Design Project: IR Emitter Mount and Steering Module

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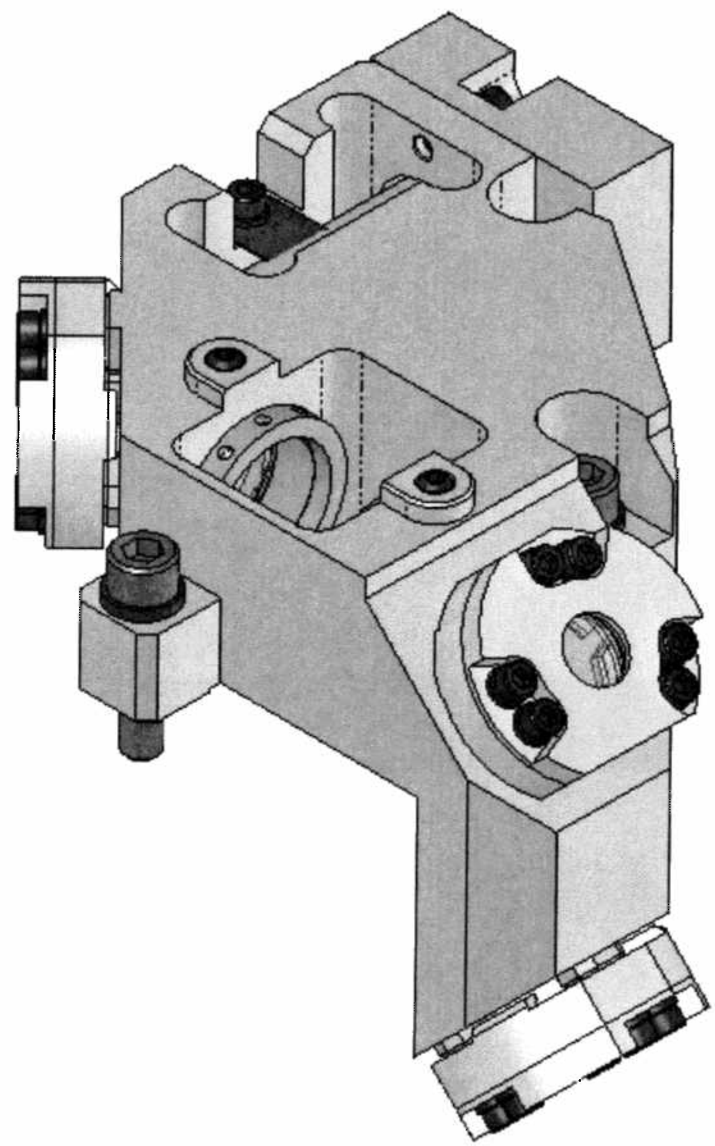
OPTI 523
May 16, 2009



Project Description:

An infrared (IR) emitter produces a 2 mm collimated beam that will be used to as a boresight reference for a primary laser beam. A mount will be designed that initially aligns the IR light to the primary laser beam within 75 μrad. In addition, the IR beam must be maintain boresight with the primary laser beam over a large operating temperature range (-40 to 80C), a moderate vibration profile, and a 20 G shock. The module will be designed as a drop-in module that can be easily installed to an existing laser system. No maintenance can be allowed so locking features on any adjustment are required.

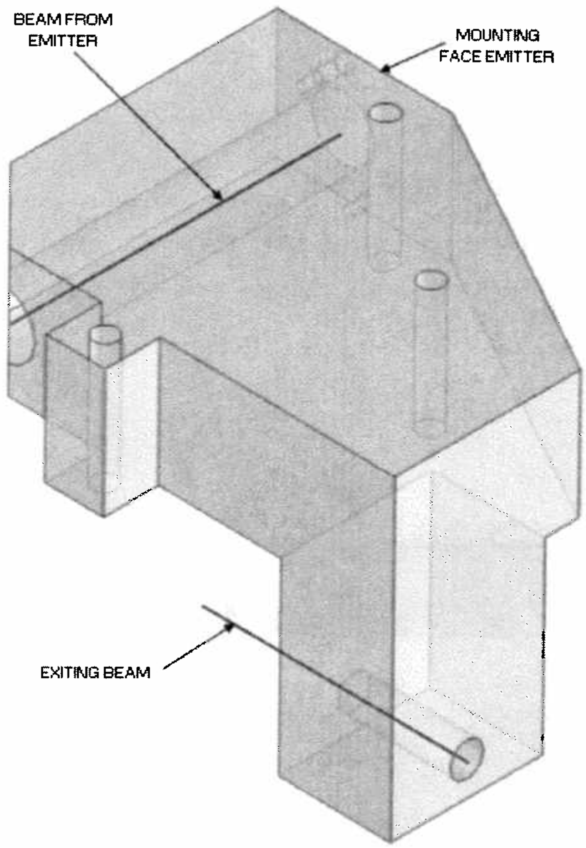


Figure 1: IR steering module

ICD:

The design of the laser system is such that the IR module must "drop-in" to features machined into the existing laser bench. As many of the laser components have already been designed, the volume allocated for the IR source is very small (See Appendix G).

In addition, the light source has already been designed. A simplified model of the emitter has been modeled and the Steering Module will provide mounting features and clearance for the emitter (See Appendix G).

The laser bench interfaces have not been permanently defined and there may be some flexibility. For now assume a flat plate made from Aluminum 6061-T6. The volume requirement for this system will be one of the most challenging specifications to meet.

Optical Requirements:

- Wavelength – MWIR (3 – 8 μm)
- Beam Diameter – 2 mm
- Initial Alignment of primary Beam – 75 μrad
- Max alignment error in primary beam – 1.5 mrad
- Primary beam size 8 mm
- IR beam shall be contained within the nominal location of the 8 mm primary beam (beam decenter specification)
- Boresight Stability (Temperature, Vibration, Shock) – 25 μrad

Derived Requirements from Emitter Design:

- Reflectance for turn mirror > 90%
- Transmission for optical components >90% over 3 – 7 um
- Minimum clamping force of .1 lb on cylindrical portion of emitter

Environment:

- Operating Temperature -40 C to 80C
- Storage Temperature -60 to +80C
- Operational vibration in accordance with MIL 810F, Method 514.5, Category 13 and 14
- Module must survive 20 G shock load
- Maintain optical performance specifications given environmental conditions

Other:

- All material used must be low outgassing (>1% TML, >.1% CVCM)
- No maintainence will be allowed for life of system

Note:

The boresight error associated with the location and orientation of the emitter has already been taken into account at the system level specifications for the Steering Module. All specifications addressing the initial alignment and boresight stability of the Steering Module are intended for the position and orientation of all three turn mirrors and the two steering wedges. All models and pictures of the emitter are strictly for volume allocation purposes. The design of the emitter will not be addressed in this report.

Design Concept:

The design of the IR Steering Module includes a monolithic aluminum bench that serves as the mounting platform for each optical component. The optical components of the emitter are pressed into a v-groove located in the optical bench with a stainless steel spring. The tolerances applied to the v-groove are driven by the design of the emitter and are not addressed in this report.

Due to the geometry provided in the ICD (See Appendix G), three mirrors are required to fold the beam to the exit beam location. The fused silica fold mirrors are housed in captive mirror mount assemblies that are assembled prior to their integration to the optical bench. When assembled to the optics bench, the fold mirrors interface to lapped surfaces in the optics bench.

The only adjustment in the system is provided by two Risley Prisms – referred to as steering wedges - located between the first and second mirrors. The decision to go with steering wedges rather than adjustable mirror mounts was a result of the large operational temperature range. A push-pull adjustment would not have provided a low boresight stability adjustment. The steering wedges correct the angular error cause by assembly tolerances found in the optics bench – the displacement is corrected by a second set of steering wedges within the laser. The optic for the steering wedge is made from Calcium Fluoride and is bonded into a 300 series stainless steel mount.

The Steering Module locates to two pins and three lapped surface on the laser bench. These features fully constrain the module and allow the module to be assembled off-line and dropped into the laser assembly. When assembled to the laser, a final adjustment is made and the steering wedges are locked by two set screws.

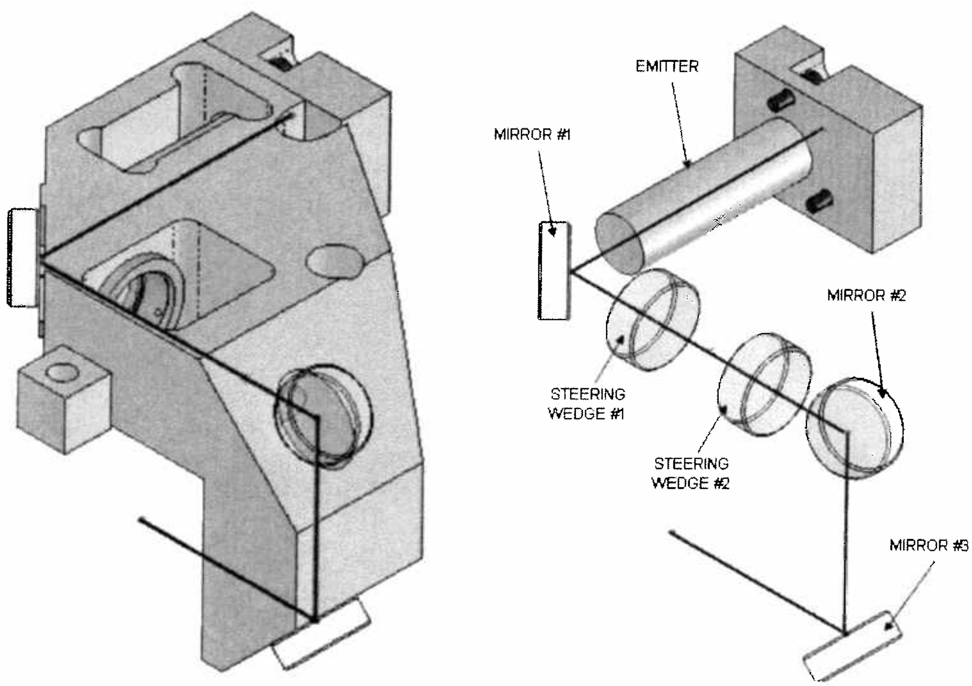


Figure 1: Preliminary design and optical layout

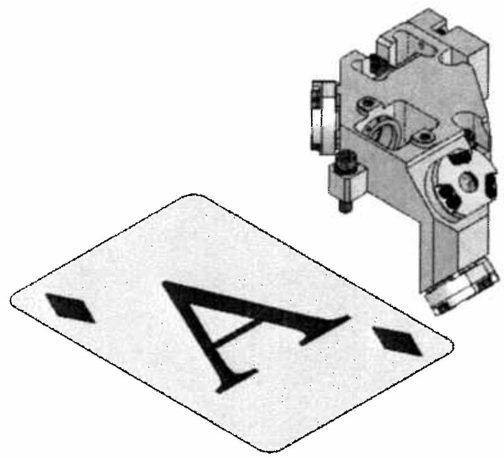


Figure 2: Steering Module next to regulation playing card

Design Details:

An exploded view of the mirror mount assembly can be seen in Figure 3. The mirror is loosely assembled inside the mirror mount and initially rests on the captive features on the mount. The wave spring is then places inside the bore of the compression plate and the three screws are tightened to the mount. At this point in the assembly, the optics is loaded against the captive features in the mount. These features have loose tolerances as the mirror will be located to the lapped pads on the optics bench at the next assembly. The spring exerts a force of three pounds on the back surface of the optic when assembled to the optics bench which is more than enough force to prevent the optic from coming off of the lapped pads given a 20 G shock load.

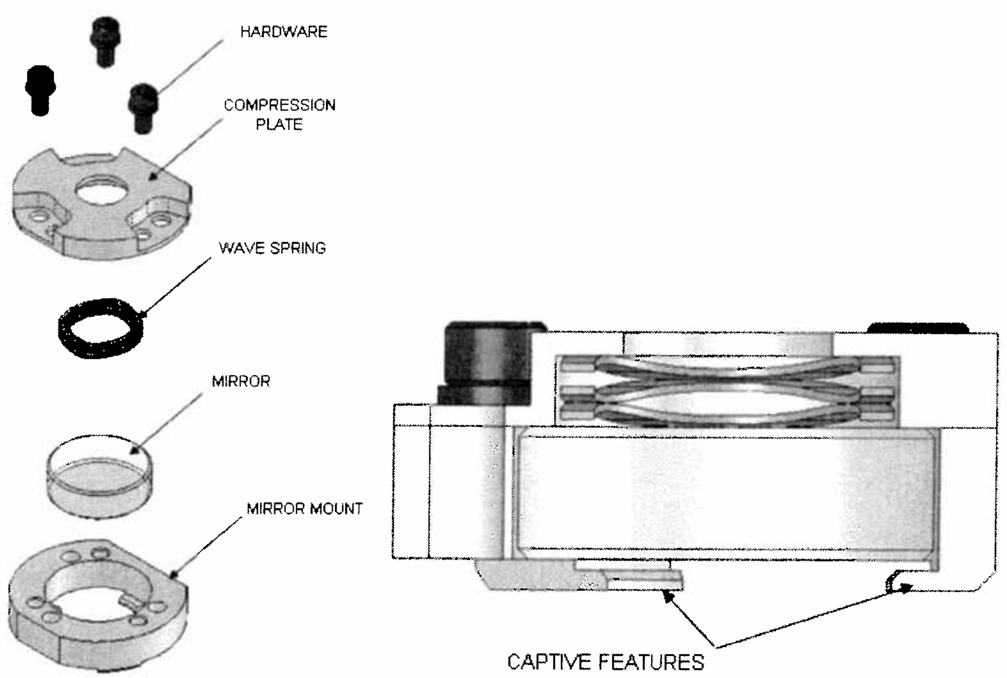


Figure 3: Exploded view and cross section of Mirror Mount Assembly

The Rotation Mount Components can be seen in Figure 4. As stated previously, the optic is made from Calcium Fluoride and is bonded into a 300 series stainless steel mount. Calcium Fluoride was chosen due to its high transmission and low dispersion over the 3 to 7 um range. The rotation mount is made from Stainless steel as its CTE is very close to that of Calcium Fluoride (15 ppm/°C for stainless steel and 19 ppm/°C for Calcium Fluoride).

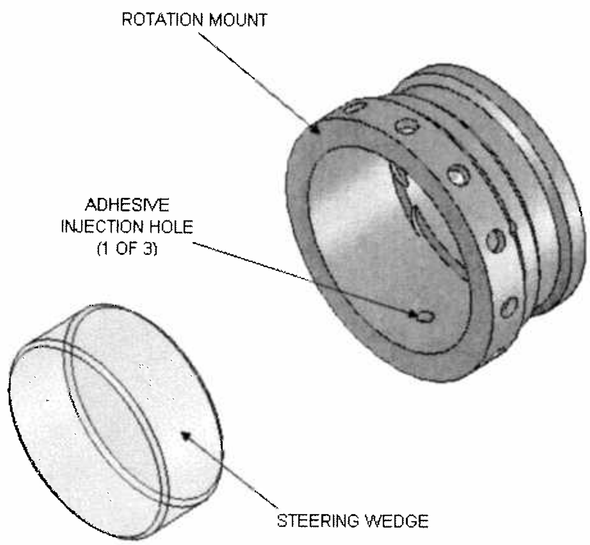


Figure 4: Exploded view of Rotation Mount Assembly

The optic is located inside the mount to three relatively flat pads. After the optic is placed against the pads, a force should be exerted on the optic to prevent the optic from moving while a small amount of Mil-Bond adhesive bonds the optic to the mount. The assembly should then be taken to the 71°C to cure for 3 hours (manufacturer recommendation, see Appendix C).

