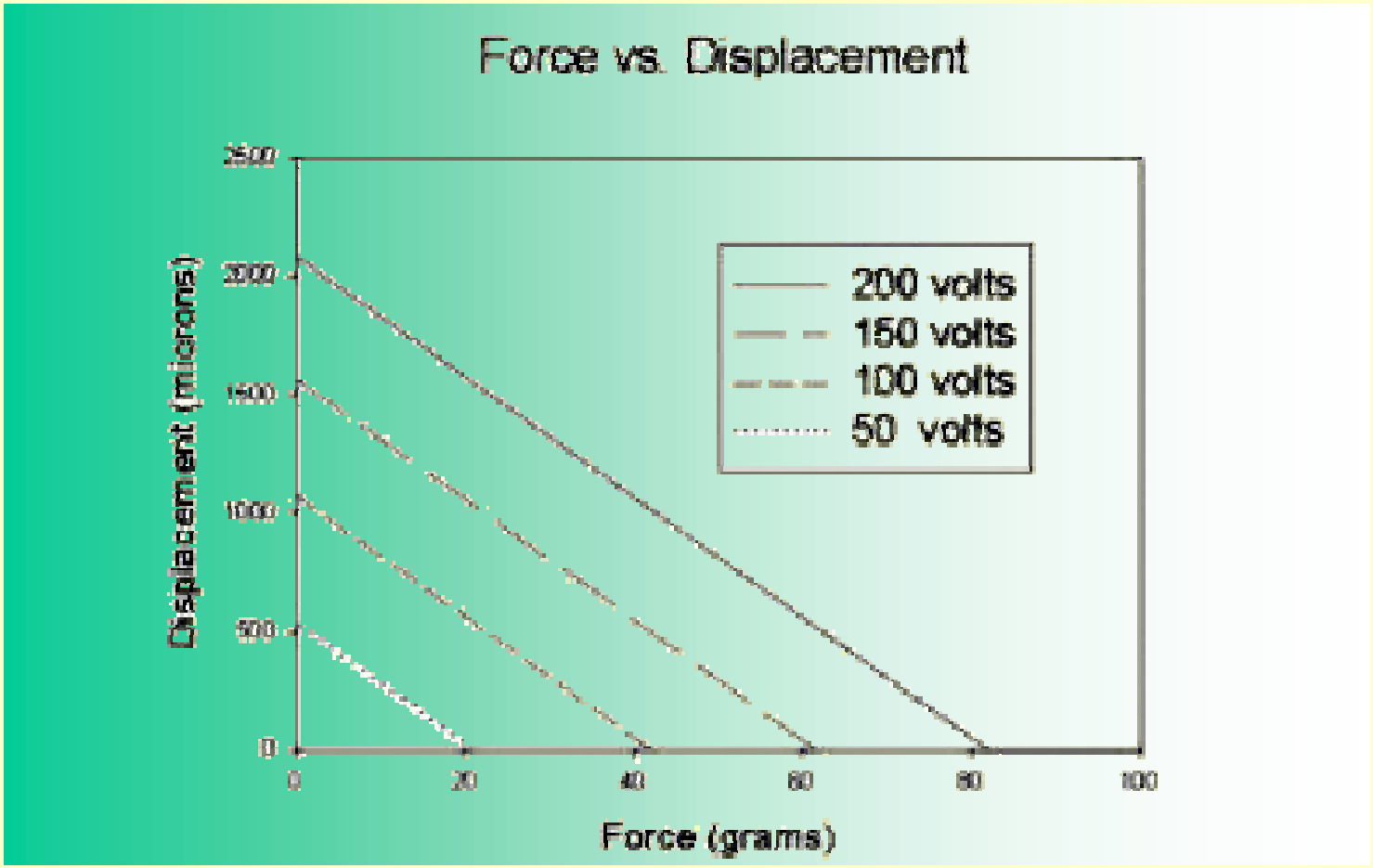
MECHANICAL DIMENSIONS :

Length (mm)	86.5
Width (mm)	72.5
Thickness (mm)	0.54

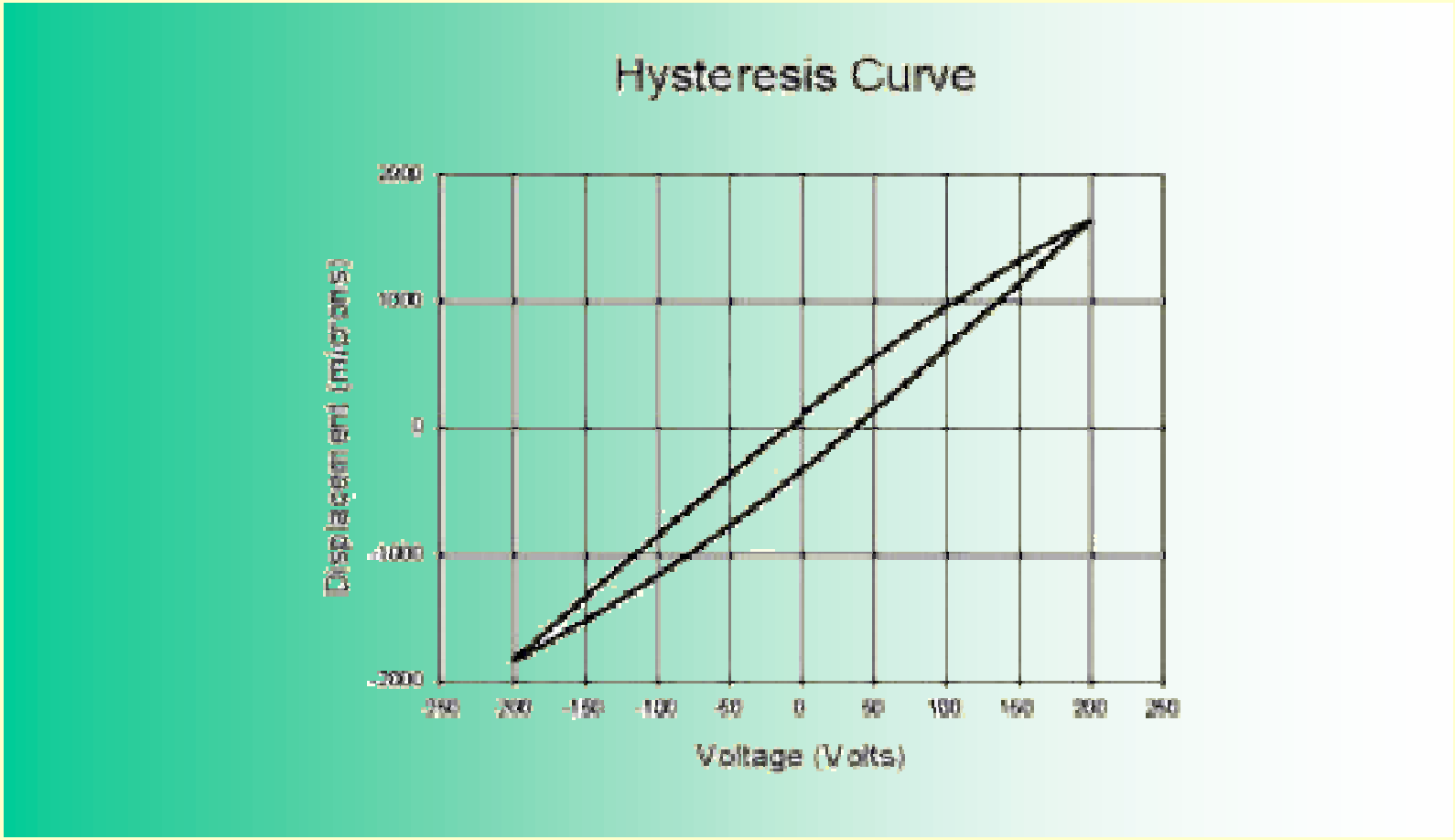
Smart Structural Panel



SSP Specifications



SSP Specifications



SSP Specifications

Features:

- Large displacement
- Moderate force capability
- Low power consumption
- Flexible design

Applications:

- Control elements
- Smart structure research
- Robotics
- Fibre-optic instrumentation

Smart Control System

- The Smart Control System will provide feedback control for the Smart Strut and Smart Panel sub-systems
- The SCS will also include the interfaces necessary for the operation of the sub-system modules like SSM and SSP.

Smart Control System

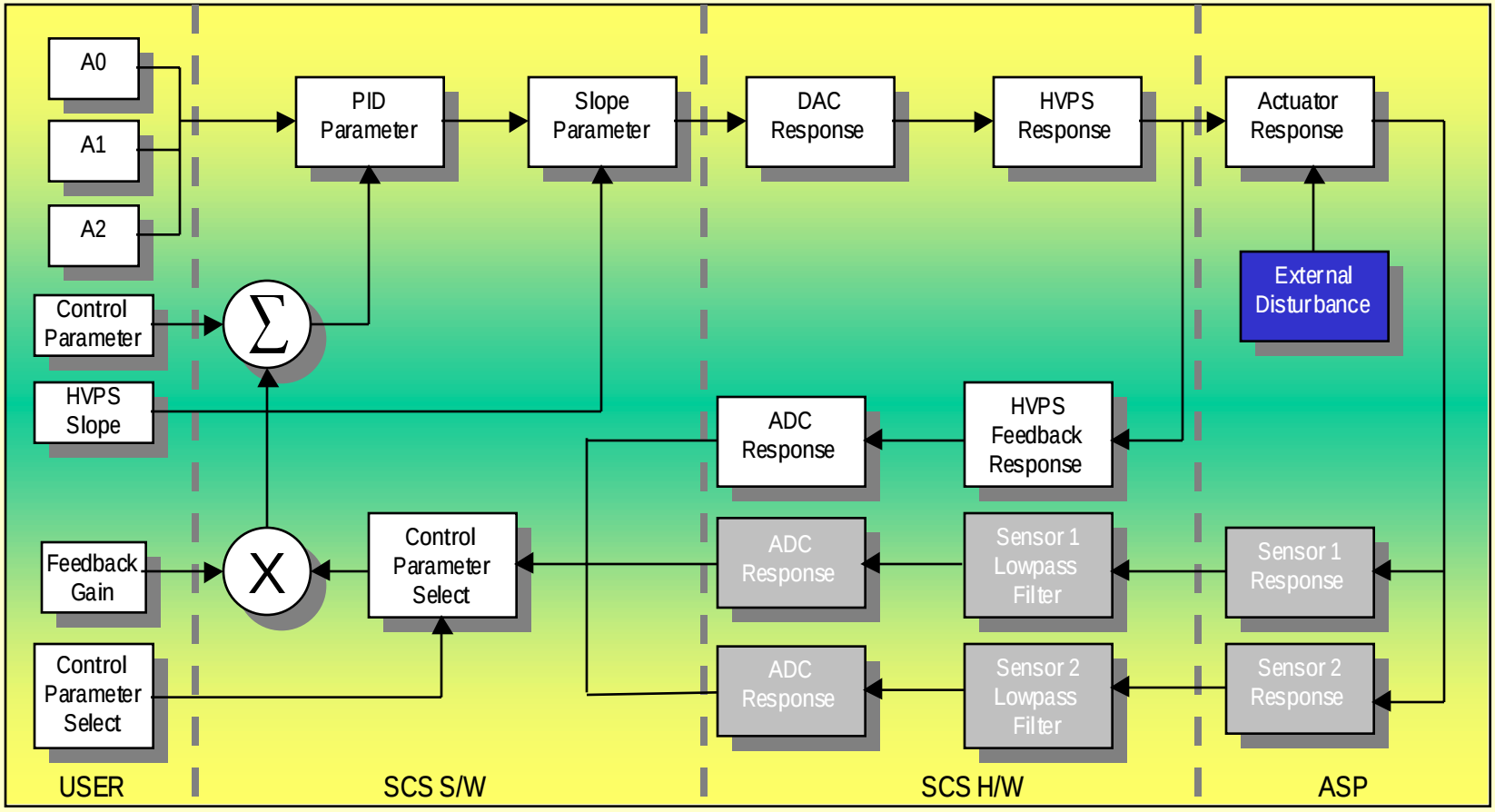
- The SCS will consist of the following:
  - Analogue-to-digital and digital-to-analogue converters
  - Input signal amplification and filtering
  - Control algorithm
  - Digital signal processor (DSP)
  - Output power supply

SCS Features

The output channels interface to external High-Voltage Power Amplifier modules. The interface allows the amplifier module to be used as two individual ground-referenced amplifiers or as a single bridge mode amplifier. The SCS should also accept drive voltage feedback to the controller.

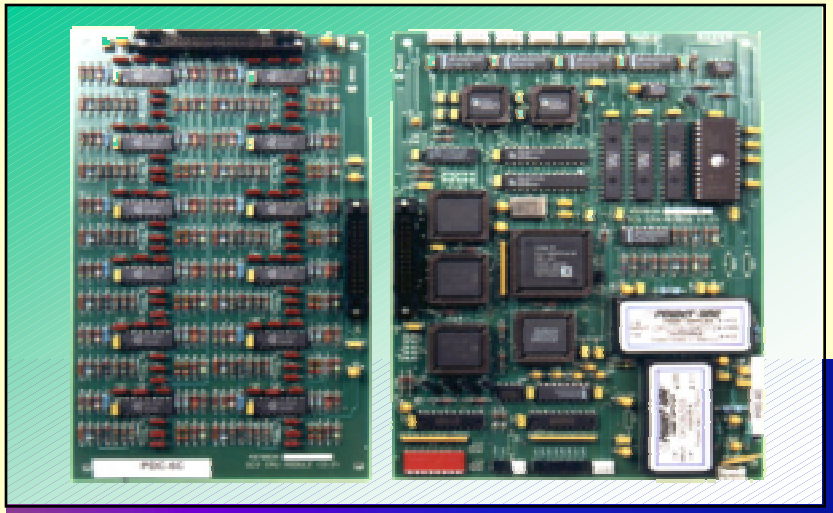
External inputs can come from several sources. Typically, one or two sensors are used to monitor the controlled device (such as a piezoelectric actuator). The parameter monitored is sensed by a transducer, a device that converts the parameter being monitored into an electrical signal. The transducer output is then conditioned, through amplifiers and filters, before being input to one of the channels on the SCS.

SCS Single Channel Overview



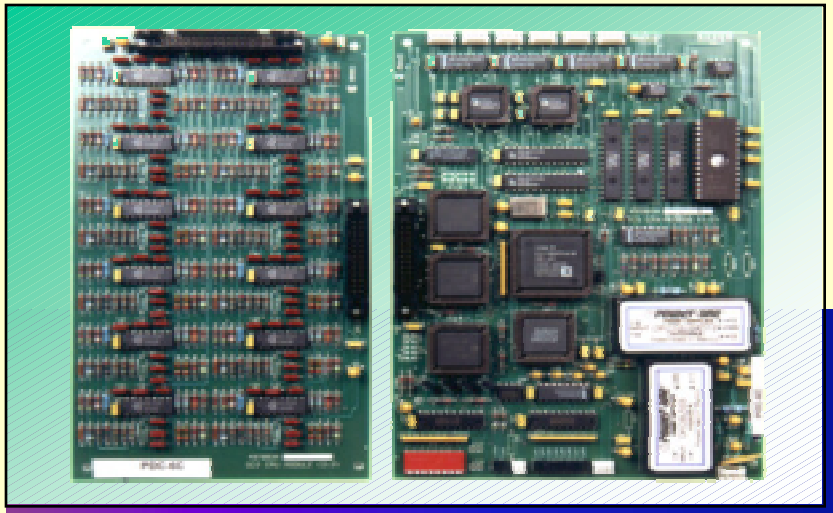
Smart Structures - Smart Control System

Six-Channel DSP-Based High Voltage Controller



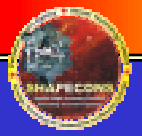
The SCS is a six-channel, microprocessor-based High Voltage Controller. It consists of a serial interface, a digital signal processor (DSP), six (6) controlled interfaces, and an 18-channel data acquisition system (DAS). Six of the DAS channels are used to monitor the high-voltage power amplifier (HVPA) outputs. The other 12 are available for use with external inputs. The unit is powered by an external 12-volt DC source. (28V for Aircraft operation)

SCS Features



The SCS is controlled by a host computer through an RS-232 or RS-485 serial interface. The interface is used to set up the controller, to set the output voltages, and to read the input signal levels. A closed-loop digital control system ensures that the output voltage is maintained at the preset value. Up to 31 devices can be accommodated on the RS-485 serial bus.

SCS Features



Applications:

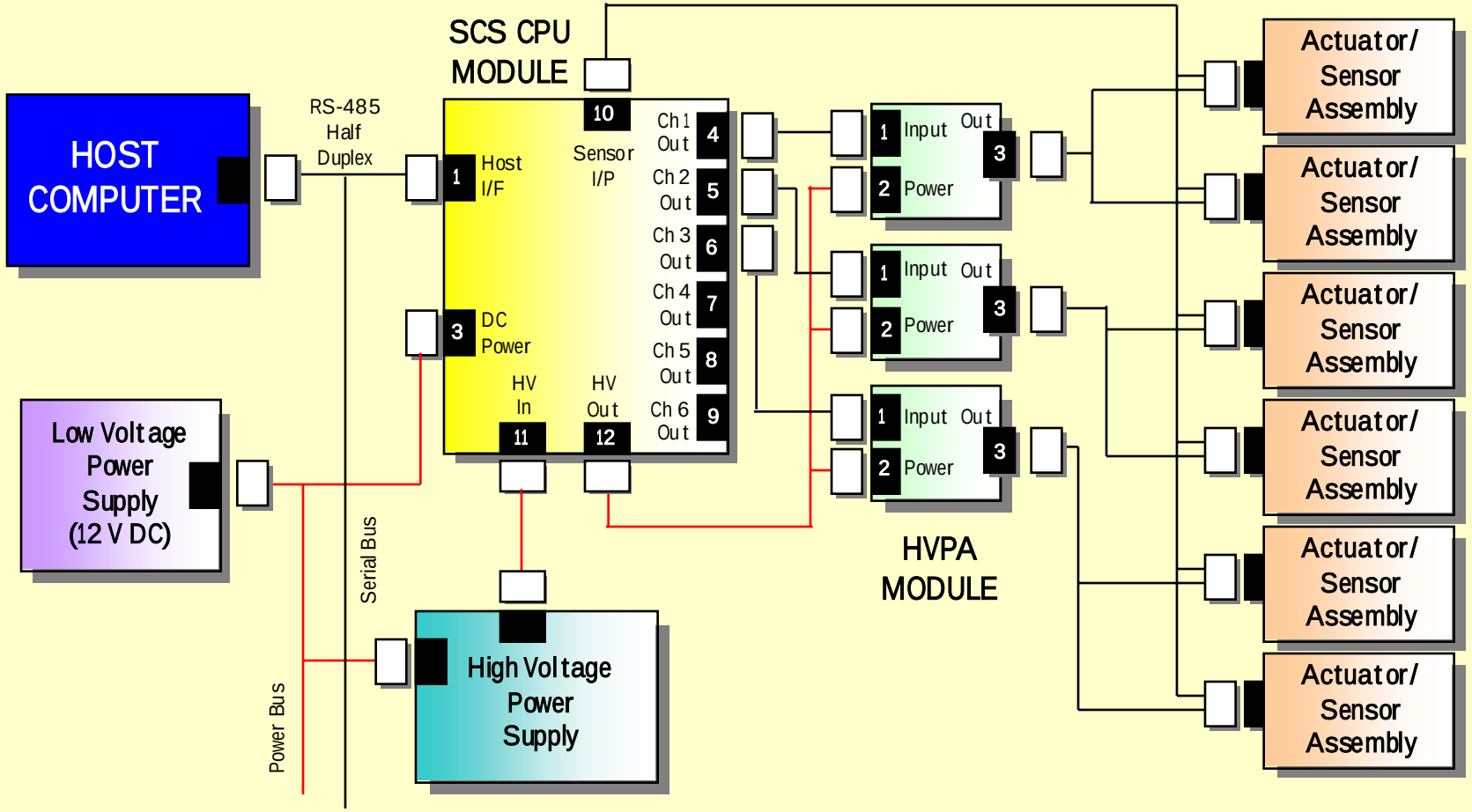
Piezo servomechanism control
Smart structure research
HV component characterization
Instrumentation

Features:

Interfaces to high-voltage amplifiers
Six output channels
Two analogue input channels
Built-in data acquisition system
RS-232/485 serial interface
Up to 31 modules on serial bus
PID control function built in

Smart Structures - Smart Control System

Smart Control System (SCS) - Functional Schematic



Smart Structures - Smart Control System

SS10 Four Channel Programmable Controller

techsupport@sensortech.ca

Application Sectors for Smart Structure Sub-Systems

SECTOR	APPLICATION	BENEFIT	Smart Structure Utilization		
			ASM	ASP	SCS
Aerospace	Health Monitoring	Damage Detection		●	
	Vibration Control	Life Cycle Management	●	●	●
	Shape Control	Fuel Savings		●	●
Defence	Shape Control	Firing Accuracy of Weapons	●	●	●
		Fuel Savings through Adaptive Wings, Rockets and Missiles		●	●
	Vibration Control	Quieter Submarines and Ships	●		●
		Life Cycle Management		●	●
	Health Monitoring	Early Detection of Damage		●	
Automotive	Noise Control	Passenger Comfort (Cabin)		●	●
	Vibration Control	Engine Life Cycle Management	●		●
	Health Monitoring	Damage Detection (Early Warning)		●	

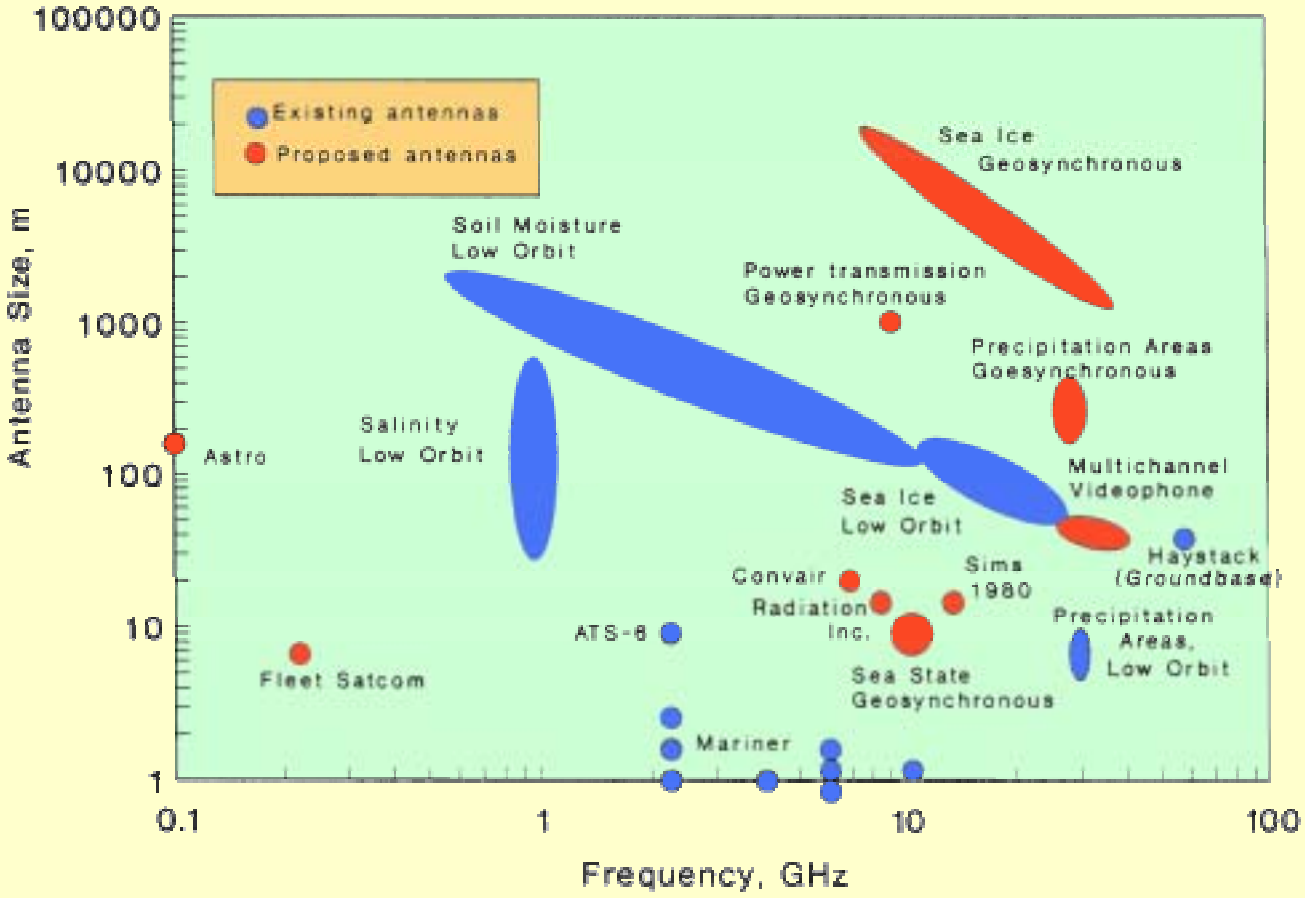
Application Sectors for Smart Structure Sub-Systems