Fabrication Plan:

The fabrication plan for the Steering Module Assy is as follows:

- Prepare Mil-Bond adhesive per manurfacturer specifications
- Load Mil-Bond into pressure regulated dispenser (suggest use of EFD 2400)
- Bond steering wedge into rotation mount
- Cure rotation mount assembly at 71°C for 3 hours
- Assemble mirror assembly
- Assemble one rotation mount at a time into the optics bench
- Hand tighten set screw to prevent rotation mount from falling out
- Assemble mirror mount assemblies to optics bench – torque screws to 3.5 in-oz
- Locate emitter cylindrical component to the v-groove in optics bench
- Tighten screw on spring to load cylindrical portion of emitter to bench
- Torque screws at back-end of emitter to the optics bench to 3.5 in-oz

- Assemble Steering Module to Pre-Alignment tool – torque #4-40 screws to 39 in-oz (See Figure 6 for conceptual design of Pre-Alignment tool)
- Rotate steering assembly until beam passes through each aperture in Pre-Alignment tool – torque set screws to 19 in-oz to lock adjustment
- Remove from Pre-Alignment tool and assemble to laser
- Make final adjustment when assembled to laser - torque set screws to 19 in-oz to lock adjustment

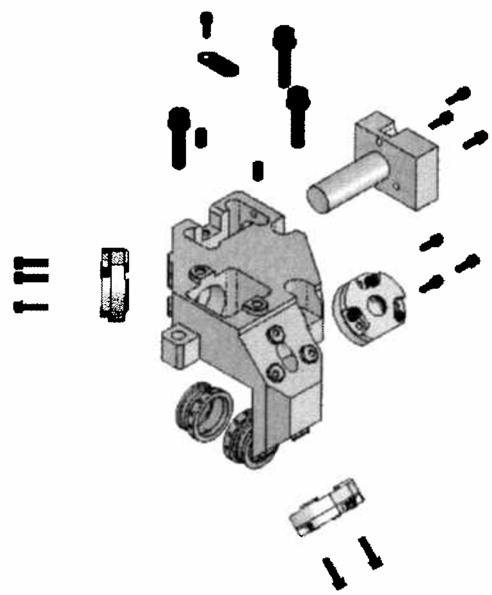


Figure 5: Exploded vies of assembly (see Drawing DP-01 for detailed assembly drawing)

As stated above, the assembly procedure requires a pre-alignment tool to prevent assembly issues internal to the design of the steering module from delaying the laser assembly. The tool will have the exact mounting features that exist in the laser bench (two pins, three lapped pads). Two pin holes (1 mm holes) separated by 10 inches will be placed along the nominal exit beam axis (see Figure 6).

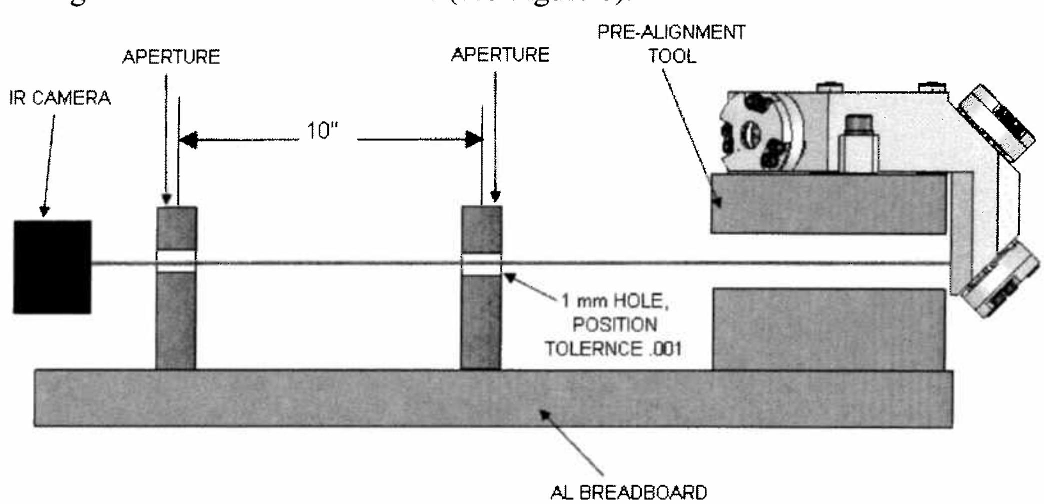


Figure 6: Pre-Alignment Tooling Concept

An IR camera (selected to the specifications of the emitter) will be located to the breadboard after the apertures. After the beam is aligned to the apertures, the apertures will be removed and the location and beam quality coming out of the steering module will be measured by the camera.

Analysis Summary:

Table 1 presents the requirements for the design of the Steering module and how each requirement is met. A brief description of each analysis follows.

Table 1: Requirement Matrix

Requirement	Value	How Requirement Is Met
Operating Wavelength	3-8 um	Emitter design
Beam Diameter	2 mm	Emitter design
Initial Alignment	75 urad	Tolerance Analysis (see Appendix D)
Decenter	±4 mm	Tolerance Analysis (see Appendix D)
Boresight Stability	25 urad	Error Budget, Thermal Analysis, Vibration Analysis
Turn Mirror Reflectance	>90%	Mirror Design (see Drawing DP-06)
Transmission	>90% (3um - 7um)	Steering Wedge Design (see DP-09, Appendix D)
Emitter Clamping Force	.1 lb	Spring Design (see Appendix A)
Operation Temperature Range	-40 to +80C	See Thermal Analysis
Storage Temperature	-60 to +80C	See Thermal Analysis
Vibration per MIL-STD 810F	see Appendix	See Vibration Analysis
Shock Survival	20 G	Spring Design (see Appendix A)

The two critical components to the design of the Steering Module include the wedge design (See Appendix D) and the boresight stability calculations (See Appendix E). Calcium Fluoride wedges were selected based on the optical requirements for transmission and a derived requirement from initial alignment and boresight stability - low dispersion over the wavelength range. Based on the tolerances that are selected for the optics bench, a 2 degree wedge was designed into the optics. This should provide a stable adjustment capable of correcting the mechanical tolerances machined into the bench. The calcium fluoride wedges (CTE = 19 ppm/°C) are going to be bonded into stainless steel mounts (CTE = 15 ppm/°C) at three equally spaced radial locations with Mil-Bond. Mil-Bond is a low outgassing, moderately compliant adhesive that will accommodate the small CTE mismatch. All thermally induced rotations or translations of the corrective wedges are negligible as the optics are insensitive to these small errors.

The boresight stability requirement is broken down to vibration and thermally induced boresight errors. The third component of the error budget has been allocated for small errors in the mounting of the mirrors to the machined surfaces of the optics bench. The tolerances of the mounting surfaces on the optics bench have tight tolerances applied to them, however, experience shows that there will be very small errors at the extremes of the operating and storage temperatures.

For the vibration induced boresight error a modal analysis has been performed on a finite element model (FEM) of the optics bench. The first mode is very high (≈5000 Hz) and is outside the frequency range of the random vibration spectrum. Deflections were measured from the FEM at the mounting locations for each mirror and rotation and translation error were calculated in a post processing spreadsheet. The acceleration levels are very low for random vibration and the first mode is very high resulting in very low levels of boresight error (> 2 μrad). All vibration induced rotations are below the allocated values.

The thermally induced boresight error is calculated in a similar manner. First, the temperature distributions are computed in a steady state thermal analysis. The temperature distributions are based on a 15 degree temperature difference between the laser bench and enclosure. The conductivity of the aluminum and the insulating air gap between the enclosure and the Steering Module resulted in a temperature gradient of less than 0.1°C. The temperature distribution is then applied to a structural static model with boundary conditions that simulate the mounting features of the optics bench. Rotation and translations are computed from the FEM and all calculations show that the design meets the system level requirements. See Appendices D and E for details.

Preliminary System Test Plan:

The preliminary system test plan will require a test fixture to be constructed with the same mounting features that will be present in the laser bench (two pins and three lapped surfaces). Ideally, the test fixture will also be the pre-alignment tool described in the fabrication plan. A single point diamond turned (SPDT) reference surface will be cut into the test fixture that will act as an initial alignment reference for all tests and alignment procedures. The Steering Module will be mounted to the test fixture and tested to the environments described in the specification. The test fixture will then be placed in a thermal chamber with a window. An autocollimator will be placed in front of the window of the thermal chamber to measure the difference in the pointing between the reference surface and the output of the steering module. This test can actively measure the boresight stability of the system.

The test fixture will have a bolt pattern that matches an existing fixture from a vibration table. The test fixture will be designed to have a natural frequency of above 2000 Hz when the Steering Module is assembled. Accelerometers will be placed on the Steering Module and the test fixture and a sine sweep will be the supplied input. From this test, the natural frequency of the Steering Module will be measured. If the natural frequency from the test matches (within 10%) the natural frequency from the analysis, the calculated vibration induced stability values will be accepted. The random vibration profile will also be applied to the test fixture and alignment measurements will be made before and after the vibe test.

The camera described in the fabrication plan will also be used to measure all optical performance characteristics (decenter, wavelength, alignment, diameter). If additional optics or hardware are needed to measure requirements for the system they will be selected as commercially off the shelf items.

Appendix A: Spring Analysis – Simple springs no FEA required

There are two spring in the Steering Module Design. The emitter spring clip is required to hold the cylindrical portion of the emitter to the v-groove cut in the optics bench. A flat spring has been designed based on the following criteria:

$$P_{MIN} = W f_s a_G$$

$$\Delta = (1 - \nu_M^2)(4PL^3)/(E_M b t^3 N)$$

$$S_B = 6PL/(bt^2 N)$$

The dimensions of the spring are presented in the following table:

b (in)	0.197
t (in)	0.005
L (in)	0.236

The spring is required to supply a force of 0.1 lb. The nominal deflection of the spring has been designed to be .015 inches. This deflection will vary due to the diameter tolerance of the cylindrical portion of the emitter (±.002", see DP-03) and the height tolerance for the spring land in the optics bench (±.003"). Table 2 presents the clamping force provided by the spring and the stress in the spring material given the deflection of the spring. The material of the spring is 17-4PH stainless steel which has a yield strength of 115ksi.

Table 2: Emitter spring parameters

Deflection (in)	Force (lb)	Stress (psi)
0.01	0.14	41300
0.015	0.22	62000
0.02	0.29	82700

The other spring in the system is the wave spring supplied by Smalley (see Appendix B). All parameters are given by Smalley and the mirror mount has been designed to accommodate the spring at the manufacturer suggested working height. The load required to prevent the optic from coming off of the lapped pads during a 20 G shock load is .024 lbs and the load provided by the spring 3 lbs.

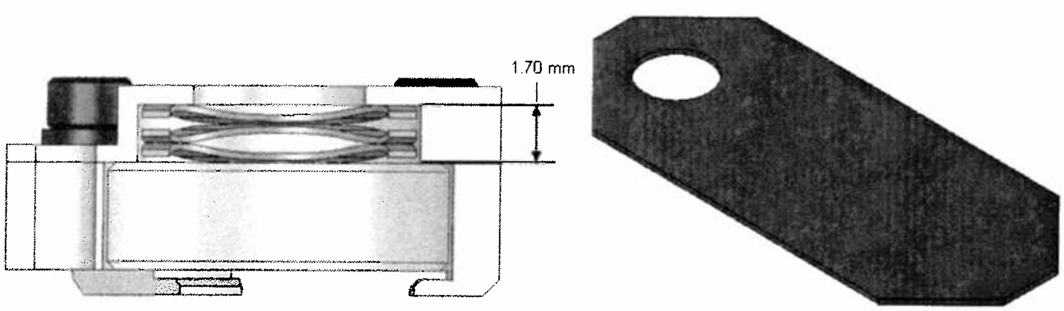


Figure 7: Springs in Steering Module

Appendix B: Smalley Wave Spring

Smalley® Steel Ring Company

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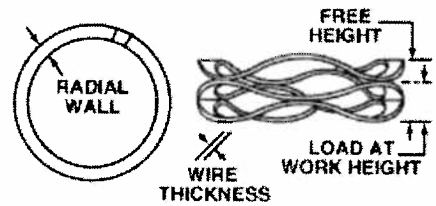
Wave Spring Properties



Part Number:	**CM08-L1**
Spring Type:	**Crest-to-Crest**
Operates in Bore (mm):	**8.00**
Clears Shaft Dia. (mm):	**5.00**
Load (N):	**15**
Work Height (mm):	**1.70**
Free Height (mm):	**2.82**
Number of waves/turn:	**2.5**
Number of Turns:	**3**
Number of Shims:	**0**
Wire Thickness (mm):	**0.20**
Wire Radial Wall (mm):	**0.81**
Spring Rate (N/mm):	**13.42**

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Appendix C: Mil-Bond Adhesive Specifications

TYPE Milbond Adhesive System

Milbond is an elastomeric-epoxy adhesive system for most glass to metal bonding applications. Milbond kits include an adequate quantity of spacer materials requested by the Military to maintain a bond layer thickness of .015" (.38mm). Milbond meets Military specification MIL-A-48611. Milbond can also be used in glass to glass, glass to plastic, metal to plastic, and metal to metal bonding.

Milbond Type I kit:
This kit contains 2 components of primer to paint substrates prior to application of adhesive and 2 components of adhesive, as well as sufficient quantity of spacer material.

Milbond Type II Kit:
This kit contains 2 components of adhesive and spacer material. This kit is used for substrates that will not be subjected to hostile environments and exhibit slightly less tensile shear strength than the Type I kit.