SECTOR	APPLICATION	BENEFIT	Smart Structure Utilization		
			ASM	ASP	SCS
Industrial	Vibration Control	Machine Tool Chatter Control	●		●
		Foundation Isolation	●		●
		Operator Comfort in Heavy Machinery	●		●
	Noise Control	Airconditioning, Ventilation		●	●
		Exhaust Systems		●	●
Medical	Health Monitoring	Early Warning Systems (Preventive-medicine)		●	
	Shape Control	Surgical Micro-Robots		●	●
		Surgical Tools	●		●
Civil	Vibration Control	Protection of Bridges	●		●
		Earthquake Protection	●		●
	Health Monitoring	Bridges		●	

Typical Applications for Space Technology

- Antennas
  - lightweight and deployable antennas required
  - sufficient aperture area and accuracy required in order to accomplish mission goals
  - communication antenna and reflector performance require phased arrays for wide parabolic dishes which can maintain their shape to a high degree of accuracy

Antenna requirements



Space Environment Effects

- Vacuum
  - Solar UV degradation, contamination

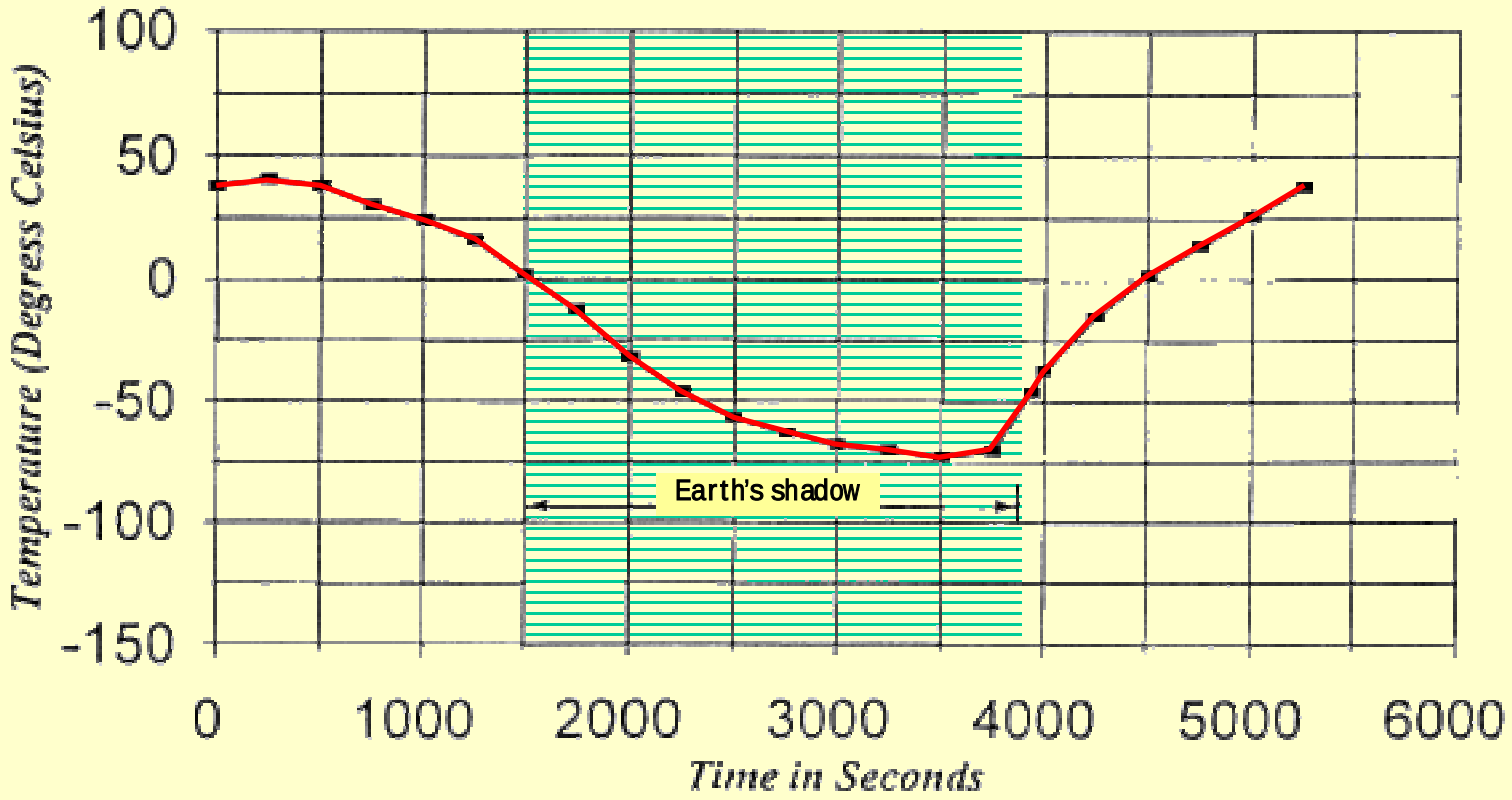
  Neutral

  - Mechanical effects
    - Aerodynamic drag, physical sputtering
  - Chemical effects
    - Atomic oxygen attack, spacecraft glow
- Micrometeorid/Orbital debris
  - Hypervelocity impacts

Space Environment Effects

- Plasma
  - Spacecraft charging
    - Shift in ground potential
  - Electrostatic discharging
    - Dielectric breakdown
    - Gaseous arc discharge
  - Enhanced sputtering
    - re-attraction of contamination
- Radiation
  - Total dose effects
    - Solar cell degradation
    - Sensor degradation
    - Electronics degradation
  - Single event effects
    - Upsets, latchup, etc.