Approximate Curing Times

Mix Ratio	Room Temperature 25°C (77°F)	Oven Temperature 71°C (160°F)
Epoxy 1:1 (by weight)	7 days	3 hours
Primer 1:1 (by volume)	1 hour (to touch) 24 hours (to dry)	Not Recommended

Specifications

```
Pot Life @ 25°C...............................Primer- 8 Hours
                                              Epoxy- 30 Min.
Coverage at .015inch (.38mm)..................1322 sq inches
Tensile Shear @ 25°C..........................2,099 psi
  - After 60 min @ 70°C.......................992 psi
  - After 60 min @ -50°C......................2,561 psi
  - After 10 min @ 70°C(100% R.H.)............1,892 psi
    (test to failure at .015inch bond
    layer thickness, all failures
    cohesive, thinner bond layers yield
    higher results.)
Modulus of Elasticity @
   -50°C......................................85,900 psi
   +20°C......................................23,000 psi
   +70°C......................................1,070 psi
    (2inch long specimens were used,
    5 specimens per test, and the
    crosshead speed was .2"/min)
Mechanical Shock @
   -40°C......................................250-400G*
   +20°C......................................250-400G*
   +70°C......................................250-400G*
    (Shock pulses were approximately half
    sinewave; 1.5 millisecond duration.)
Linear Coefficient Of Expansion
   From (+20°C) - (-54°C).....................6.2x10-5/°C
   From (+20°C) - (+70°C).....................7.2x10-5/°C
    (2inch long (50mm) substrates were used,
    2 substrates per test.)
Outgassing TML (Total Mass Loss)..............0.98%
CVCM (ASTM E595)..............................0.03%
   (Collected Volatile Condensable Material)
Thermal Conductivity.........................300-350 x 10-5 cal/(sec)(sq.cm)(°C)(cm)
Specific Heat @
   40°C.......................................3 cal/(gm)(°C)
   60°C.......................................35 cal/(gm)(°C)
   80°C.......................................48 cal/(gm)(°C)
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Appendix D: Initial Alignment and Wedge Design

The tolerances applied to the optics bench are based on the range of adjustment provided by the steering wedges. The steering wedges correct angular error of a beam by rotating about the mechanical axis (see Figure 8).

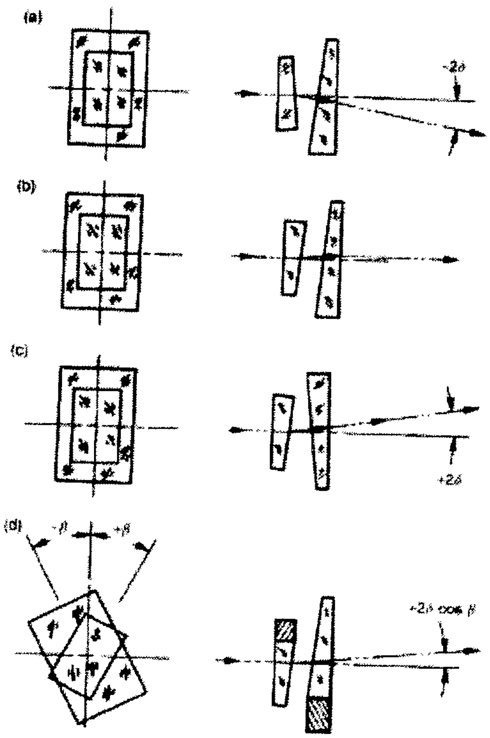


Figure 8: Steering wedge operation (borrowed from Yoder).

The correction in angle is governed by the following equation:

$$\delta_\lambda = (n_\lambda - 1)\theta$$

where n is the refractive index of the wedge material, θ is the wedge in the optic, and the δ is the angle exiting the wedge pair. The λ subscript on the variables n and δ is a reminder that the equations are sensitive to wavelength. The operation of the IR Steering Module requires a broad range of wavelength (3 to 7 um). As such, the dispersion of the optical material over this range needs to be very small to make the initial alignment specification. Figure 9 presents the refractive index as a function of wavelength for transmissive optical materials over the wavelength range defined by the specification.

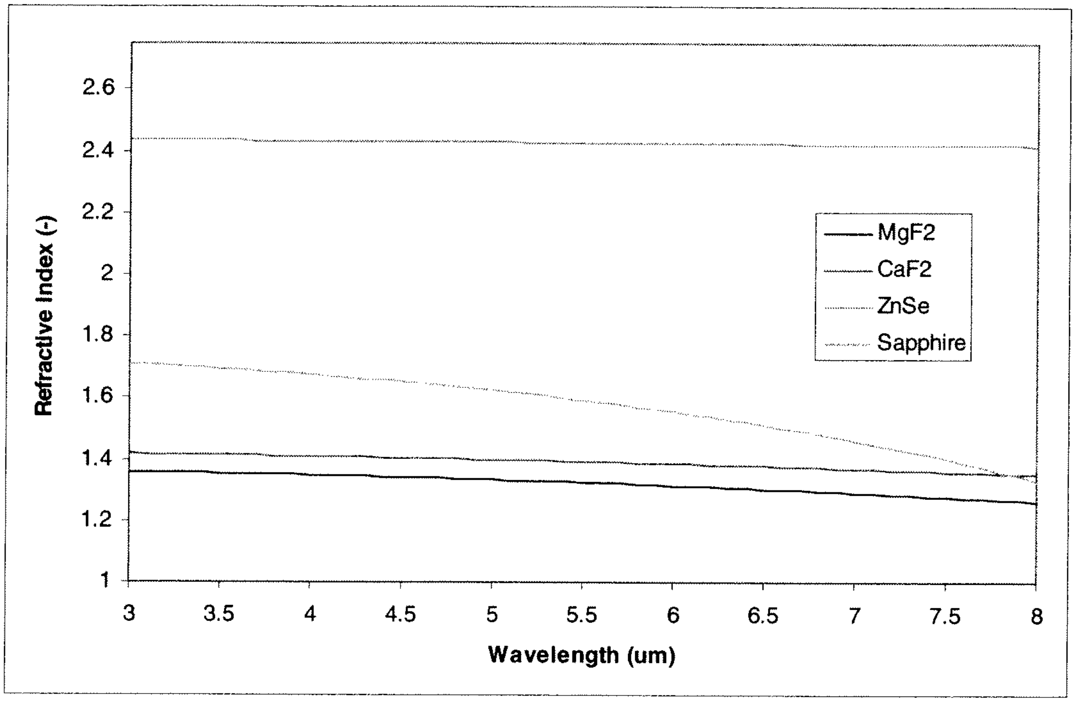


Figure 9: Refractive index for steering wedge candidate materials

In addition to the low dispersion, the optical material needs to be >90% transmissive over the operating wavelength range. Figures 10 through 13 present the published transmission values for the material considered for the steering wedge.

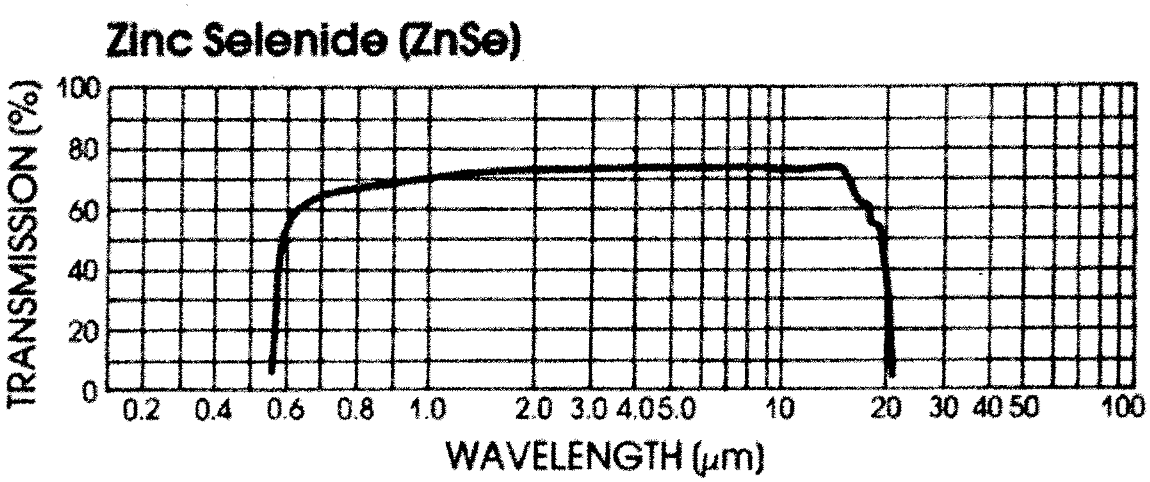


Figure 10: Transmission of Zinc Selenide.

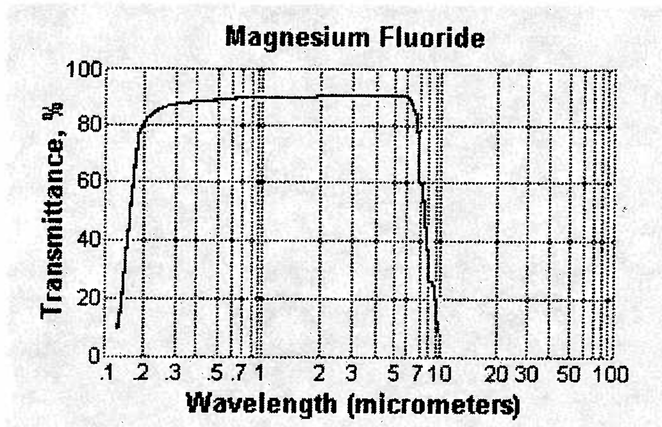


Figure 11: Transmission of Magnesium Fluoride.

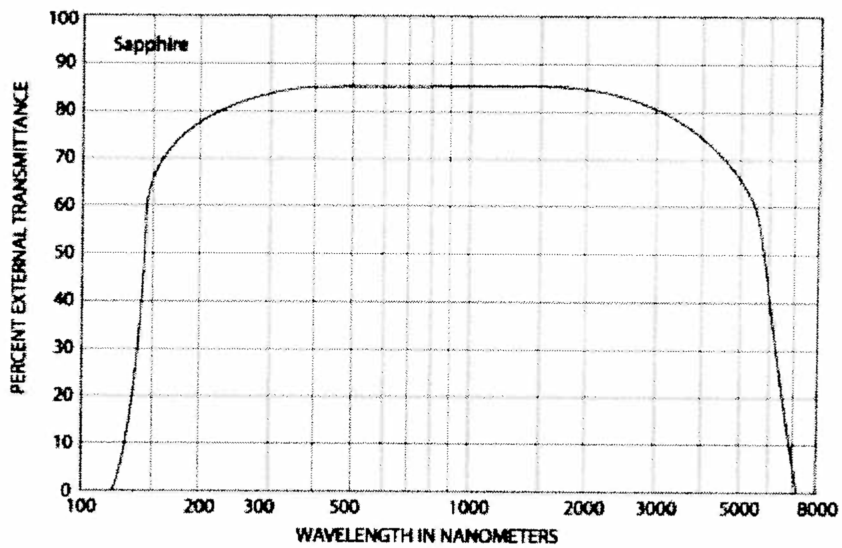


Figure 12: Transmission of Sapphire.

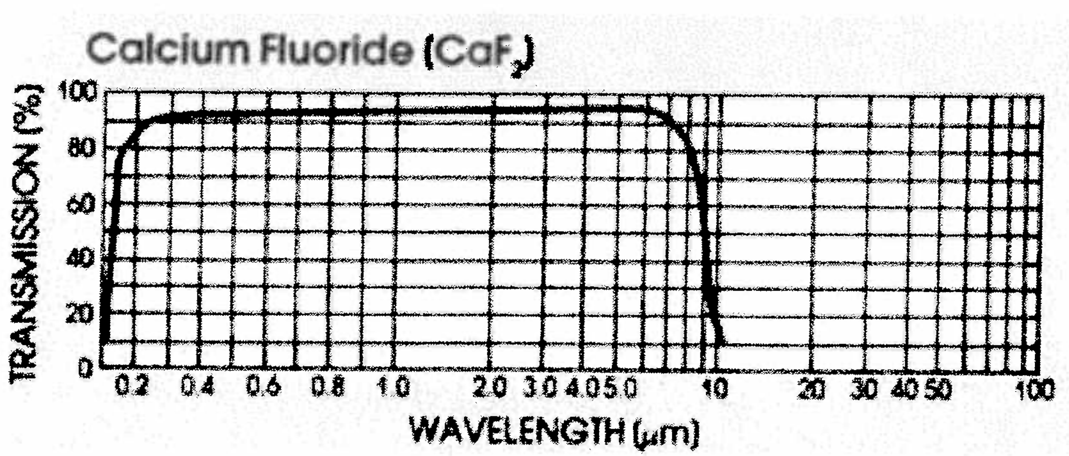


Figure 13: Transmission of Calcium Fluoride.

Calcium Fluoride is the only optical material considered that meets the specifications of the Steering Module. The wedge angle applied to the steering wedges was determined in accordance with the tolerances that can be held on the bench. Table 3 presents the tolerances that can be applied to the bench and the corresponding alignment error. The tolerance in this case refers to a surface profile for the three pads that orient the mirror on the steering module relative to the A, B and C datum.

Table 3: Tolerance budget and corresponding alignment error

Tolerance and Component	Tolerance (in)	Effective Length (in)	Rotation (urad)	Sensitivity	Alignment Error (urad)
Turn Mirror #1 Rotation About Y	0.0005	0.394	1270	2	2540
Turn Mirror #1 Rotation About Z'	0.0005	0.394	1270	2	2540
Turn Mirror #2 Rotation About Y'	0.0005	0.394	1270	**2**	2540
Turn Mirror #2 Rotation About Z	0.0005	0.394	1270	**2**	2540
Turn Mirror #3 Rotation About Y'	0.0005	0.394	1270	2	2540
Turn Mirror #3 Rotation About Z	0.0005	0.394	1270	2	2540
Error in Laser	-	-	-	-	1500
RSS					**6400**

From the root sum square result of all the alignment errors in the system, the wedge angle in the steering wedge can now be determined. Table 4 presents the maximum correction angle of the steering pair given the wavelength and wedge of the optic.

Table 4: Performance of the Calcium Fluoride steering wedges for specific geometries

Calcium Fluoride		.5 degree wedge	1 Degree Wedge	2 Degree Wedge
Wavelength	Index of Refraction	Range of Adjustment (mrad)	Range of Adjustment (mrad)	Range of Adjustment (mrad)
3	1.4179	3.65	7.29	14.59
3.5	1.4140	3.61	7.23	14.45
4	1.4096	3.57	7.15	14.30
4.5	1.4046	3.53	7.06	14.12
5	1.3990	3.48	6.96	13.93
5.5	1.3926	3.43	6.85	13.71
6	1.3856	3.36	6.73	13.46
7	1.3693	3.22	6.45	12.89

The 1 degree wedge barely meets the specifications while the 2 degree wedge has a "safety factor" of 2 built into the design. The 2 degree wedge will be used for the Steering Module and a profile tolerance of .0005 with respect to datum A, B and C will be applied to the optical bench mirror mount locations.

Appendix E: Error Budget and Boresight Stability Analysis

The boresight stability for the Steering Module is 25 urad over temperature and vibration loads. An error budget has been established such that the root sum squared, RSS, of the individual components of error is 25 urad. Equal amounts of error have been budgeted for the vibration and thermal loading of the Steering Module. A smaller amount of error has been budgeted for smaller errors that can not be accounted for through thermal and structural analysis. These errors occur due to small imperfections (dust particles, burrs, surface roughness) found on the optics bench. All precautions have been made to reduce the probability of these errors to occur, however, they have been included in the error budget to be conservative. Table 5 presents the error budget for the Steering Module.

Table 5: System Boresight Error Budget

Specification	Boresight Stability Requiement (urad)	25
Contributors	Vibration	14.4
	Thermal	14.4
	Random Mount Error	14.4
	RSS	**25**

As the random vibration can be applied to any axis, the vibration budget is broken down further in Table 6

Table 6: System Boresight Error Budget

Specification	Vibration Requiement (urad)	14.4
Contributors	X Direction	8.3
	Y Direction	8.3
	Z Direction	8.3
	RSS	**14.4**

To determine the boresight stability of the Steering Module through thermal and vibration loading, a finite element model (FEM) has been constructed based on the geometry of the Steering Module (see Figure 14). Split lines have been placed on the critical surfaces of the Steering Modules (turn mirror mounting surfaces, See Figure 15) and post processing of the deflected surfaces is required to compute the rotation and translation of the critical surfaces.

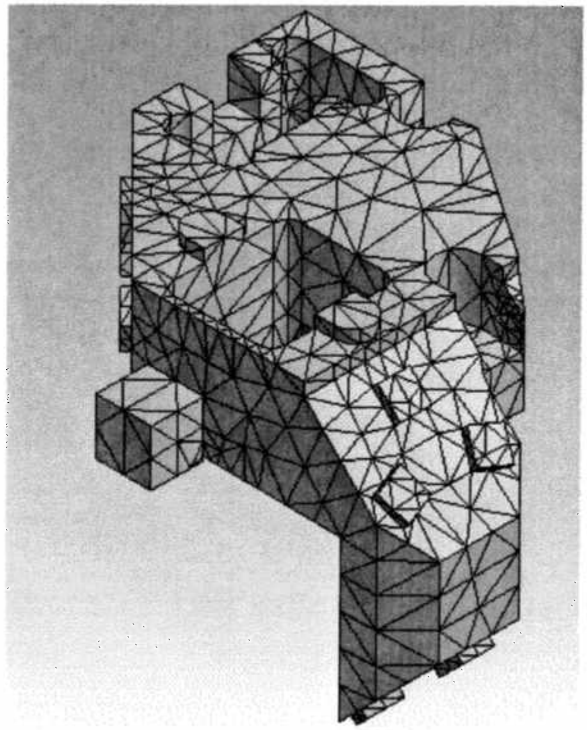


Figure 14: Meshed finite element model

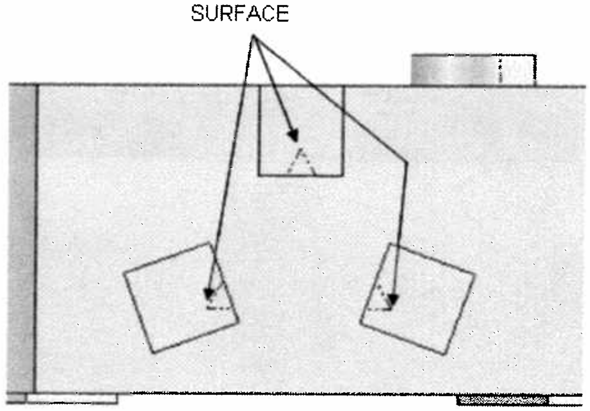


Figure 15: Split line and node location for critical surface

The rotations of the critical surfaces are calculated by measuring the displacements of three nodes placed on the critical surfaces at the extents of the mirror diameters (See Figure 15). Rotations are determined based on the displacement differential of each node. A more accurate and complex result can be computed by calculating the normal vector created by the surface however, the displacement differential method produces higher angular rotations and is less prone to calculation error – thus conservative.

The optical design was then analyzed to determine the sensitivities of each optic (see Appendix F). A coordinate system was established based on the FEM geometry (see

Figure 16). As can be expected, the magnification of angular error for each mirror to rotation about any axis other than the optical axis is a factor of 2. The steering wedges are transmissive and are only sensitive to rotation about their mechanical axis. From Appendix F, the sensitivity of this error is negligible.

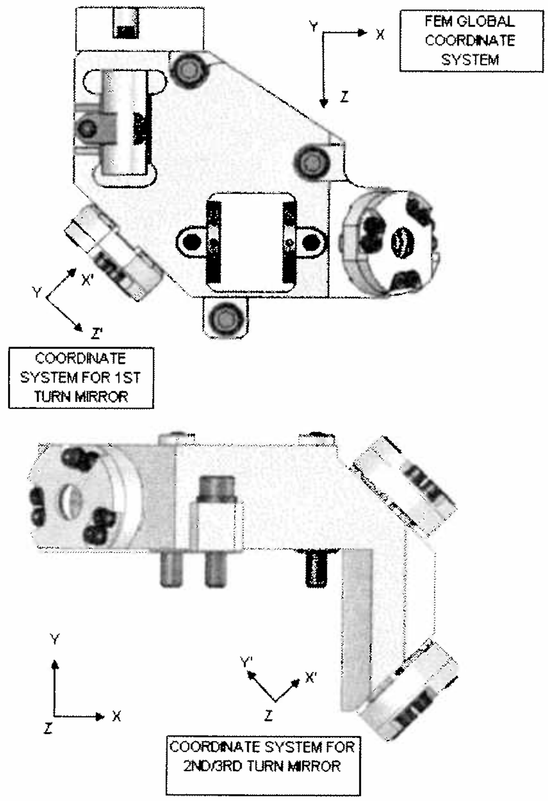


Figure 16: Coordinate Systems for Boresight Error Calculation

The vibration profile that the Steering Module will be subject to is defined in MIL-STD 810F Method 514.5. The application of the Steering Module is for fixed wing aircraft (Category 13) and rotary wing aircraft (Category 14). As there is no information known about the specific aircraft that is to be used, the highest suggested acceleration spectral density values have been assumed (See Figure 17).