Thermal Cycling in a Space Antenna

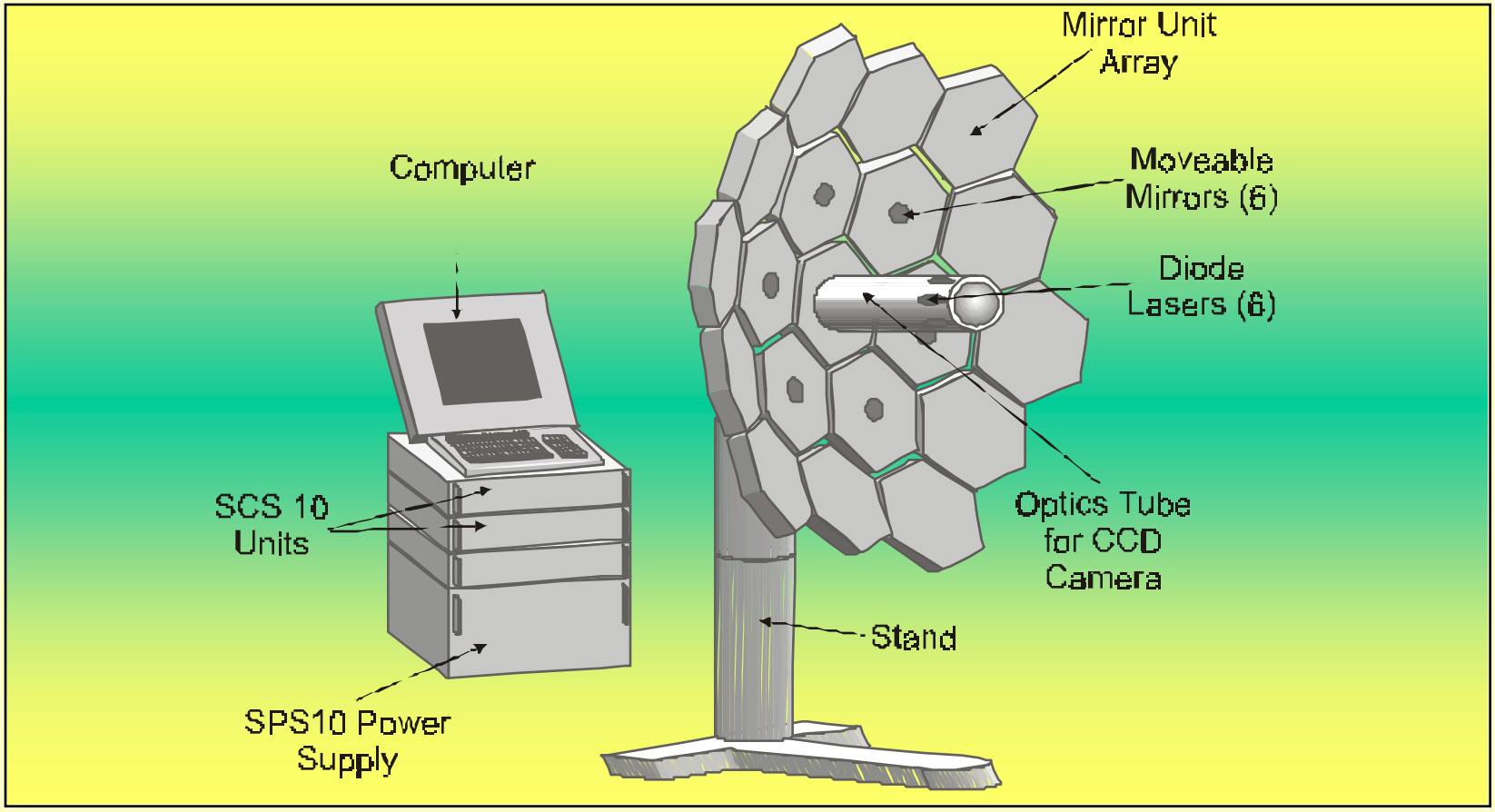


Definition

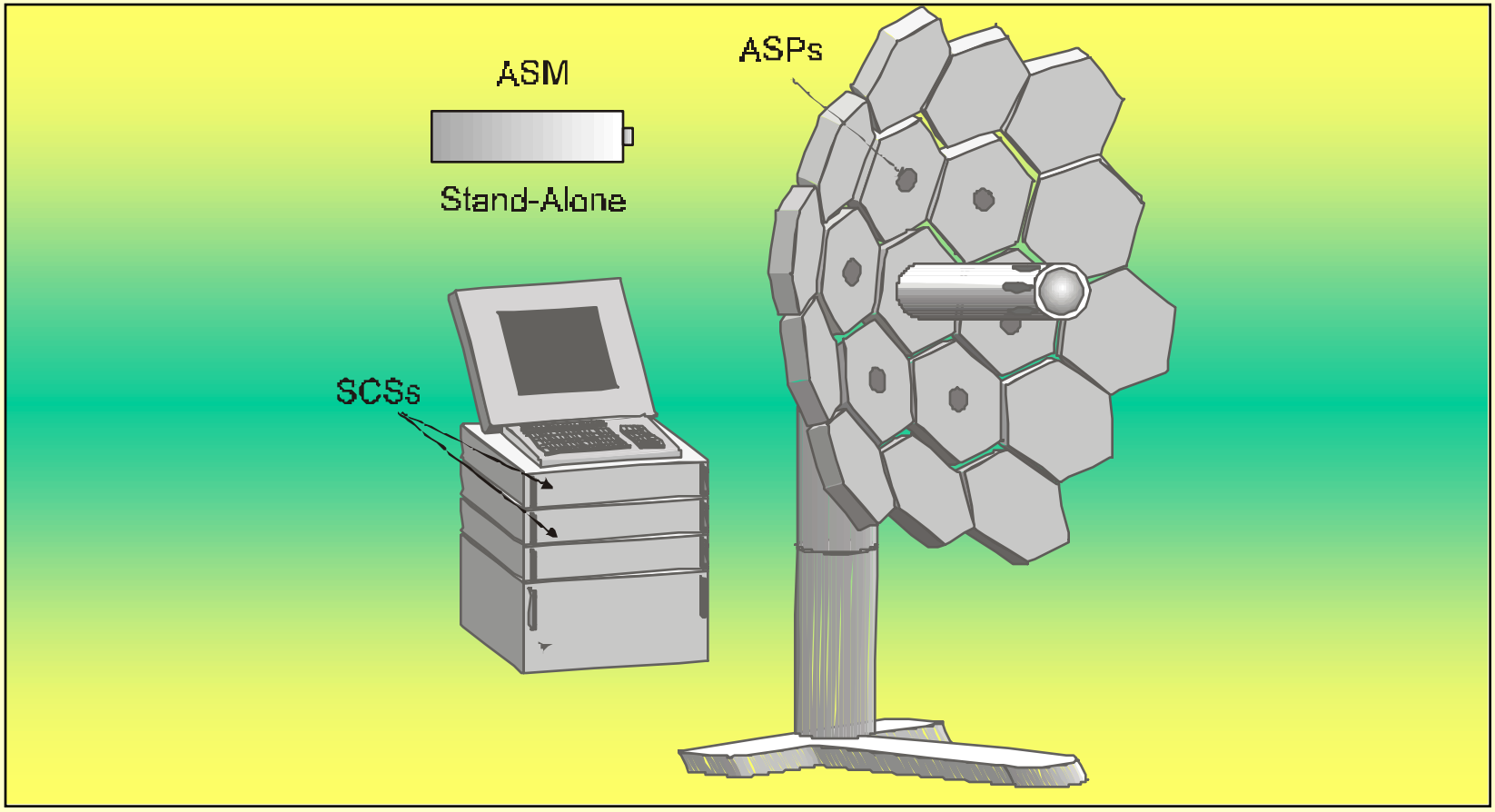
SHAPECONS: Spatial High Accuracy Position Encoding and Control System

SHAPECONS is a Smart Structure demonstration system that emulates a large parabolic reflector. The system incorporates smart structure components that were developed for the Canadian Space Agency under a research program.

System Overview

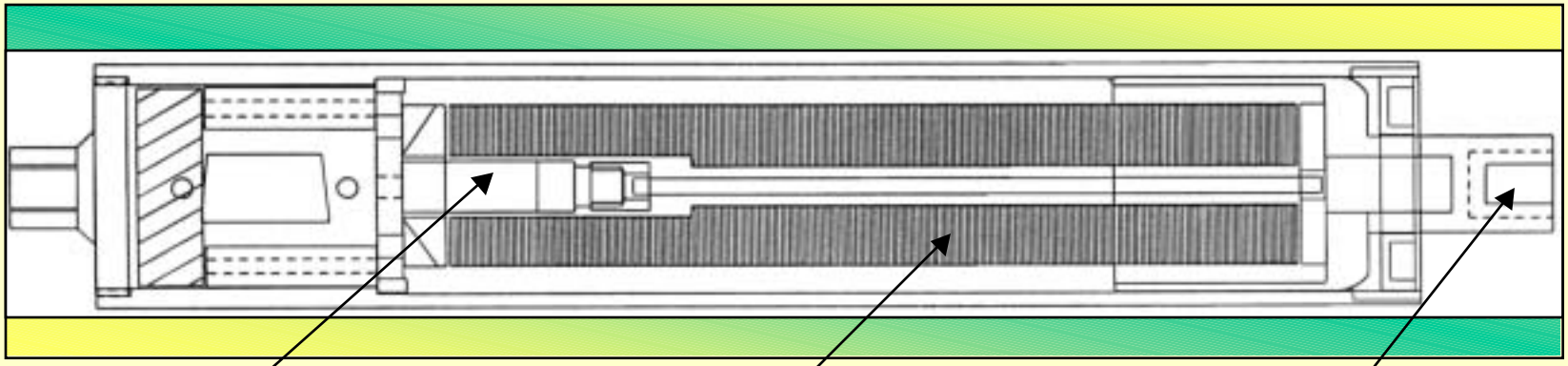


Smart Structure Integration



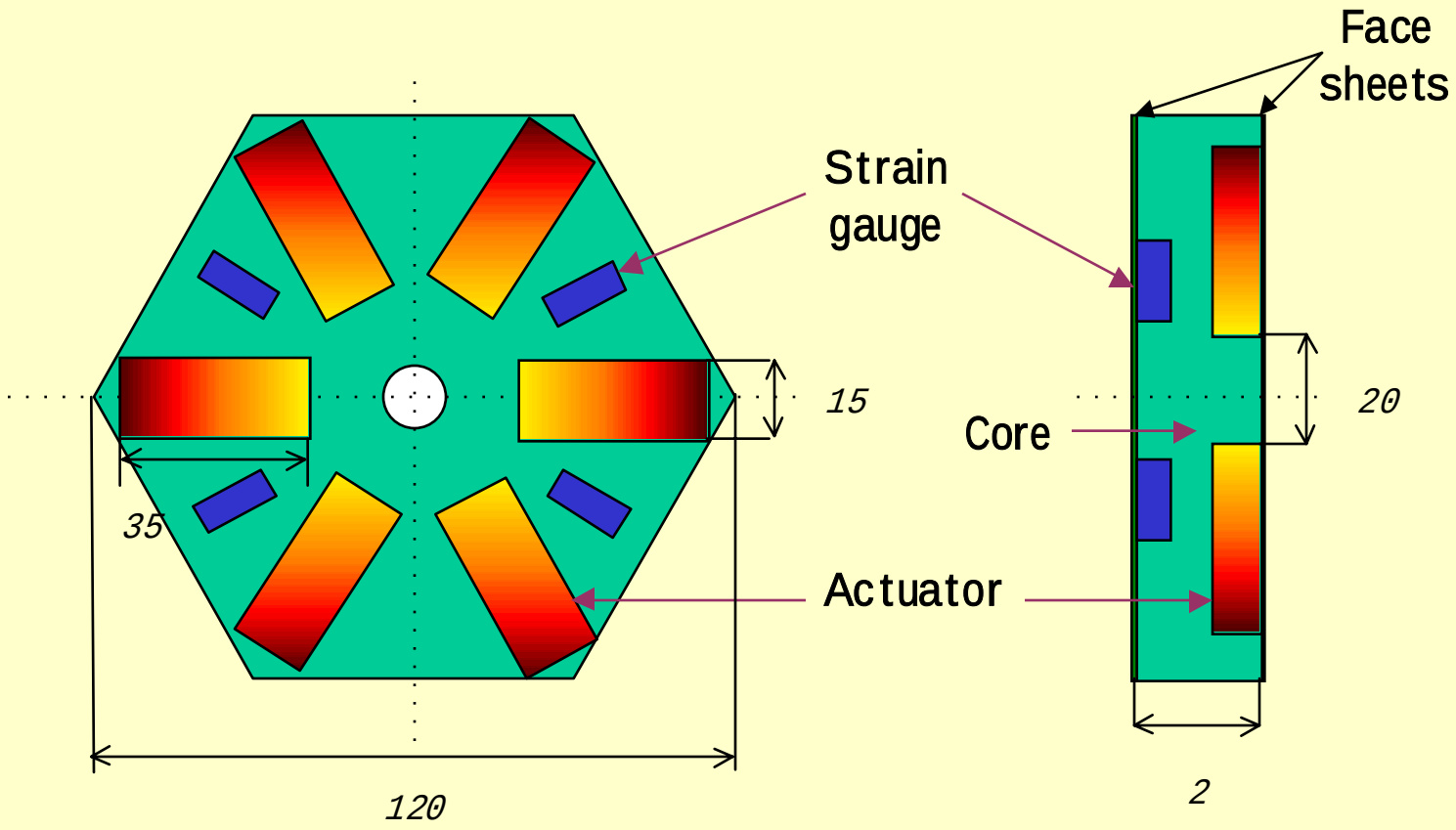
SHAPECONS System

Smart Strut Member (SSM)