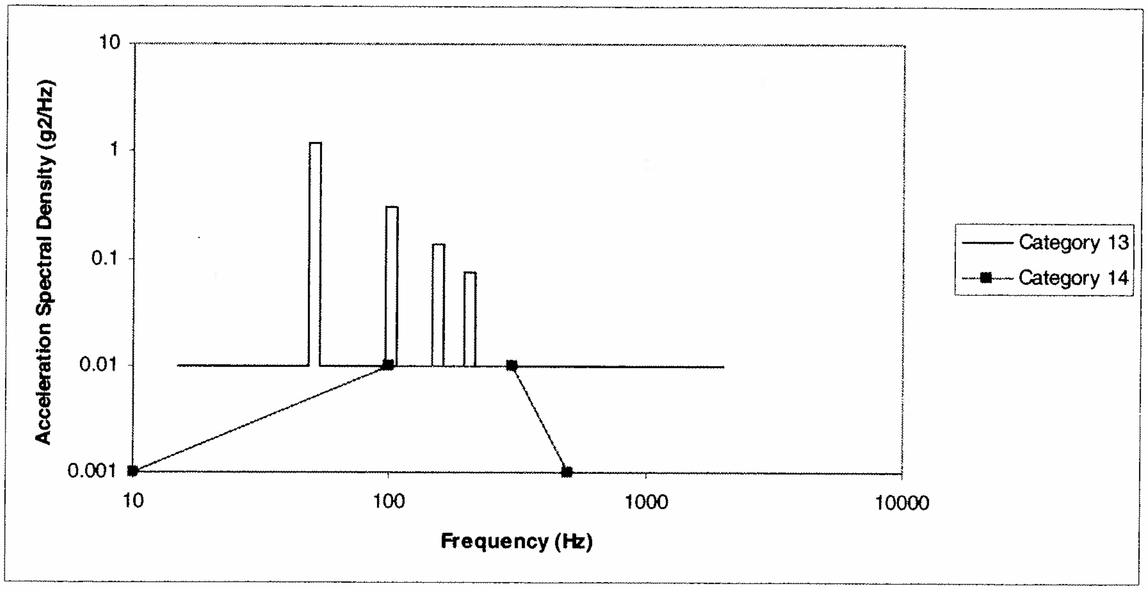


Figure 17: Acceleration Spectral Density Functions of MIL-STD 810 514.5, Categories 13 and 14

To determine the vibration induced boresight error, modal analysis of the optics bench is required. A finite element model was put together using ANSYS to determine the modes of the bench. Figures 18 through 20 show the first 3 modes of the optics bench.

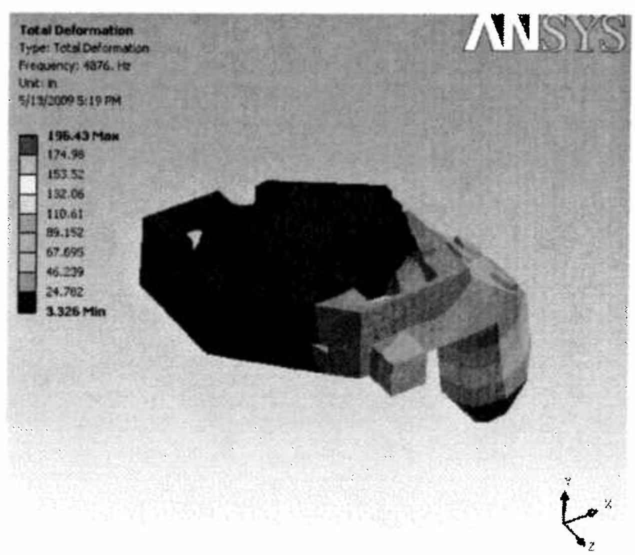


Figure 18: First mode of optics bench – bending about z axis – 4876 Hz

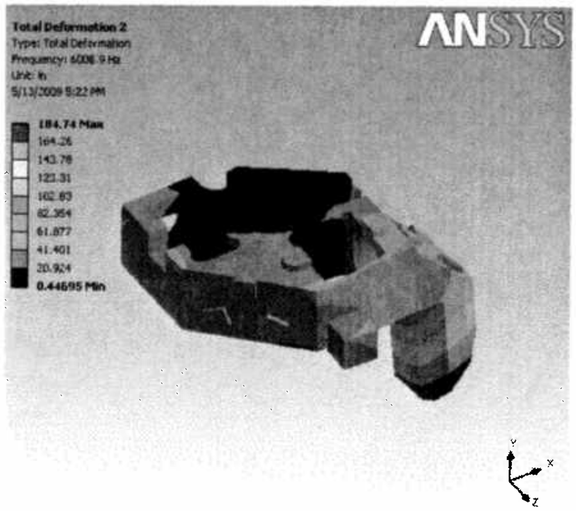


Figure 19: Second mode of optics bench – bending about x axis – 6009 Hz

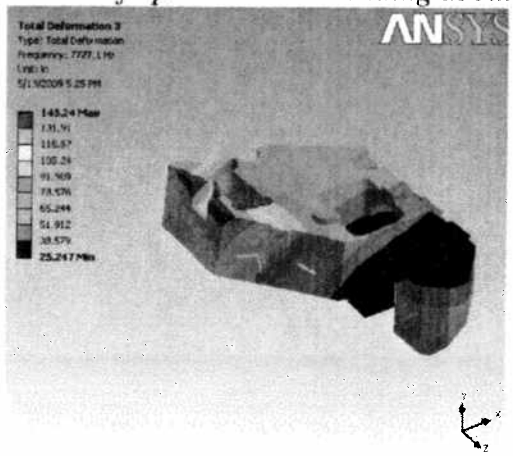


Figure 20: Third mode of optics bench – bending near emitter – 7727 Hz

As the first mode of the bench is above the frequency range of the random vibration spectrum, the resulting angular errors of the mirror mounting surfaces are expected to be very low. All rotations of the bench (see Tables X, Y, Z) are below the budgeted values from Appendix F which indicates that the Steering Module design meets specification (25 urad).

Table 7: Resulting boresight error given random vibration applied in x-direction

1		ANSYS			Static Displacements			Rotation					
		UX (m)	UY (m)	UZ (m)	ΔX (mm)	ΔY (mm)	ΔZ (mm)	θx (μrad)	Dir	θy (μrad)	Dir	θz (μrad)	Dir
X Direction													
TURN MIRROR #1	NODE_62	7.74E-09	1.02E-08	5.836E-10	5.268E-06	1.014E-05	9.492E-07	-	-	**0.14**	CCW	**0.40**	CW
	NODE_53	3.67E-09	1.14E-08	1.656E-09									
	NODE_43	4.39E-09	8.92E-09	6.079E-10									
TURN MIRROR #2	NODE_37	4.53E-09	4.84E-09	6.476E-09	7.352E-06	1.016E-05	8.935E-06	-	-	**0.63**	CCW	**1.15**	CCW
	NODE_22	6.19E-09	1.15E-08	1.066E-08									
	NODE_30	1.13E-08	1.41E-08	9.668E-09									
TURN MIRROR #3	NODE_16	4.18E-08	1.72E-08	7.32E-09	4.839E-05	1.094E-05	3.505E-06	**0.40**	CCW	-	-	**1.81**	CW
	NODE_1	4.81E-08	6.67E-09	1.632E-09									
	NODE_9	5.52E-08	8.96E-09	1.563E-09									

Table 8: Resulting boresight error given random vibration applied in y-direction

1		ANSYS			Static Displacements			Rotation					
		UX (m)	UY (m)	UZ (m)	ΔX (mm)	ΔY (mm)	ΔZ (mm)	θx (μrad)	Dir	θy (μrad)	Dir	θz (μrad)	Dir
Y Direction													
TURN MIRROR #1	NODE_62	5.37E-09	1.30E-08	2.74E-09									
	NODE_53	3.46E-10	1.54E-08	2.72E-09	2.159E-06	1.302E-05	2.694E-06	-	-	0.04	CCW	0.46	CW
	NODE_43	7.59E-10	1.06E-08	2.62E-09									
TURN MIRROR #2	NODE_37	4.03E-10	1.43E-08	7.96E-09									
	NODE_22	2.01E-09	1.46E-08	5.67E-09	1.879E-06	1.746E-05	6.259E-06	-	-	0.82	CCW	0.65	CCW
	NODE_30	3.23E-09	2.34E-08	5.15E-09									
TURN MIRROR #3	NODE_16	1.86E-08	2.08E-08	1.30E-08									
	NODE_1	2.19E-08	1.24E-08	1.94E-08	2.137E-05	1.802E-05	1.726E-05	0.54	CW	-	-	0.79	CCW
	NODE_9	2.37E-08	2.08E-08	1.94E-08									

Table 9: Resulting boresight error given random vibration applied in z-direction

1		ANSYS			Static Displacements			Rotation					
		UX (m)	UY (m)	UZ (m)	ΔX (mm)	ΔY (mm)	ΔZ (mm)	θx (μrad)	Dir	θy (μrad)	Dir	θz (μrad)	Dir
Z Direction													
TURN MIRROR #1	NODE_62	3.75E-09	8.15E-09	2.37E-09									
	NODE_53	8.82E-10	9.36E-09	1.81E-09	1.971E-06	8.233E-06	1.966E-06	-	-	0.04	CCW	0.20	CW
	NODE_43	1.28E-09	7.19E-09	1.73E-09									
TURN MIRROR #2	NODE_37	2.88E-09	2.44E-09	1.77E-09									
	NODE_22	2.48E-09	2.33E-09	5.56E-09	2.912E-06	3.917E-06	4.158E-06	-	-	0.45	CCW	0.21	CCW
	NODE_30	3.38E-09	6.98E-09	5.14E-09									
TURN MIRROR #3	NODE_16	3.83E-09	2.28E-09	2.70E-08									
	NODE_1	4.14E-09	2.59E-09	3.38E-08	3.922E-06	4.123E-06	3.150E-05	0.43	CW	-	-	0.25	CCW
	NODE_9	3.80E-09	7.51E-09	3.37E-08									

Additionally, the Steering Module will see thermal distortion as the Steering Module bolt to an optics bench and is in close proximity to a colder enclosure. The largest steady state temperature difference between the bench and enclosure is 15°C. The boundary conditions of the steering module can be seen in the Figure 21.

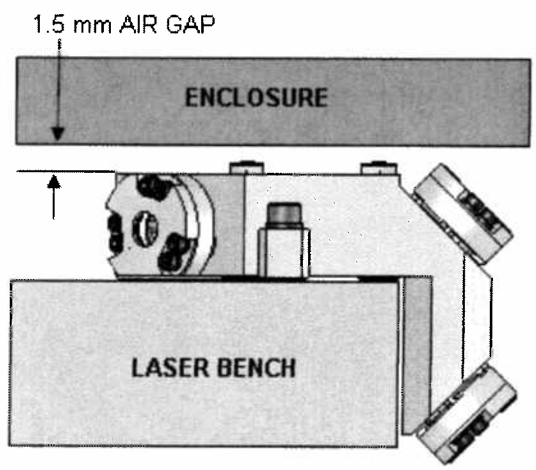


Figure 21: Schematic of thermal model

The two conditions that will present the worst case rotation and translations of the Steering Module exist when operating at the high and low end of the operating temperature range. As the air gap is small, convective heat transfer will be ignored as "conduction" through air will be the primary heat transfer mode between the top of the Steering Module and the Enclosure. The heat transfer coefficient between the enclosure and Steering module will be 17.5 W/m2-C - which is consistent with a 1.5 mm air gap. Conductivity of air is assumed to be .0262 W/m-C. The first condition that will be analyzed occurs when the laser bench is 80°C and the enclosure is 65°C. Figure 22 presents the temperature plot of the Steering Module at this condition.