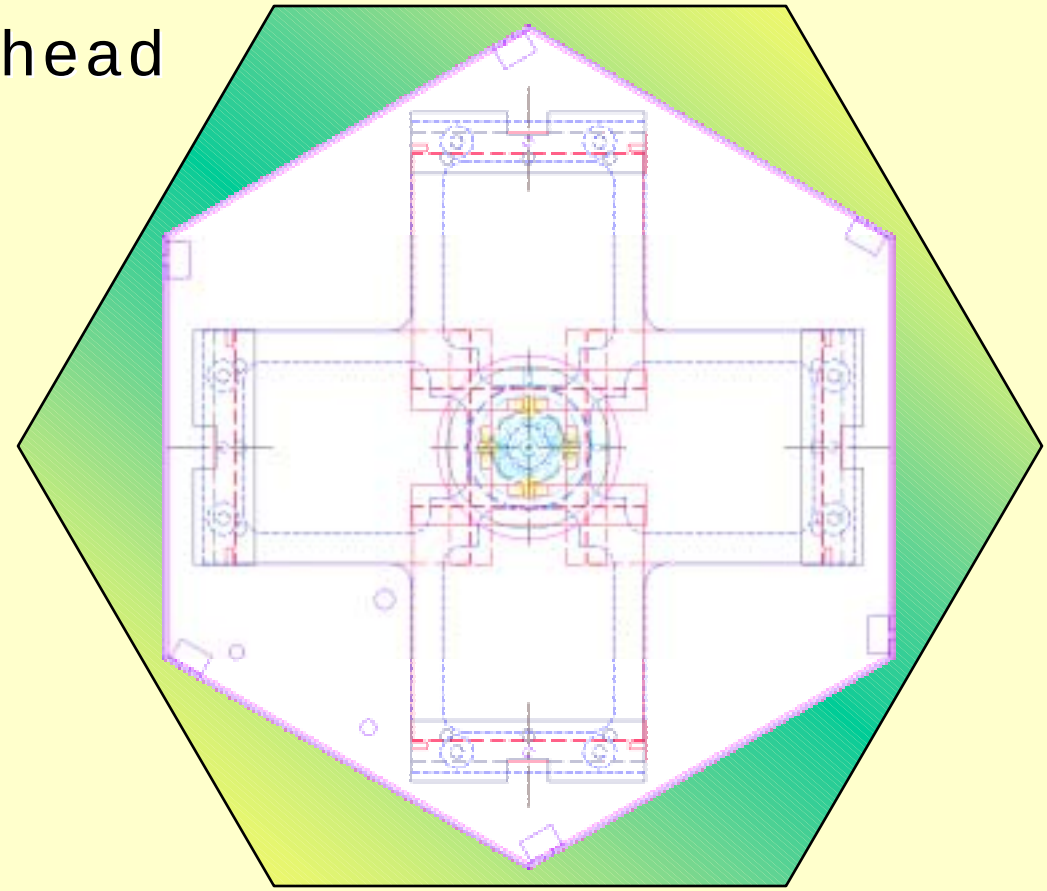
SSM Cutaway Drawing

Smart Structural Panel



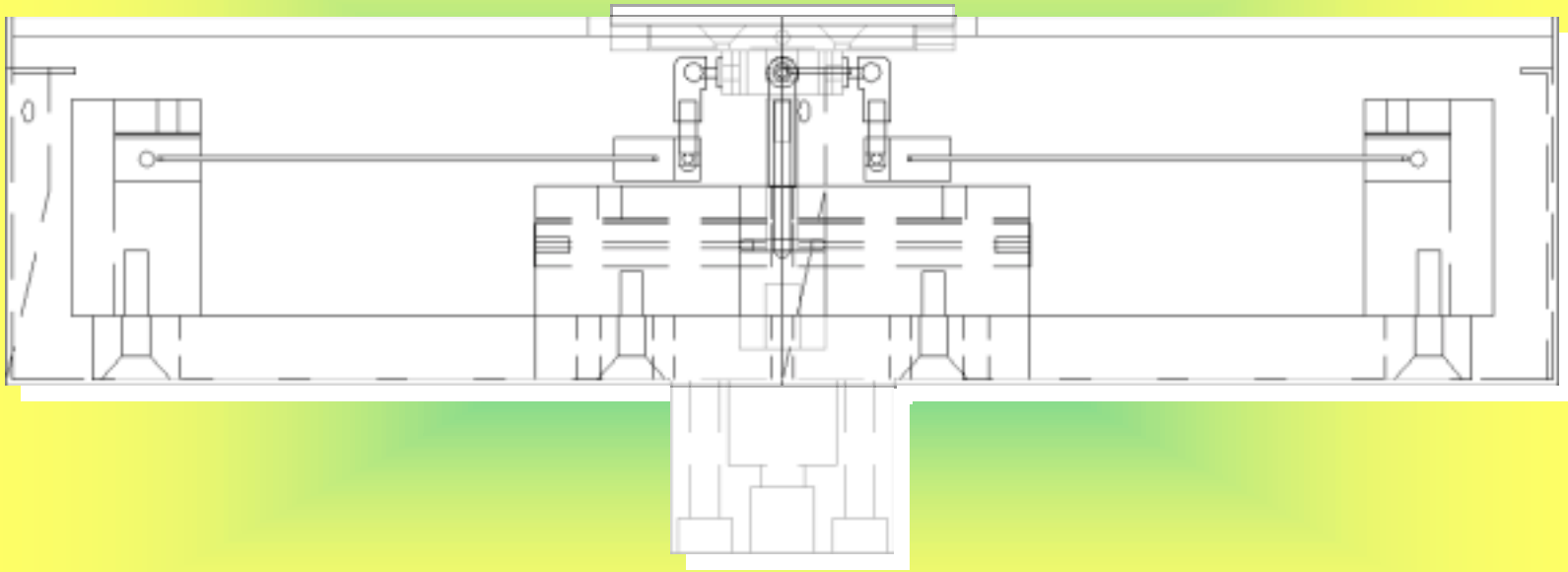
Mirror Control Unit (MCU)

Overhead

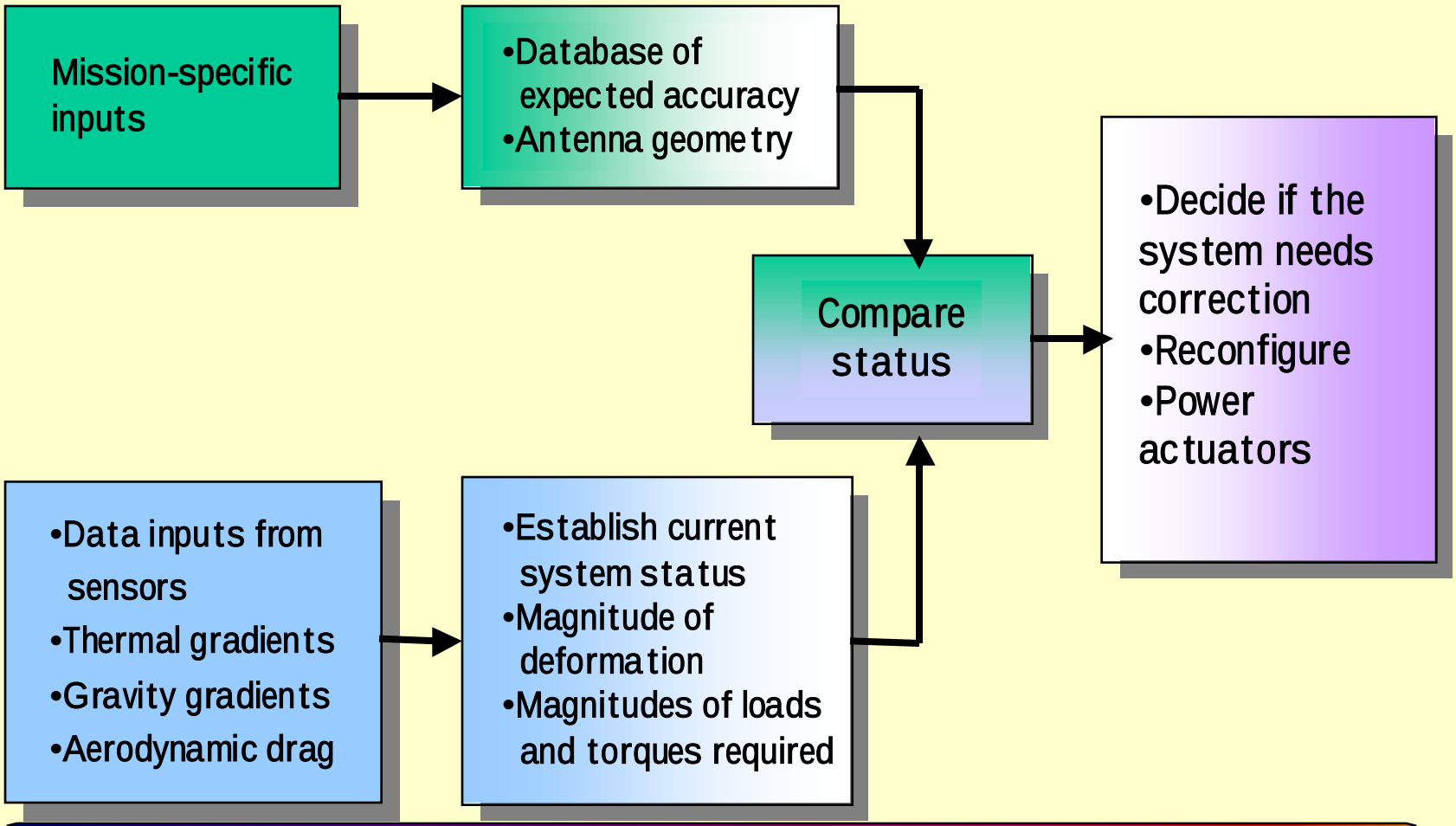


Mirror Control Unit (MCU)

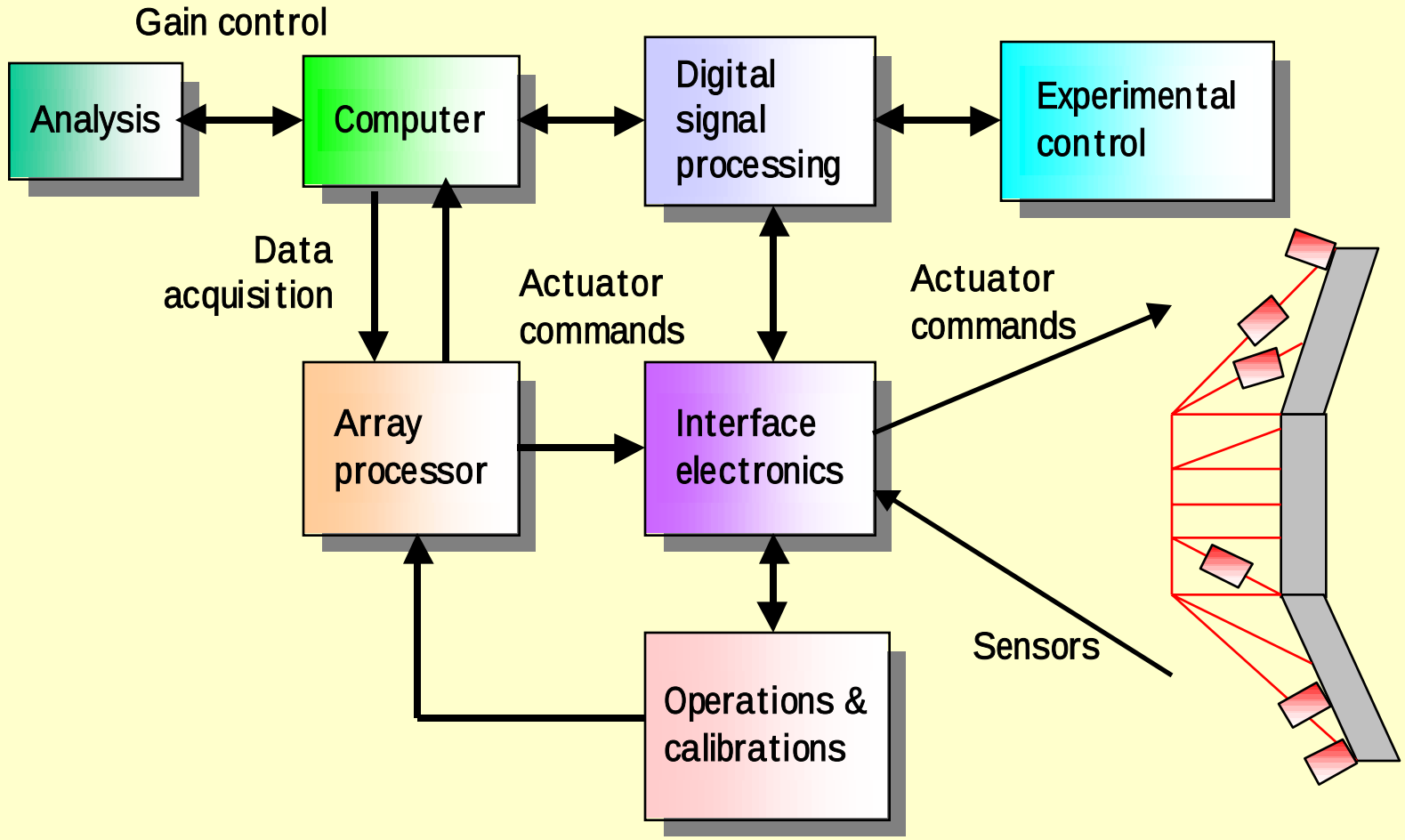
Cross-section



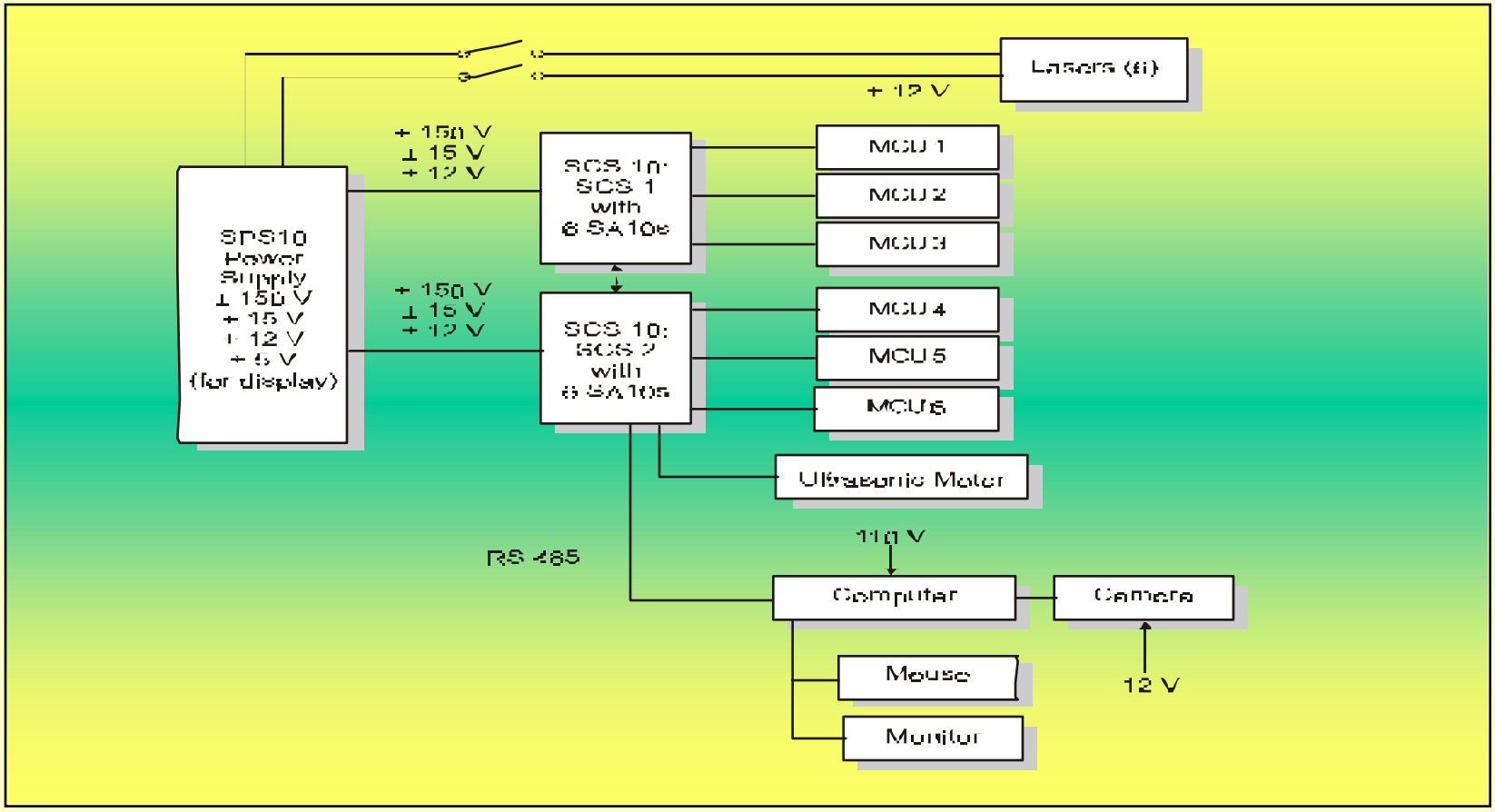
Functional Flow Diagram



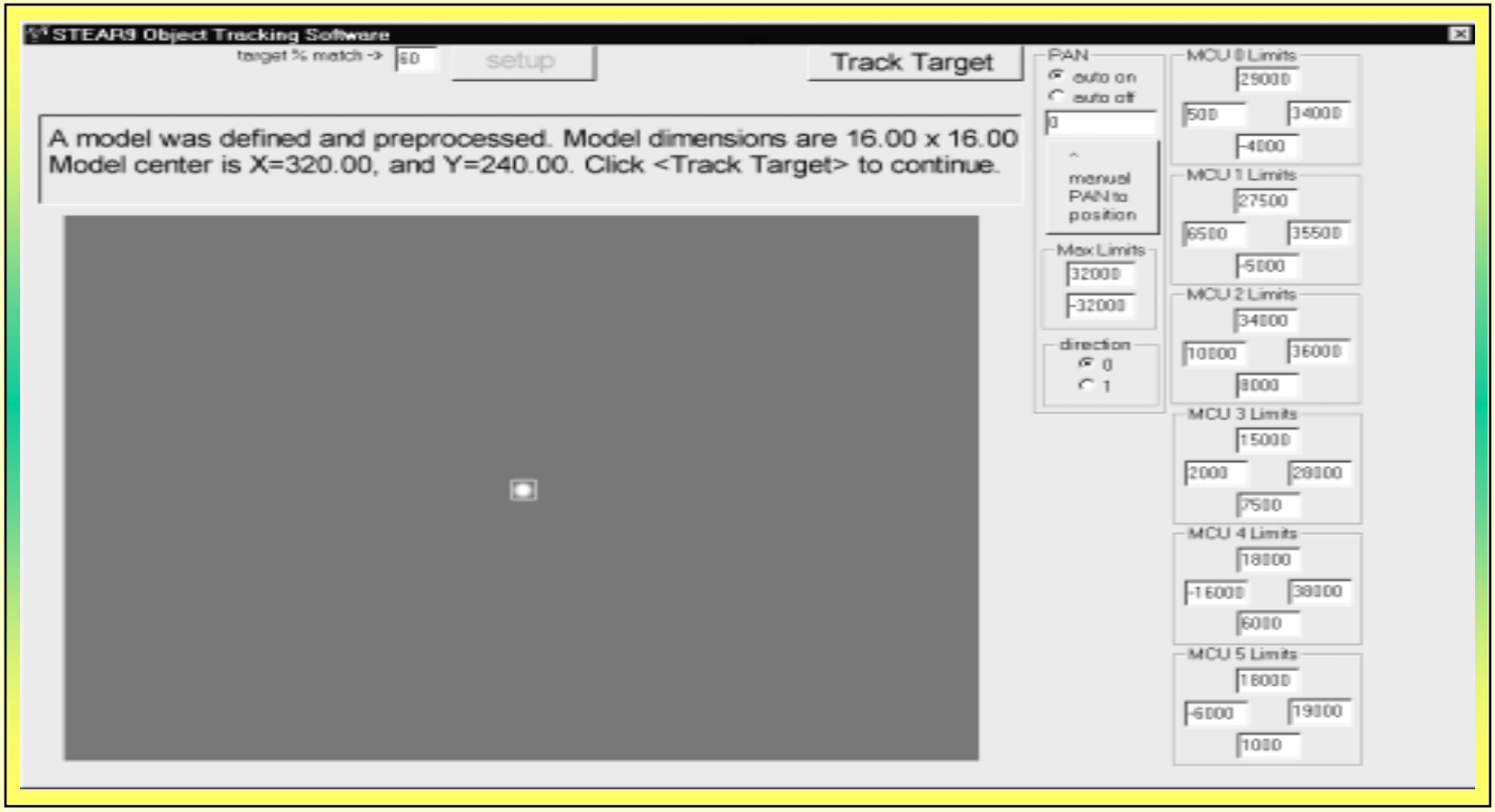
Functional Flow Diagram



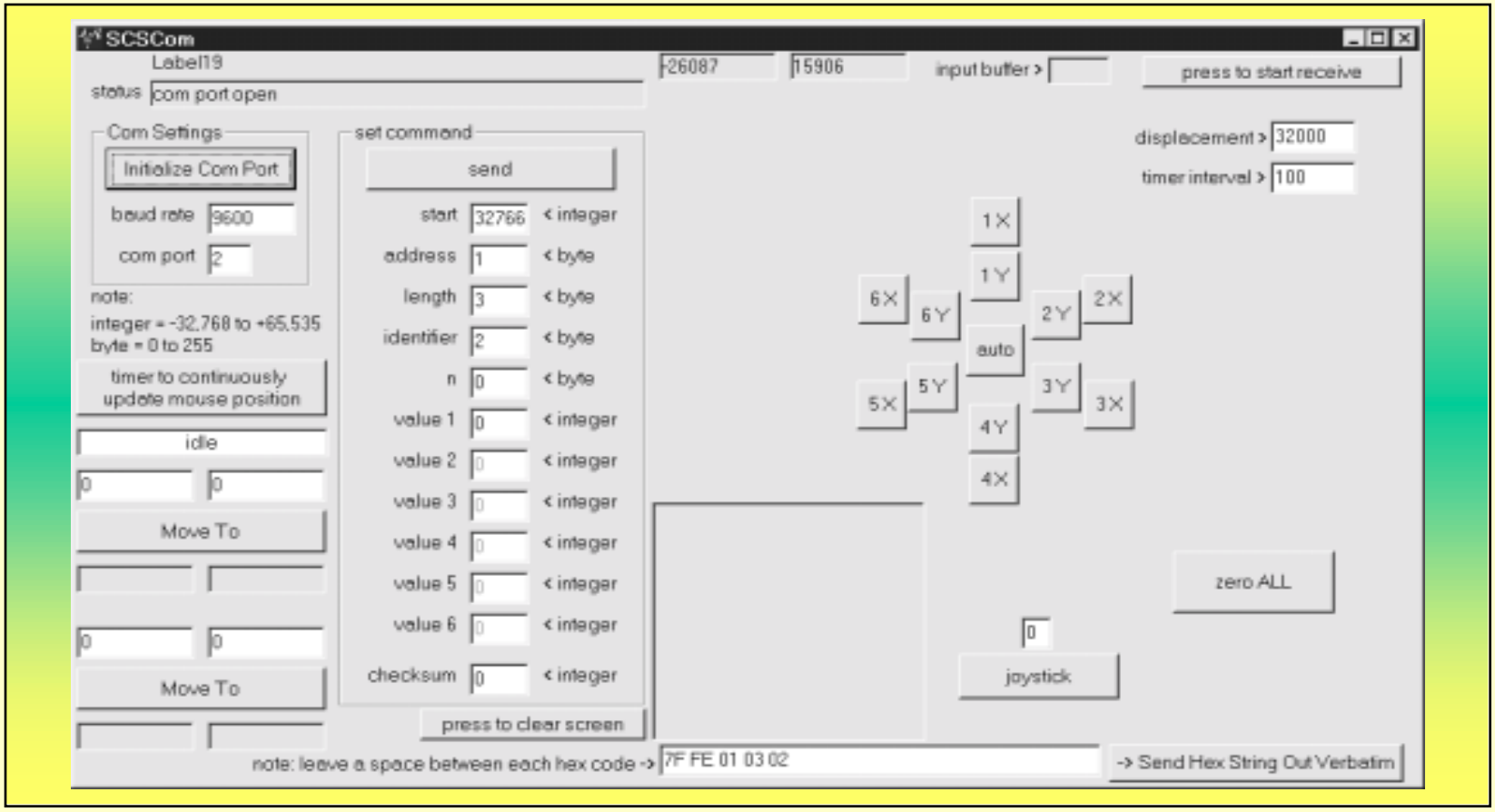
SHAPECONS Block Diagram



STEAR Tracking

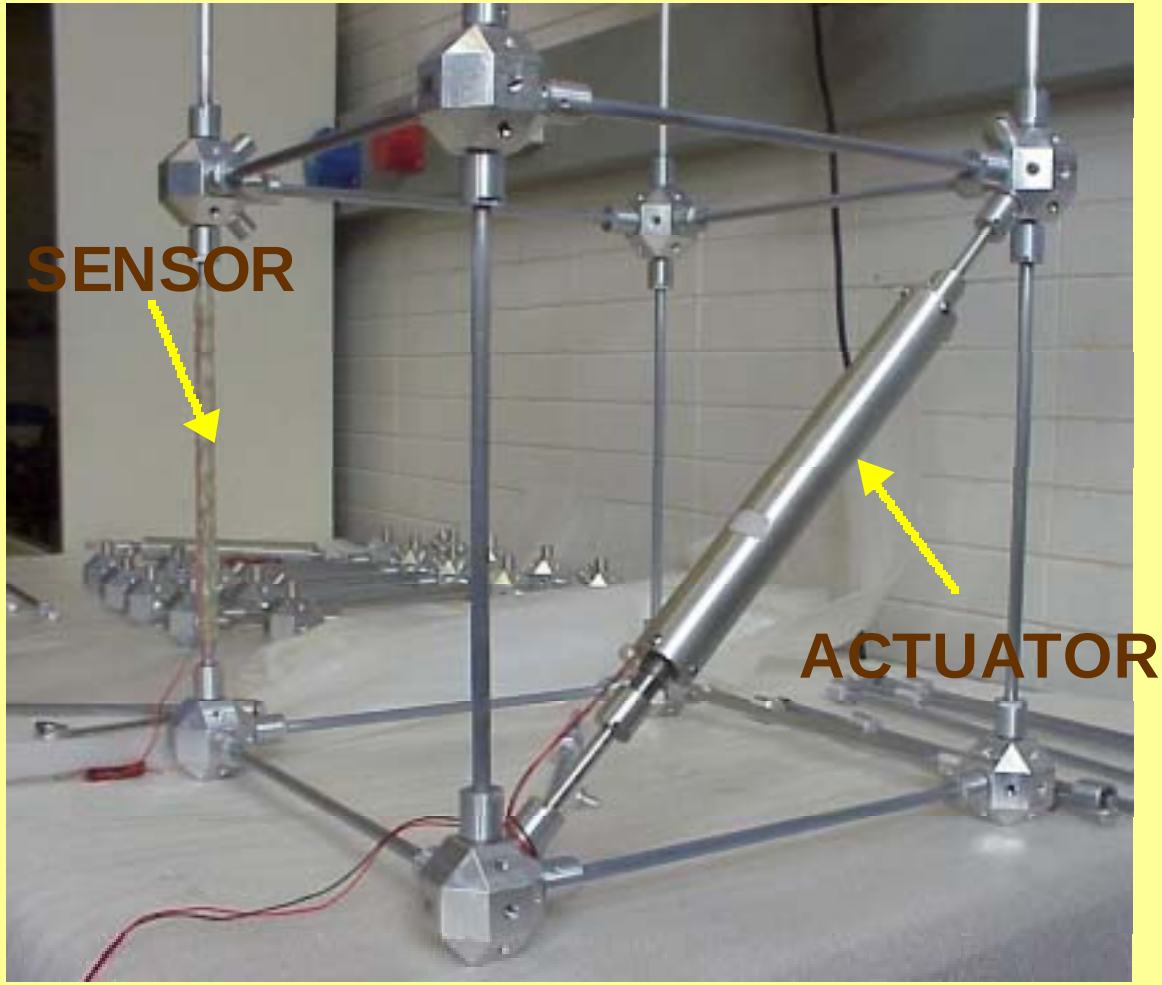


SCSCom Screen

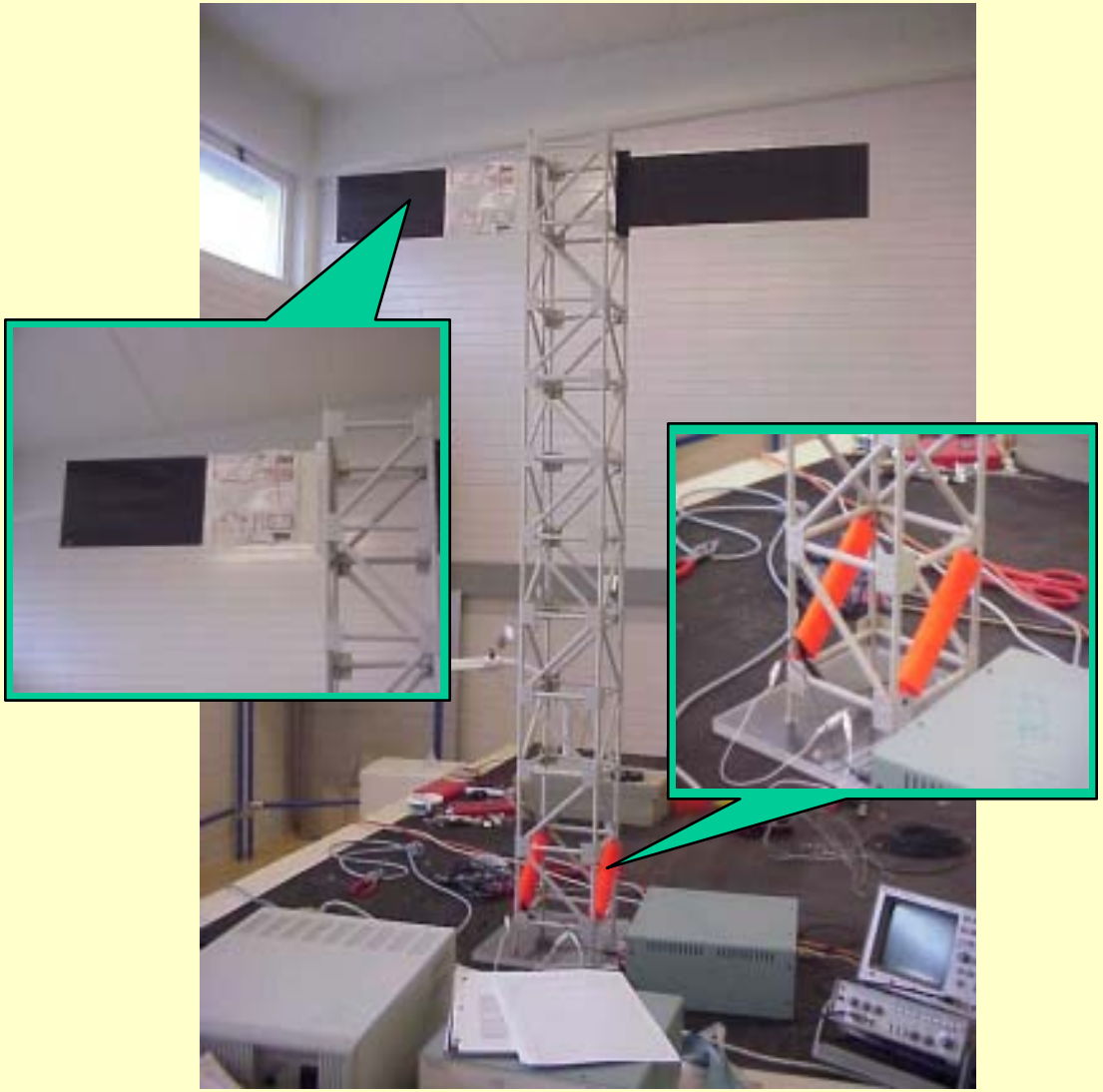


Application II: Adaptive Truss

Demonstrator



ADAPTIVE STRUCTURES