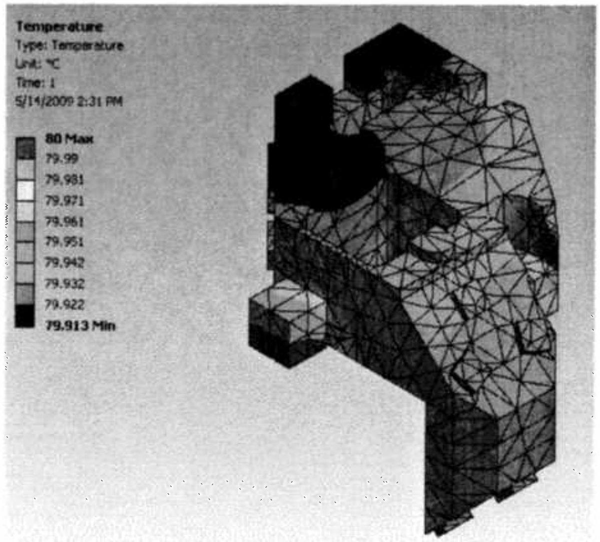


Figure 22: Temperature gradient for operation at high temperature.

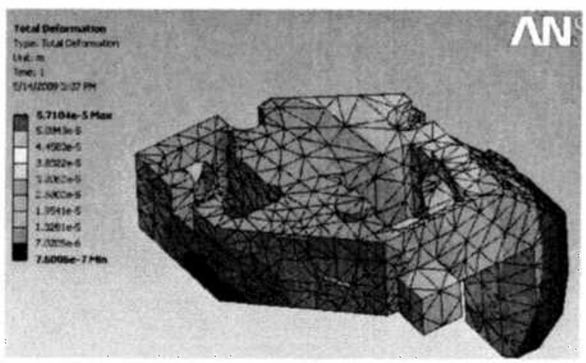


Figure 23: Resulting deformation for structural analysis with boundary conditions from thermal analysis.

The resulting rotations and translations of the bench are assumed to be very small as the temperature gradient is 0.1°C across the entire bench. The rotations and translations are presented in Table 10.

Table 10: Resulting boresight error for high temperature operation

1		ANSYS			Static Displacements			Rotation					
		UX (m)	UY (m)	UZ (m)	ΔX (mm)	ΔY (mm)	ΔZ (mm)	θx (μrad)	Dir	θy (μrad)	Dir	θz (μrad)	Dir
HIGH TEMP													
TURN MIRROR #1	NODE_62	6.83E-06	1.62E-05	1.78E-05	6.818E-03	9.462E-03	1.780E-02	-	-	0.70	CCW	0.63	CCW
	NODE_53	2.67E-06	6.09E-06	1.37E-05									
	NODE_43	1.10E-05	6.09E-06	2.19E-05									
TURN MIRROR #2	NODE_37	5.60E-05	1.42E-05	1.77E-05	6.060E-02	9.464E-03	1.770E-02	-	-	2.50	CCW	0.71	CCW
	NODE_22	6.32E-05	7.08E-06	1.19E-05									
	NODE_30	6.32E-05	7.08E-06	2.35E-05									
TURN MIRROR #3	NODE_16	6.56E-05	-1.95E-05	1.77E-05	6.082E-02	-2.428E-02	1.772E-02	1.46	CCW	-	-	0.70	CCW
	NODE_1	5.84E-05	-2.67E-05	1.19E-05									
	NODE_9	5.84E-05	-2.67E-05	2.36E-05									

Similarly, Figure 24 and Tables 11 are for low temperature operation.

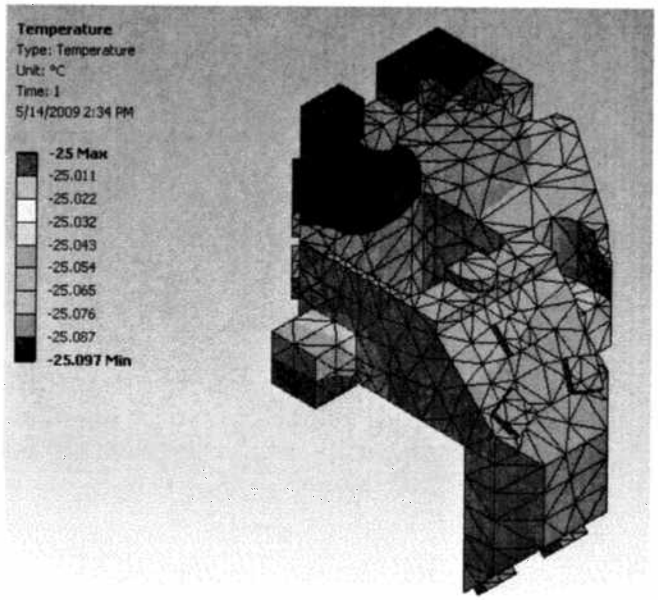


Figure 24: Temperature gradient for operation atlow temperature

Table 11: Resulting boresight error for low temperature operation

1		ANSYS			Static Displacements			Rotation					
		UX (m)	UY (m)	UZ (m)	AX (mm)	AY (mm)	AZ (mm)	θx (μrad)	Dir	θy (μrad)	Dir	θz (μrad)	Dir
LOW TEMP													
TURN MIRROR #1	NODE_62	-5.27E-06	-1.25E-05	-1.38E-05	-5.262E-03	-7.293E-03	-1.375E-02	-	-	0.76	CCW	1.40	CCW
	NODE_53	-2.06E-06	-4.68E-06	-1.06E-05									
	NODE_43	-8.46E-06	-4.69E-06	-1.69E-05									
TURN MIRROR #2	NODE_37	-4.33E-05	-1.10E-05	-1.37E-05	-4.693E-02	-7.273E-03	-1.366E-02	-	-	1.15	CCW	1.16	CW
	NODE_22	-4.88E-05	-5.43E-06	-9.14E-06									
	NODE_30	-4.88E-05	-5.43E-06	-1.82E-05									
TURN MIRROR #3	NODE_16	-5.06E-05	1.51E-05	-1.36E-05	-4.690E-02	1.876E-02	-1.364E-02	2.01	CW	-	-	1.06	CW
	NODE_1	-4.51E-05	2.06E-05	-9.13E-06									
	NODE_9	-4.51E-05	2.06E-05	-1.82E-05									

All rotations are below the allocated error budget for each optic. The 25 urad pointing stability specification has been met and testing should confirm the analysis.

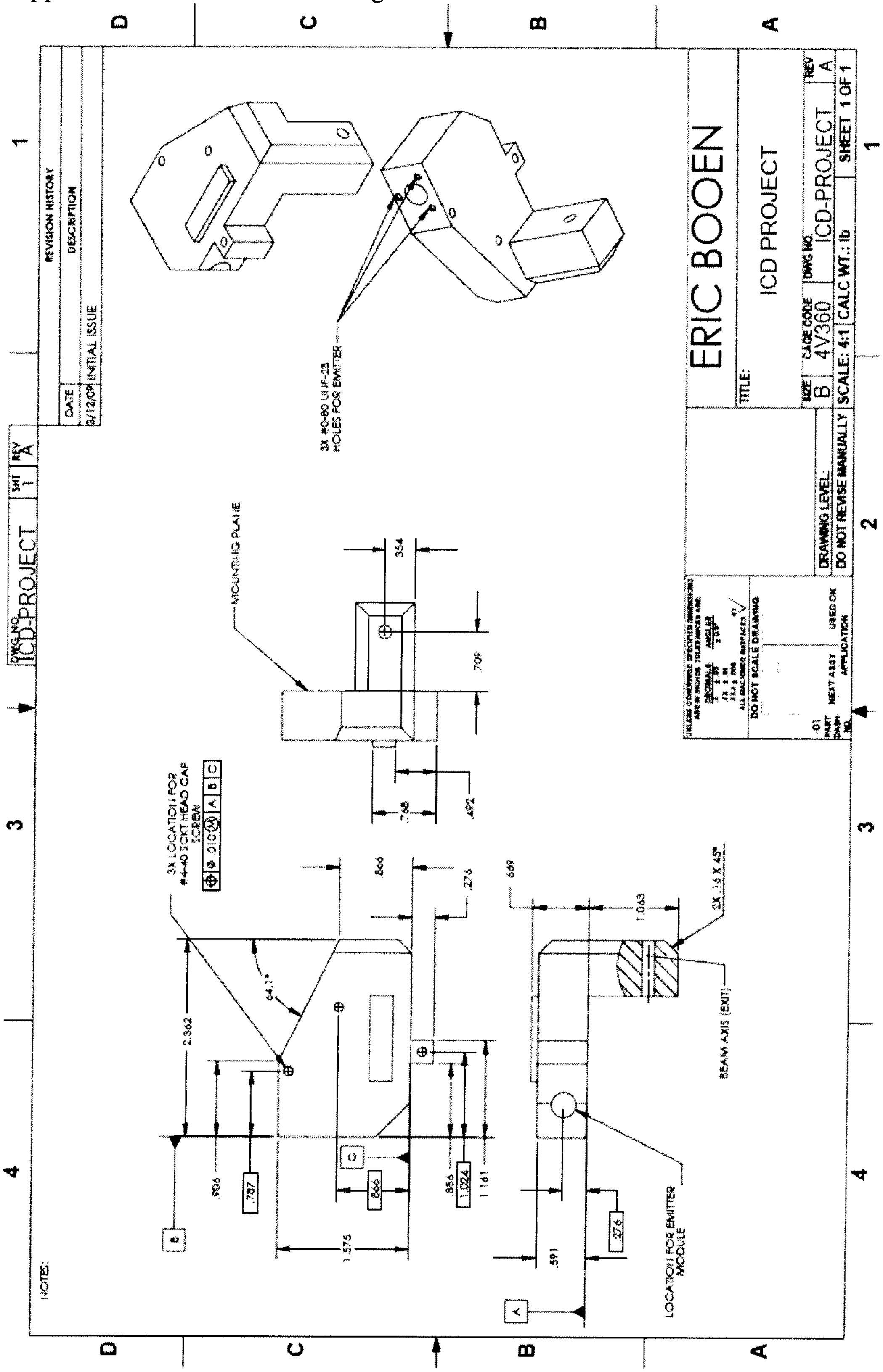
Appendix F: Sensitivity and Error Budget for Each Optic

Thermal and Random Mount Error Budget								
Turn Mirror #1	**um**	**urad**	**urad**	**Sensitivity**	**Units**	**Acceptable Error**	**Units**	**Resulting Boresight Error**
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	0	0	urad/urad	100.00	urad	0.00
Rotation about y		1	2	2	urad/urad	3.00	urad	6.00
Rotation about z		1	2	2	urad/urad	**3.00**	urad	6.00
Steering Wedge #1								
Translation about x	1		0	0	urad/um	0.00	um	0.00
Translation about y	1		0	0	urad/um	0.00	um	0.00
Translation about z	1		0	0	urad/um	0.00	um	0.00
Rotation about x		1	1	0	urad/urad	3.00	urad	0.00
Rotation about y		1	0	0	urad/urad	0.00	urad	0.00
Rotation about z		1	0	0	urad/urad	0.00	urad	0.00
Steering Wedge #2								
Translation about x	1		0	0	urad/um	0.00	um	0.00
Translation about y	1		0	0	urad/um	0.00	um	0.00
Translation about z	1		0	0	urad/um	0.00	um	0.00
Rotation about x		1	1	0	urad/urad	3.00	urad	0.00
Rotation about y		1	0	0	urad/urad	0.00	urad	0.00
Rotation about z		1	0	0	urad/urad	0.00	urad	0.00
Turn Mirror #2								
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	0	0	urad/urad	100.00	urad	0.00
Rotation about y		1	2	2	urad/urad	3.00	urad	6.00
Rotation about z		1	2	2	urad/urad	**3.00**	urad	6.00
Turn Mirror #3								
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	0	0	urad/urad	100.00	urad	0.00
Rotation about y		1	2	2	urad/urad	3.00	urad	6.00
Rotation about z		1	2	2	urad/urad	**3.00**	urad	6.00
			RSS					**14.7**

Appendix F Continued… Vibration Error Budget for Each Direction

Vibration for X, Y and Z Directions								
Turn Mirror #1	um	urad	urad	Sensitivity	Units	Acceptable Error	Units	Resulting Boresight Error
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	0	0	urad/urad	100.00	urad	0.00