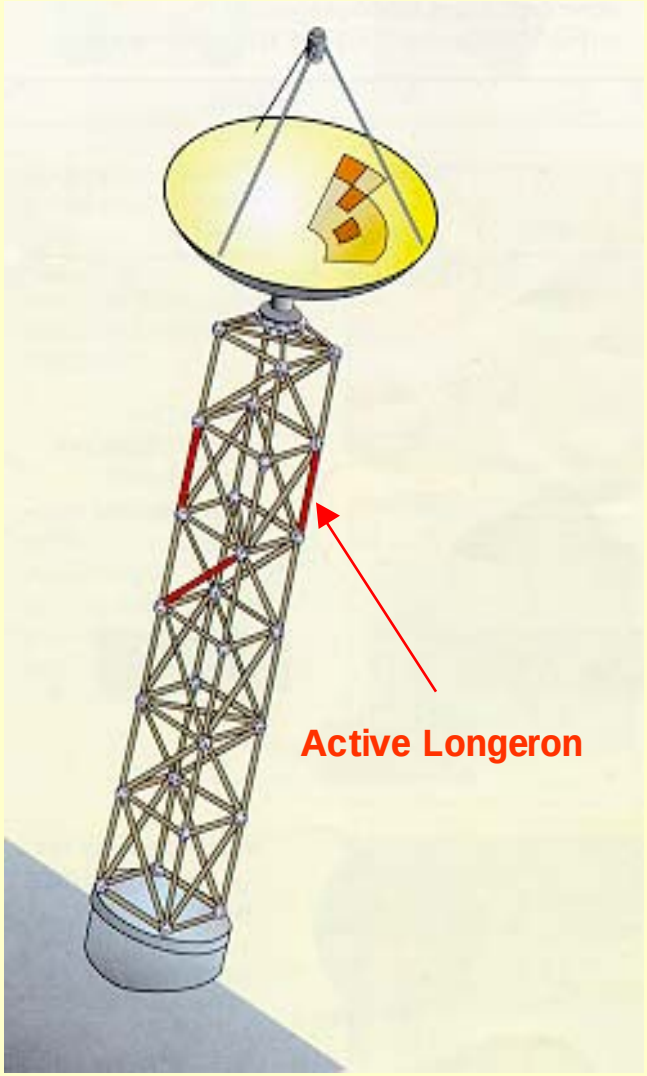


Space Station Test article

ADAPTIVE STRUCTURES

Active Longeron:
-PZT sensor and actuator stack.

Application:
-Shape and vibration control,
-Noise reduction.



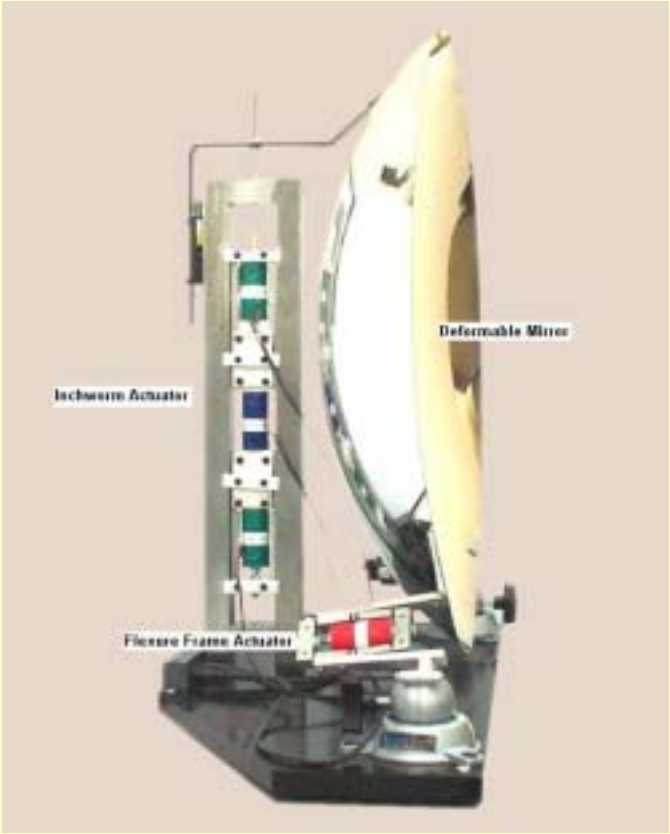
Deformable Mirror

Canadian Space Agency & Sensor Technology Limited, 1998

Deformable Mirror

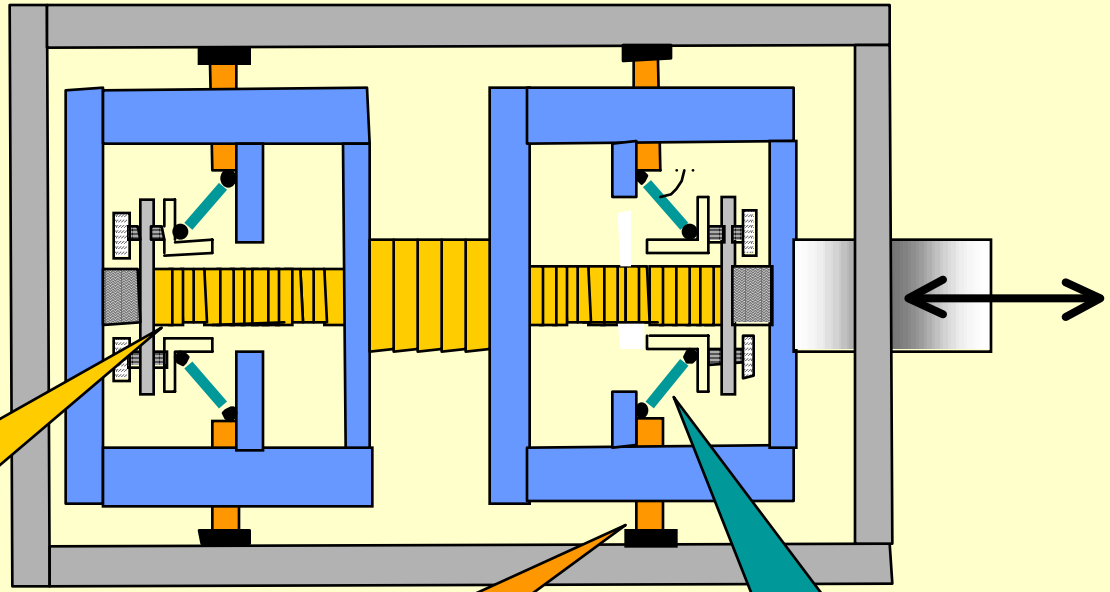
Canadian Space Agency & Sensor Technology Limited, 1998.