Rotation about y		1	2	2	urad/urad	1.69	urad	3.39
Rotation about z		1	2	2	urad/urad	**1.69**	urad	3.39
Steering Wedge #1								
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	1	0	urad/urad	3.00	urad	0.00
Rotation about y		1	0	0	urad/urad	100.00	urad	0.00
Rotation about z		1	0	0	urad/urad	100.00	urad	0.00
Steering Wedge #2								
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	1	0	urad/urad	3.00	urad	0.00
Rotation about y		1	0	0	urad/urad	100.00	urad	0.00
Rotation about z		1	0	0	urad/urad	100.00	urad	0.00
Turn Mirror #2								
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	0	0	urad/urad	100.00	urad	0.00
Rotation about y		1	2	2	urad/urad	1.69	urad	3.39
Rotation about z		1	2	2	urad/urad	**1.69**	urad	3.39
Turn Mirror #3								
Translation about x	1		0	0	urad/um	10.00	um	0.00
Translation about y	1		0	0	urad/um	10.00	um	0.00
Translation about z	1		0	0	urad/um	10.00	um	0.00
Rotation about x		1	0	0	urad/urad	100.00	urad	0.00
Rotation about y		1	2	2	urad/urad	1.69	urad	3.39
Rotation about z		1	2	2	urad/urad	**1.69**	urad	3.39
			RSS					**8.3**

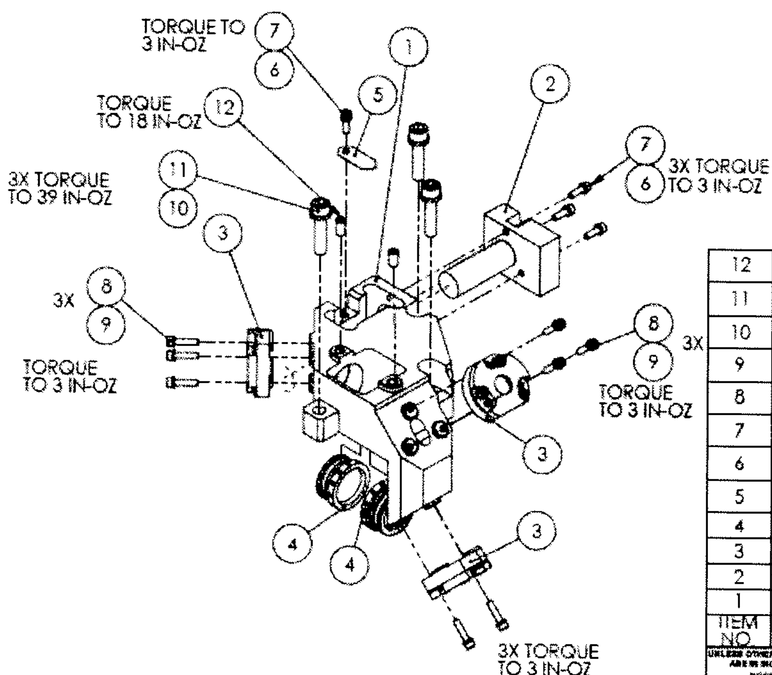
Appendix G: Mechanical Drawings



NOTES:
1. ASSEMBLY TO BE PERFORMED IN CLEAN ROOM, CLASS 1000 OR BETTER
2. TORQUE BOLTS TO SPECIFIED TORQUE VALUE - TORQUE VALUES CAN VARY ±10%

DWG NO. DP-01 | SHT 1 | REV

REVISION HISTORY	
DATE	DESCRIPTION
5/16/09	INITIAL ISSUE



ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
12	2	MIL 51021	SET SCREW, 2-56 x 3/16	SS 18-8
11	3	NAS1352C	SCREW, 4-40 UNRC-3A X .500 LG SCKT HD CAP	CRES
10	3	NAS 620	#4 WASHER NAS 620	SS 18-8
9	9	NAS 620	#0 WASHER NAS 620	SS 18-8
8	9	NASM16996	SHCS, 0-80 UNF-3A X .250 LG	SS 304
7	4	NASM16996	SHCS. 0-80 UNF-3A X .188 LG	SS 304
6	4	NAS 620	#0 FLAT WASHER	CRES
5	1	DP-11	SPRING CLIP, IR EMITTER	SS 17-4PH
4	2	DP-08	ROTATION MOUNT ASSEMBLY	-
3	3	DP-04	MIRROR ASSEMBLY	-
2	1	DP-03	IR EMITTER	-
1	1	DP-02	OPTICS BENCH	AL 6061-T6

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
DECIMALS .X ± .03 .XX ± .01 .XXX ± .005; ANGLES ± 0.5°
ALL MACHINED SURFACES 63 √
DO NOT SCALE DRAWING

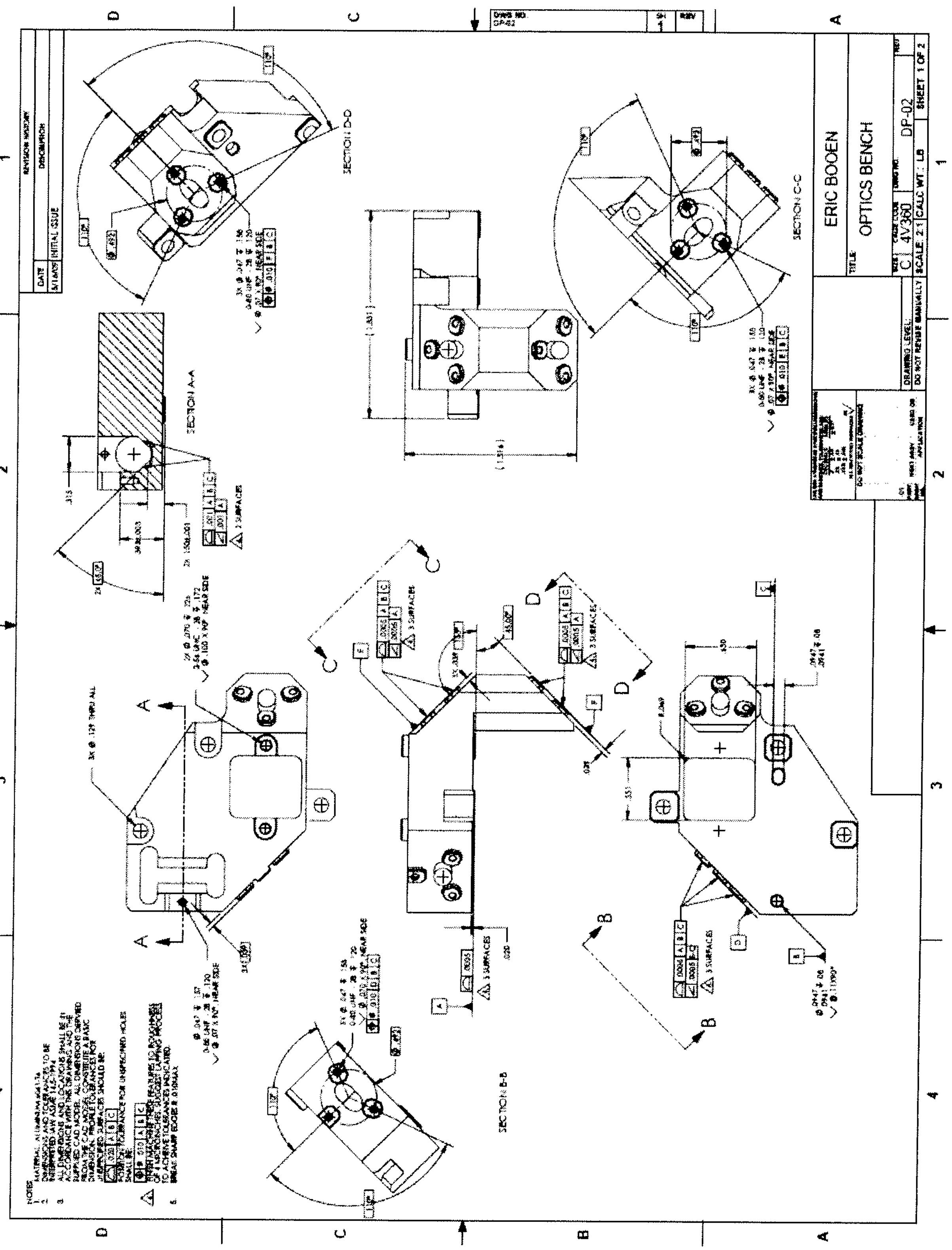
-01 PART DASH NO. | NEXT ASSY | USED ON | APPLICATION

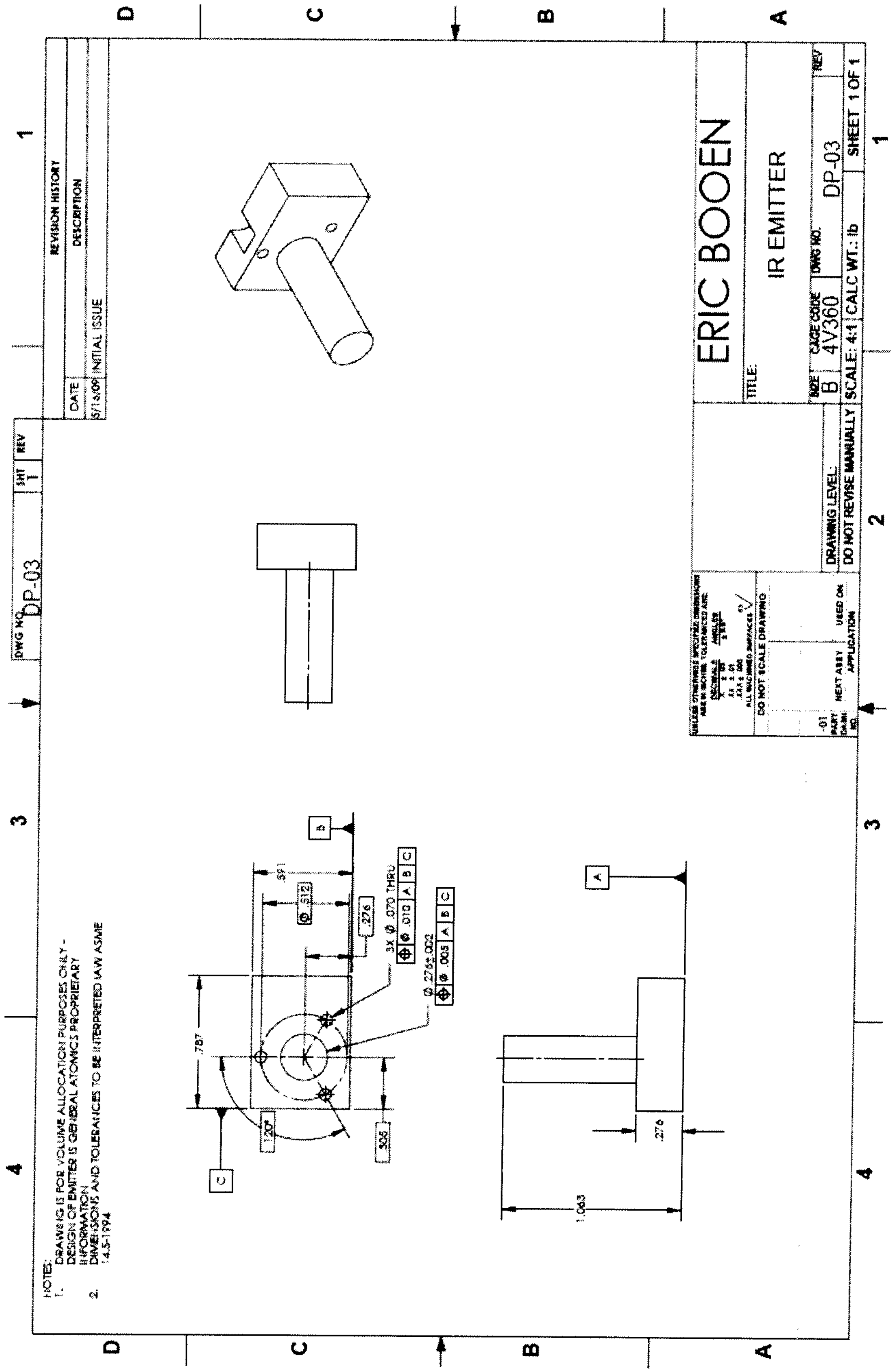
DRAWING LEVEL:
DO NOT REVISE MANUALLY

ERIC BOOEN

TITLE: IR STEERING ASSY

SIZE B | CAGE CODE 4V360 | DWG NO. DP-01 | REV
SCALE: 1:1 | CALC WT.: Kg | SHEET 1 OF 1

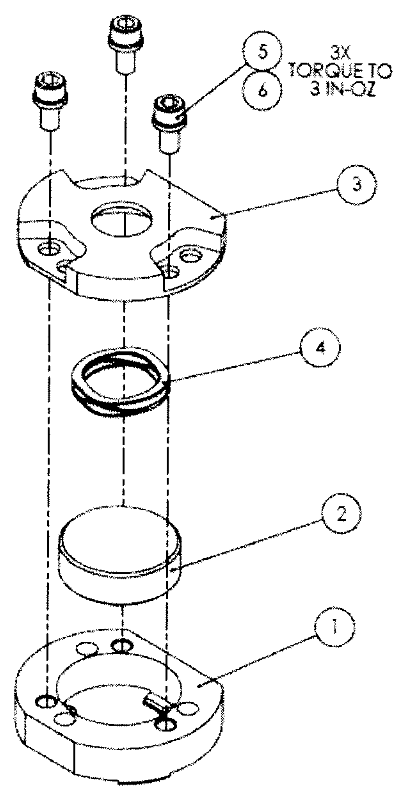

ERIC BOOEN
OPTICS BENCH
DP-02
4V360
SHEET 1 OF 2
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D


ERIC BOOEN
TITLE:
IR EMITTER
SIZE B
CAGE CODE 4V360
DWG NO. DP-03
REV
SCALE: 4:1
CALC WT.: lb
SHEET 1 OF 1
DRAWING LEVEL:
DO NOT REVISE MANUALLY
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
REVISION HISTORY
DATE
DESCRIPTION
5/16/09
INITIAL ISSUE
DWG NO. DP-03
SHT 1
NOTES:
1. DRAWING IS FOR VOLUME ALLOCATION PURPOSES ONLY - DESIGN OF EMITTER IS GENERAL ATOMICS PROPRIETARY INFORMATION
2. DIMENSIONS AND TOLERANCES TO BE INTERPRETED IAW ASME 14.5-1994
.787
.591
Ø .512
.276
.305
120°
3X Ø .070 THRU
Ø .276±.002
1.063
A
B
C

DWG NO. DP-04 | SHT 1 | REV

NOTES:
1. ASSEMBLY TO BE PERFORMED IN CLEAN ROOM, CLASS 1000 OR BETTER
2. TORQUE BOLTS TO SPECIFIED TORQUE VALUE - TORQUE VALUES CAN VARY ±10%

REVISION HISTORY	
DATE	DESCRIPTION
5/16/09	INITIAL ISSUE



ITEM NO.	QTY.	PART NO.	DESCRIPTION	MATERIAL
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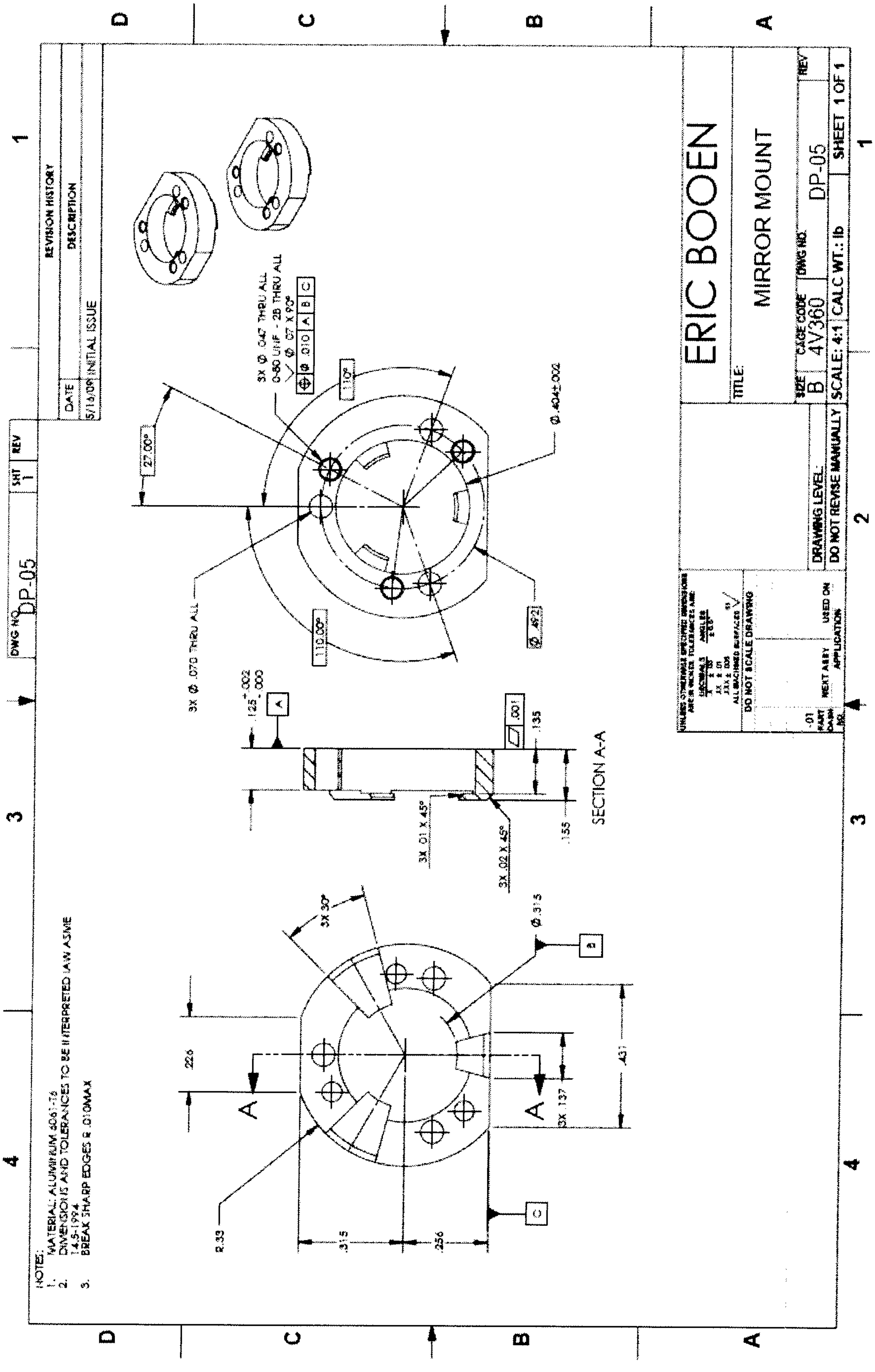
5	3	NASM16996	SHCS, 0-80 UNF-3A X .125 LG	SS 304
4	1	CM08-L1-S17	SMALLEY WAVE SPRING	316 SS
3	1	DP-07	COMPRESSION PLATE	AL 6061-T6
2	1	DP-06	IR MIRROR	FUSED SILICA
1	1	DP-05	MIRROR MOUNT	AL 6061-T6

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
DO NOT SCALE DRAWING
-01 PART DASH NO. | NEXT ASS'Y | USED ON | APPLICATION
DRAWING LEVEL:
DO NOT REVISE MANUALLY

ERIC BOOEN

TITLE: MIRROR ASSEMBLY

SIZE	CAGE CODE	DWG NO.	REV
B	4V360	DP-04	
SCALE: 3:1	CALC WT.: Kg	SHEET 1 OF 1	

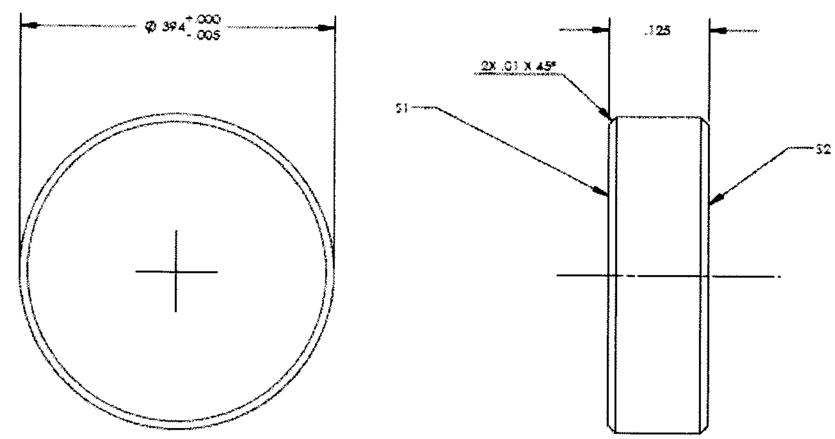


ERIC BOOEN
TITLE:
MIRROR MOUNT
SIZE B
CAGE CODE 4V360
DWG NO. DP-05
REV
SCALE: 4:1
CALC WT.: lb
SHEET 1 OF 1
DRAWING LEVEL:
DO NOT REVISE MANUALLY
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
REVISION HISTORY
DATE
DESCRIPTION
5/16/08 INITIAL ISSUE
DWG NO. DP-05
SHT 1
REV
NOTES:
1. MATERIAL: ALUMINUM 6061-T6
2. DIMENSIONS AND TOLERANCES TO BE INTERPRETED IAW ASME 14.5-1994
3. BREAK SHARP EDGES R .010MAX
SECTION A-A
3X Ø .070 THRU ALL
3X Ø .047 THRU ALL
0-80 UNF - 2B THRU ALL
Ø .07 X 90°
Ø .404±.002
Ø .492
27.00°
110°
119.00°
3X 30°
Ø .315
R.33
.315
.256
.226
.431
3X .137
.125
.135
.155
.001
3X .01 X 45°
3X .02 X 45°

NOTES:
1. ORDER COMMERCIALLY AVAILABLE MIRRORS WHEN AVAILABLE
2. ALL SPECIFICATIONS APPLY OVER THE CLEAR APERTURE

DWG NO.	SHT	REV
DP-06	1	0A

REVISION HISTORY	
DATE	DESCRIPTION
5/16/09	INITIAL ISSUE



SPECIFICATION			
Material	Type	Fused silica	
	Grade	Optical	
Mechanical	S1-S2 Wedge	≤5 Arcminutes	
	Edge Finish	Fine Grind Similar to 55 uinch RMS	
	Clear Aperture	85% of OD, Concentric to Edge	
Optical[A]		S1	S2
	Test Wavelength	633 nm	
	Surface Flatness, P-V	0.10 wave	N.A.
	Surface Flatness, RMS	N.A.	N.A.
	Surface Flatness, Slope Error	N.A.	N.A.
	Scratch-Dig[B]	10-5	Commercial polish
	Transmitted Wavefront Error	N.A.	
Coating	Angle of Incidence	44-46°	N.A.
	Polarization	Random	N.A.
	Type	Protected Gold R> 90% @ 3.0-7.0um	N.A.
	Minimum Damage Threshold	N.A.	N.A.
Environmental		Min	Max
	Storage Temperature	-60 C	80 C
	Operational Temperature	-40 C	80 C

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
DECIMALS X ± .06; XX ± .01; XXX ± .005; ANGLES ± 0.5°
ALL MACHINED SURFACES 63 √
DO NOT SCALE DRAWING

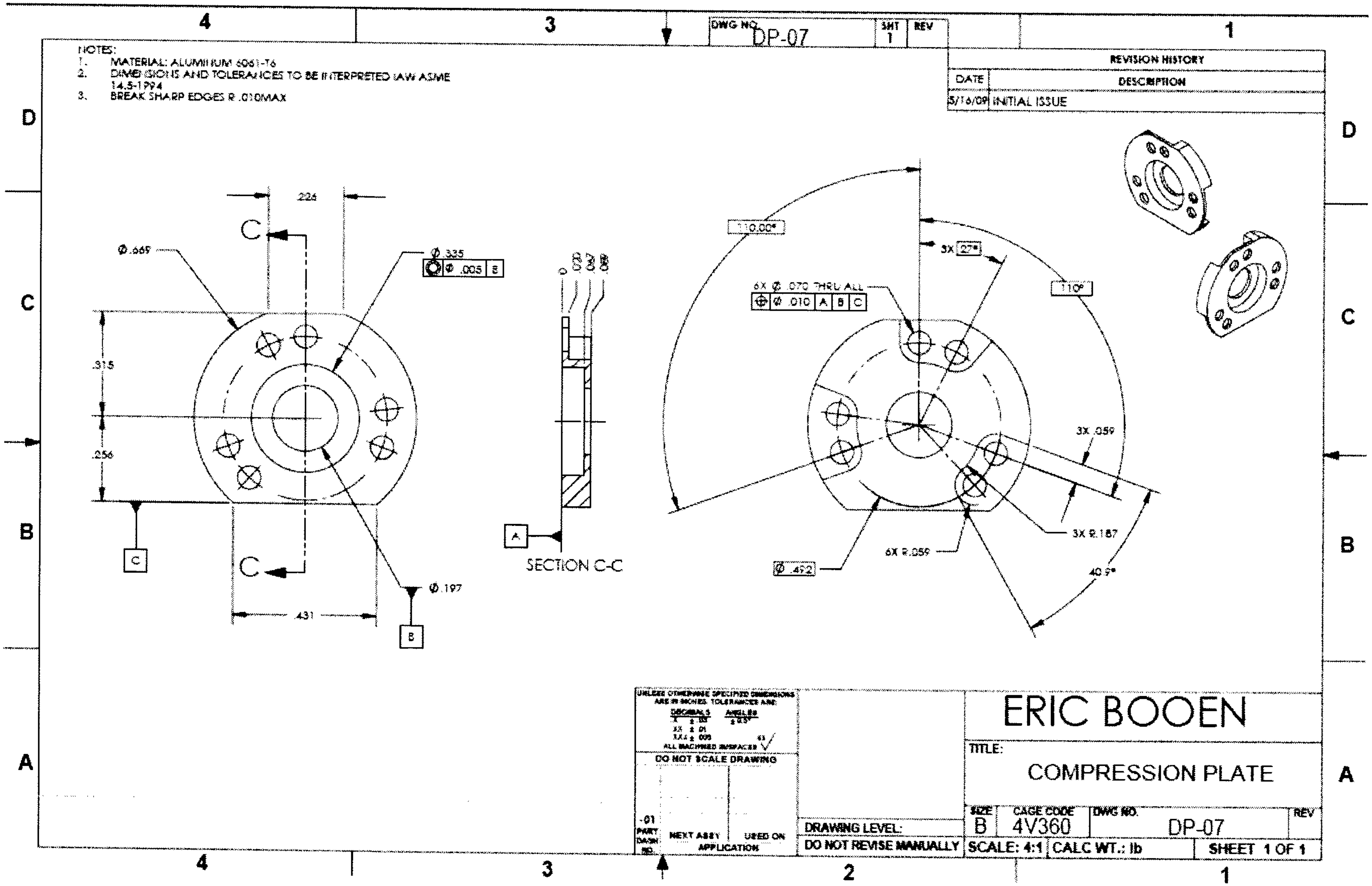
-01 PART DASH NO. | NEXT ASSY | USED ON | APPLICATION

DRAWING LEVEL:
DO NOT REVISE MANUALLY

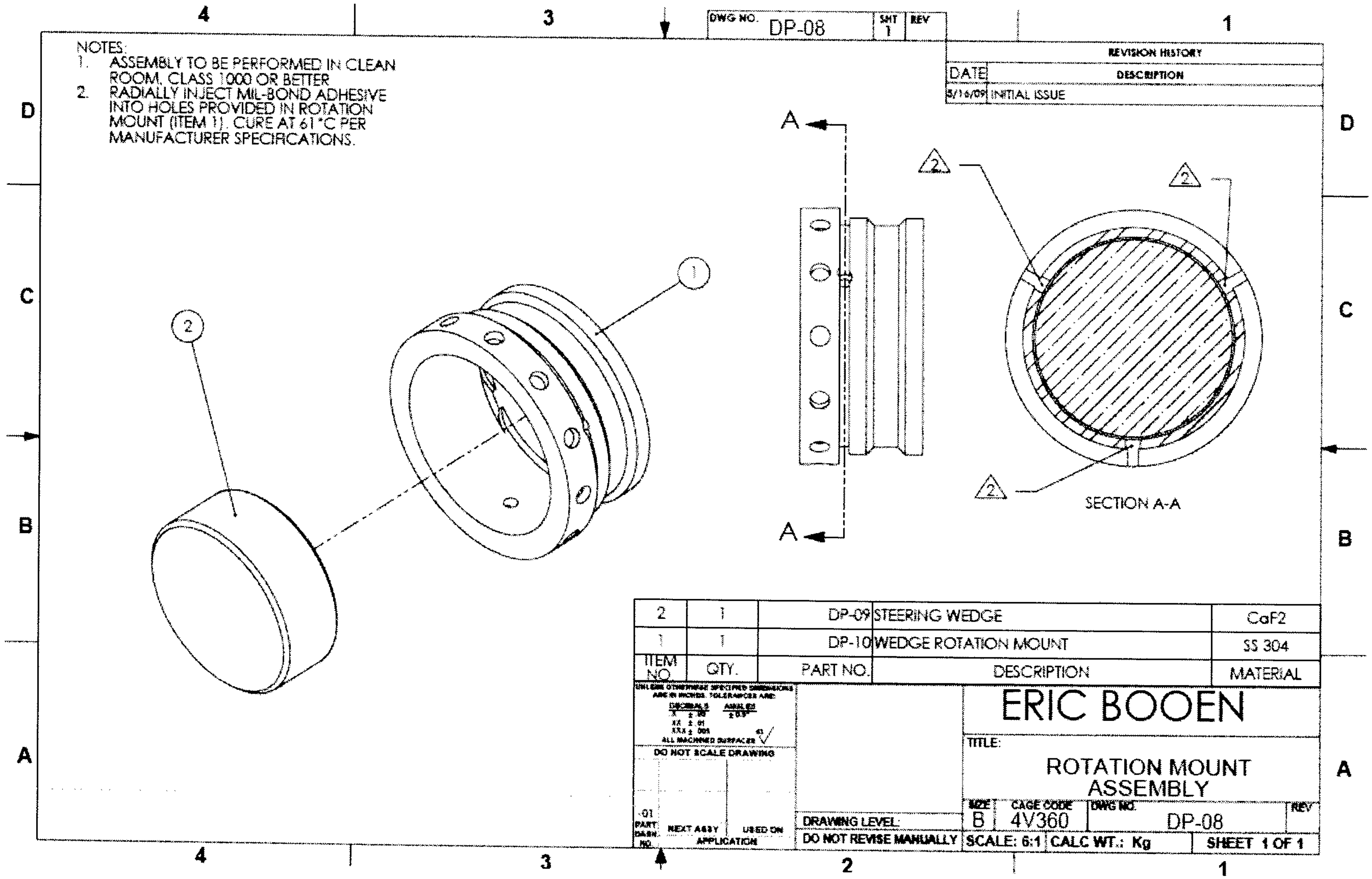
ERIC BOOEN

TITLE: IR MIRROR

SIZE	CAGE CODE	DWG NO.	REV
B	4V360	DP-06	
SCALE: 4:1	CALC WT.: 0.61lb	SHEET 1 OF 1	



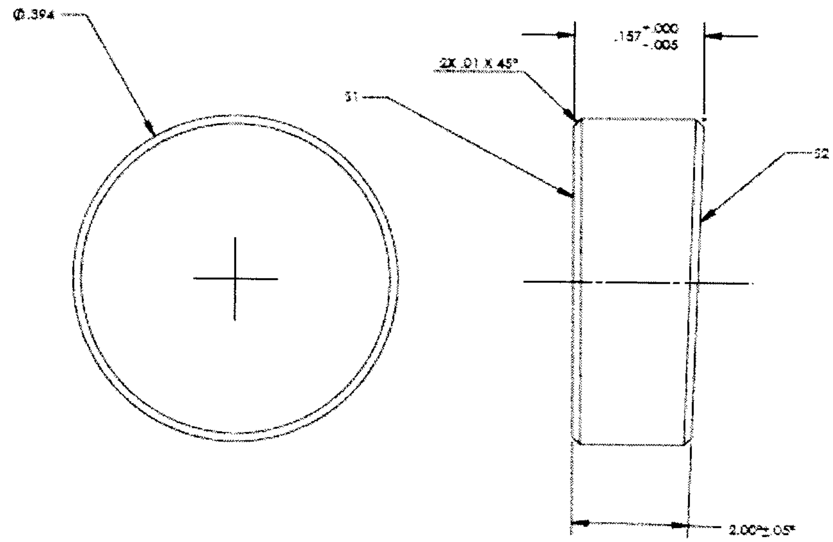
NOTES:
1. MATERIAL: ALUMINIUM 6061-T6
2. DIMENSIONS AND TOLERANCES TO BE INTERPRETED IAW ASME 14.5-1994
3. BREAK SHARP EDGES R .010MAX
DWG NO. DP-07
SHT 1
REV
REVISION HISTORY
DATE
DESCRIPTION
5/16/09 INITIAL ISSUE
SECTION C-C
6X Ø .070 THRU ALL
Ø .010 A B C
3X 27°
110°
110.00°
3X .059
3X R.187
6X R.059
40.9°
Ø .492
Ø .669
Ø .335
Ø .005 B
Ø .197
.226
.315
.256
.431
ERIC BOOEN
TITLE:
COMPRESSION PLATE
SIZE B
CAGE CODE 4V360
DWG NO. DP-07
SCALE: 4:1
CALC WT.: lb
SHEET 1 OF 1
DRAWING LEVEL:
DO NOT REVISE MANUALLY
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION


DWG NO. DP-08
SHT 1
REV
REVISION HISTORY
DATE
DESCRIPTION
5/16/09 INITIAL ISSUE
NOTES:
1. ASSEMBLY TO BE PERFORMED IN CLEAN ROOM, CLASS 1000 OR BETTER
2. RADIALLY INJECT MIL-BOND ADHESIVE INTO HOLES PROVIDED IN ROTATION MOUNT (ITEM 1). CURE AT 61°C PER MANUFACTURER SPECIFICATIONS.
1
2
A
A
2
2
2
SECTION A-A
2 | 1 | DP-09 | STEERING WEDGE | CaF2
1 | 1 | DP-10 | WEDGE ROTATION MOUNT | SS 304
ITEM NO. | QTY. | PART NO. | DESCRIPTION | MATERIAL
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
ERIC BOOEN
TITLE:
ROTATION MOUNT ASSEMBLY
SIZE B
CAGE CODE 4V360
DWG NO. DP-08
DRAWING LEVEL:
DO NOT REVISE MANUALLY
SCALE: 6:1
CALC WT.: Kg
SHEET 1 OF 1

DWG NO. DP-09 | SHT 1 | REV 0A

NOTES:
1. ORDER COMMERCIALLY AVAILABLE MIRRORS WHEN AVAILABLE
2. ALL SPECIFICATIONS APPLY OVER THE CLEAR APERTURE

REVISION HISTORY	
DATE	DESCRIPTION
5/16/09	INITIAL ISSUE



SPECIFICATION			
Material	Type	Calcium Fluoride	
	Grade	Optical	
Mechanical	S1-S2 Wedge	See tolerance	
	Edge Finish	Fine Grind	
	Clear Aperture	90% of OD, Concentric to Edge	
Optical[A]		S1	S2
	Test Wavelength	633 nm	
	Surface Flatness P-V	0.25 wave	
	Surface Flatness RMS	08 wave	
	Scratch-Dig[B]	60-40	
	Transmitted Wavefront Error	.25 wave P-V	
Environmental		Min	Max
	Storage Temperature	-60 C	80 C
	Operational Temperature	-40 C	80 C

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
DECIMALS / ANGLES
DO NOT SCALE DRAWING

-01 PART DASH NO | NEXT ASSY | USED ON | APPLICATION

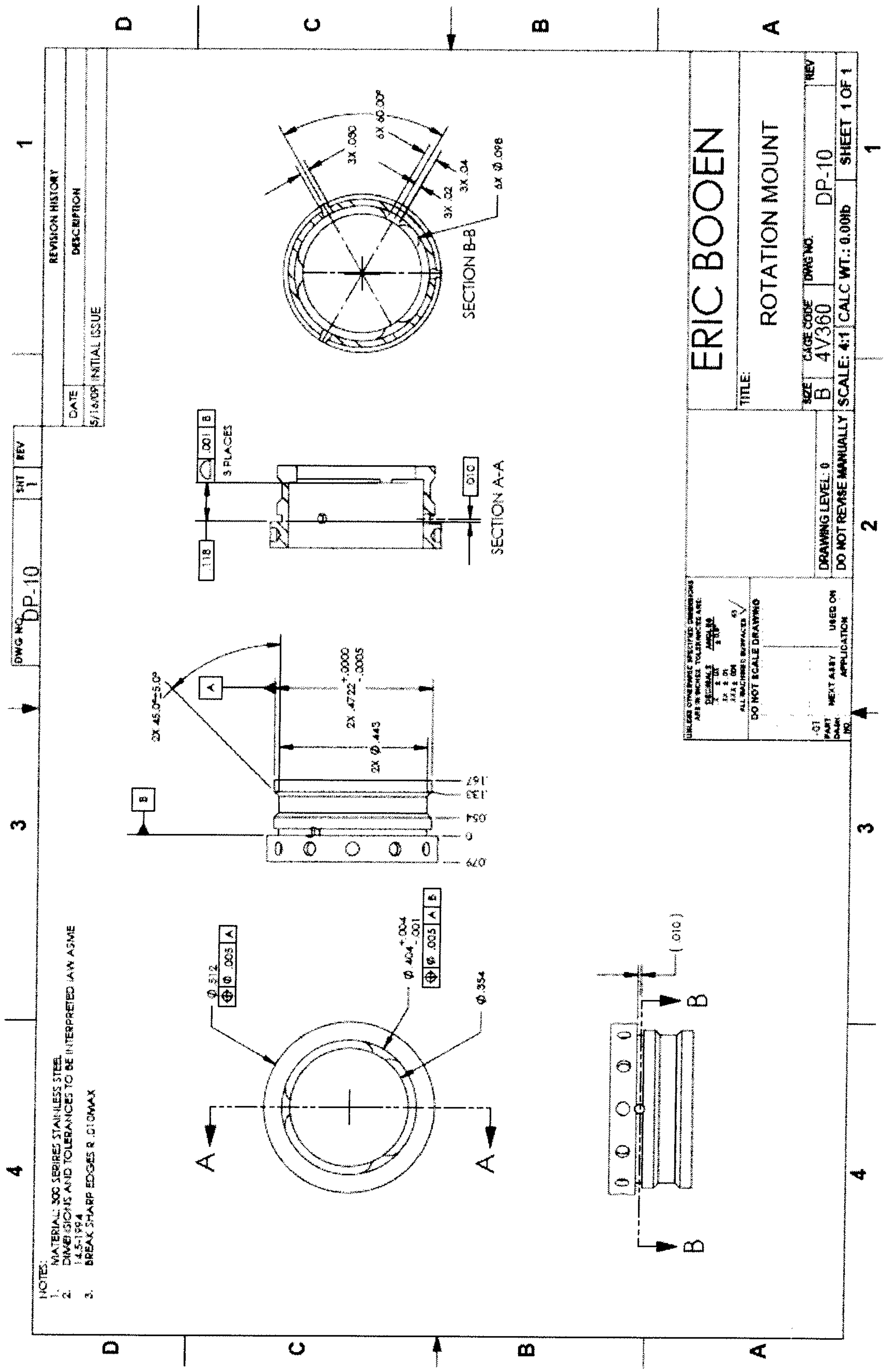
DRAWING LEVEL: 1
DO NOT REVISE MANUALLY

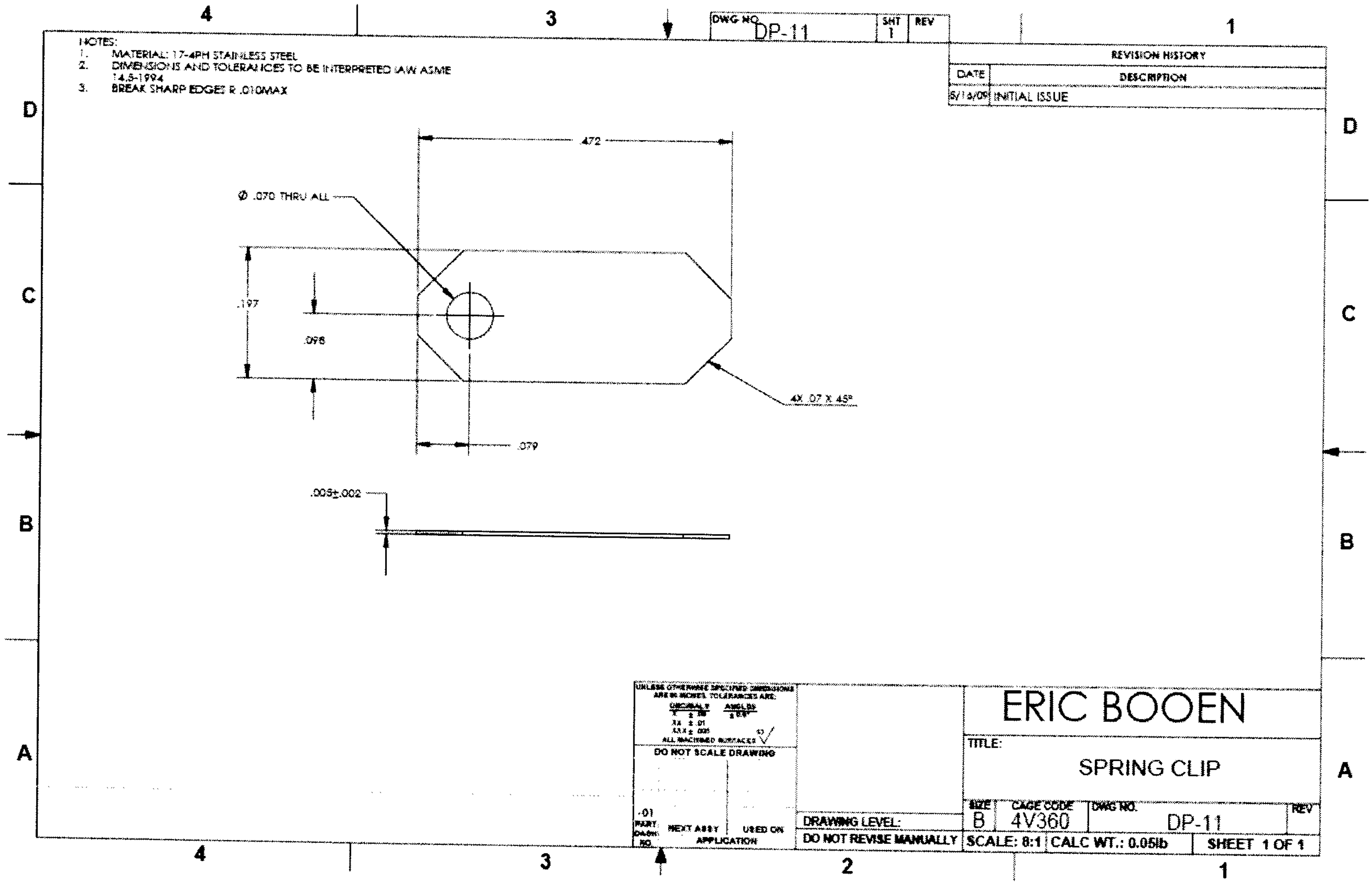
ERIC BOOEN

TITLE: STEERING WEDGE

SIZE B | CAGE CODE 4V360 | DWG NO. DP-09 | REV

SCALE: 4:1 | CALC WT.: lb | SHEET 1 OF 1


NOTES:
1. MATERIAL: 300 SERIES STAINLESS STEEL
2. DIMENSIONS AND TOLERANCES TO BE INTERPRETED IAW ASME Y14.5-1994
3. BREAK SHARP EDGES R .010MAX
REVISION HISTORY
DATE
DESCRIPTION
5/16/09
INITIAL ISSUE
DWG NO
DP-10
SHT 1
REV
SECTION A-A
SECTION B-B
3 PLACES
ERIC BOOEN
TITLE:
ROTATION MOUNT
SIZE
B
CAGE CODE
4V360
DWG NO.
DP-10
REV
SCALE: 4:1
CALC WT.: 0.00lb
SHEET 1 OF 1
DRAWING LEVEL: 0
DO NOT REVISE MANUALLY
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION


NOTES:
1. MATERIAL: 17-4PH STAINLESS STEEL
2. DIMENSIONS AND TOLERANCES TO BE INTERPRETED IAW ASME 14.5-1994
3. BREAK SHARP EDGES R .010MAX
DWG NO. DP-11
SHT 1
REV
REVISION HISTORY
DATE
DESCRIPTION
5/16/09 INITIAL ISSUE
.472
Ø .070 THRU ALL
.197
.098
4X .07 X 45°
.079
.005±.002
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWING LEVEL:
DO NOT REVISE MANUALLY
ERIC BOOEN
TITLE:
SPRING CLIP
SIZE B
CAGE CODE 4V360
DWG NO. DP-11
REV
SCALE: 8:1
CALC WT.: 0.05lb
SHEET 1 OF 1