Deformable Mirror



Multi-line
Laser Source

Inch Worm Actuator



Piezoelectric Stack

- Actuation Force
- Size

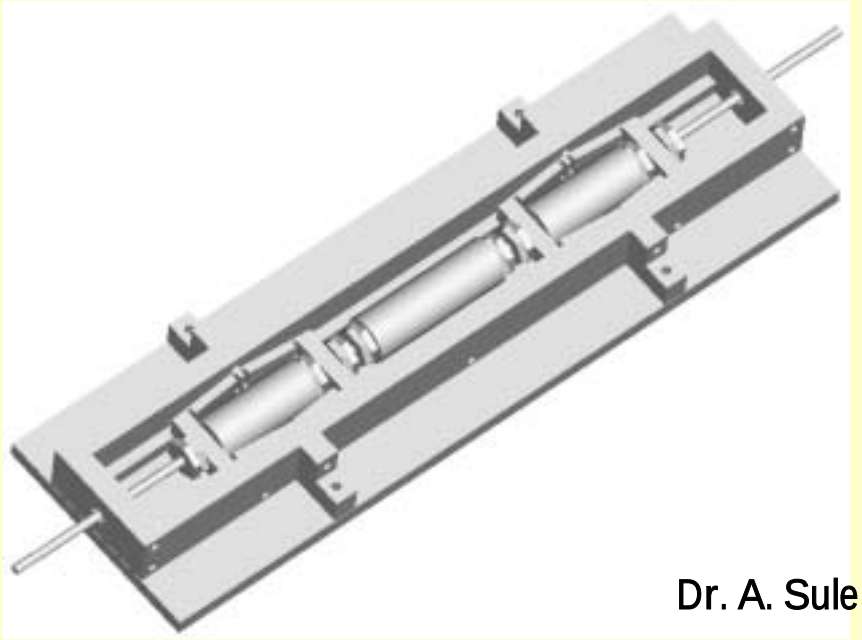
Brake Pads

- Actuation Sequence
- Friction Parameters
- Contact Dynamics

Moment Arm

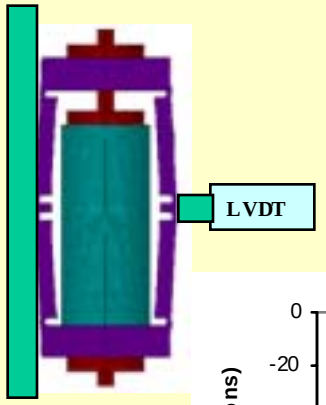
- Size
- Material
- Geometry

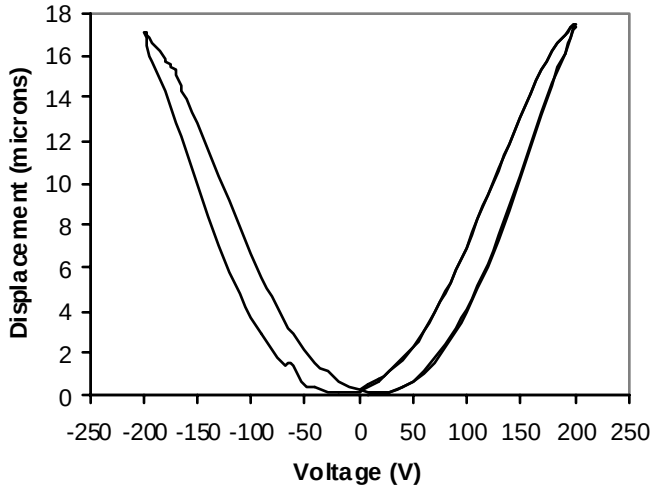
Inch Worm Actuator

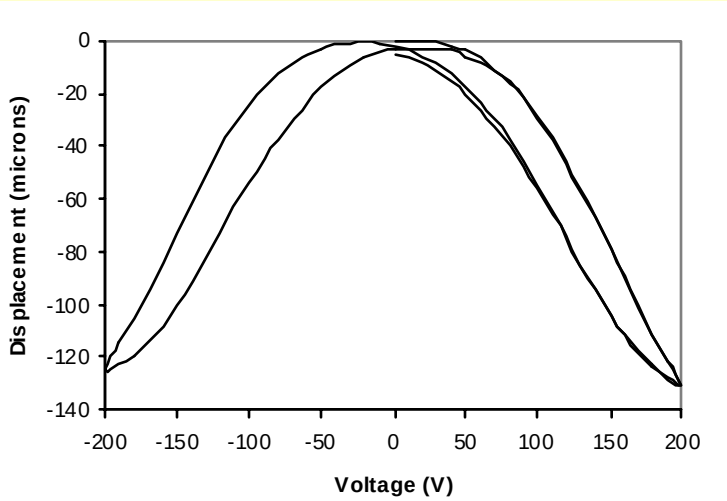


Dr. A. Suleman, University of Victoria, January 2002

Inch Worm Actuator







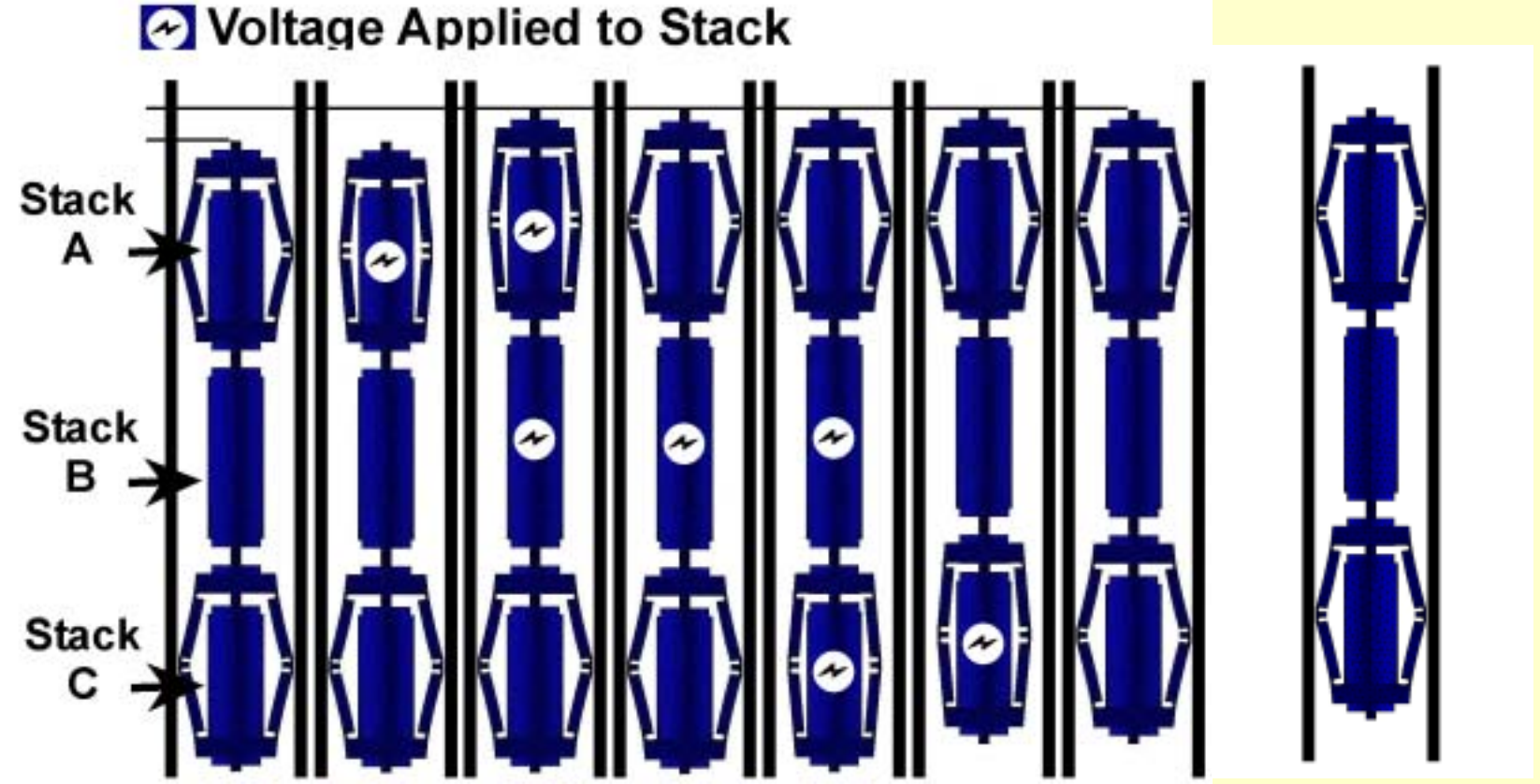
Gain = 7.5

Inch Worm Actuator

- Size

Dr. A. Suleman, University of Victoria, January 2002

Inch Worm Actuator Firing Sequence



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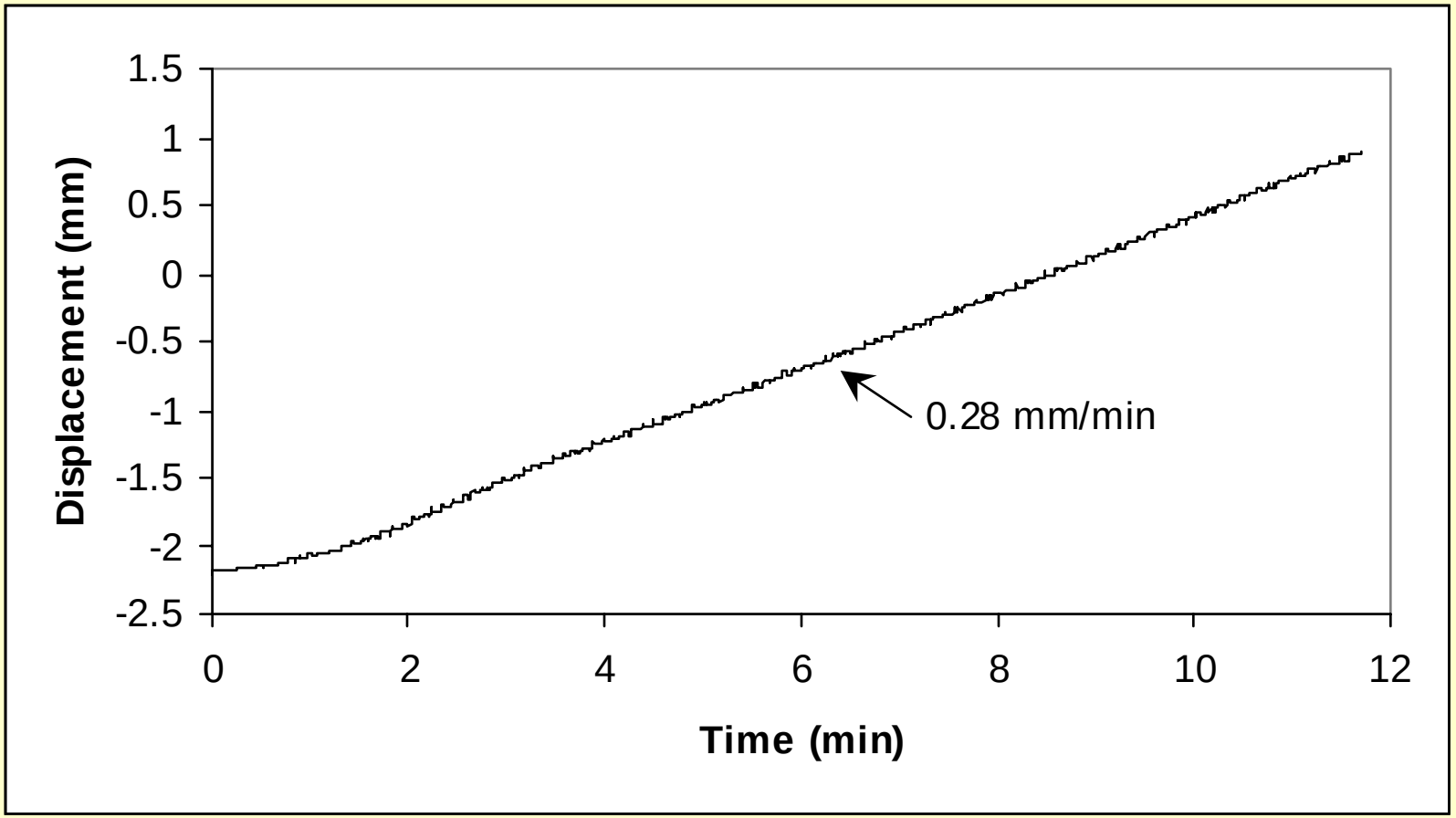
Inch Worm Actuator



- Size

Conclusions

- Smart Structure applications have been reviewed
- Some emerging themes in smart structure research are presented.
- Three generic sub-systems are described.
- Application examples are presented.