MCDONALD OBSERVATORY, UNIVERSITY OF TEXAS

HET Project Management

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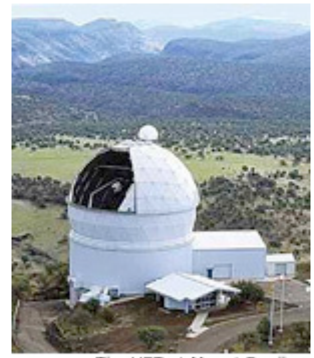


The HET at Mount Fowlkes

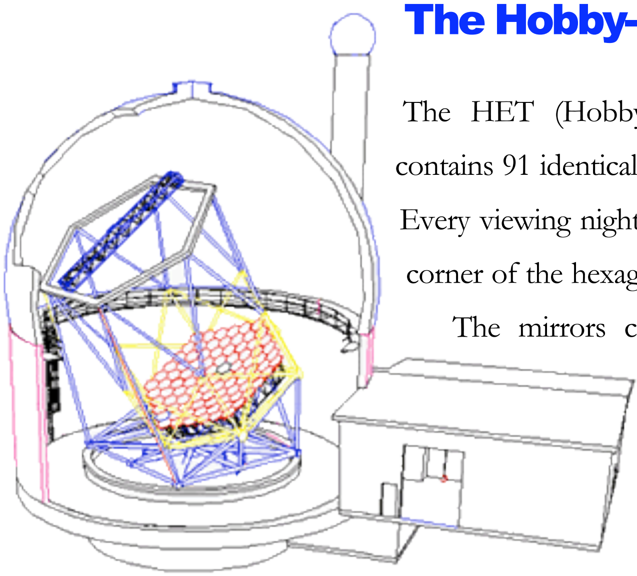
The right choice for applied engineers searching for a professional experience in applied sciences and aerospace innovation

The REU Program at the McDonald Observatory an excellent choice for any applied engineer in the aerospace or astronomical discipline. As a Mechanical Engineer it was an ideal choice for my discipline and passion for astronomy. The McDonald REU program challenges the engineering student to apply all their potential and collaborate with excellent mentors and advisors to assist the intern as you achieve completion of your specified project.

Upon entering the McDonald REU program, the aspiring engineer has attained the foundation of their education, establishing your excellence in education, present potential knowledge and the fundamentals of applied sciences and mathematics essential to contribute toward the engineering industry. Therefore, college education has paved the path for the engineer's future success in the applied engineering industry. REU programs allow the aspiring engineer to apply their present understanding and prepare the student for establishing their foundation in professional engineering.

The REU program at the McDonald Observatory establishes an experience of professional reality. It takes you upon a new dimension of research and respect to aerospace and astronomical studies. The program lasts up to ten weeks and presents each engineer with a specific project dedicated to their engineering discipline. The REU program for engineers is generally dedicated to establish the framework of project management. Project Management at the McDonald provides the aspiring engineer to use the ethics and discipline of leadership and management roles. Project Management molds the engineer into a dedicated and useful motivator, innovator, and leader for a successful project outcome and solution. I was assigned to work at the HET, the Hobby-Eberly Telescope.

The Hobby-Eberly Telescope



The HET (Hobby-Eberly Telescope), a 9.8 meter reflecting telescope contains 91 identical, 1 meter hexagonal segments made of Schott "Zerodur". Every viewing night each mirror is calibrated to precision by sensors at each corner of the hexagon to create one single 78 m^2 (839.59 ft^2) primary mirror. The mirrors create a honey-combed hexagonal-shaped mirror. This primary has a focal length of 13 meters (F 1.3), which reflects toward a secondary mirror that interprets the resolved image to an acquisition camera and fiber optic feeds to the telescope operators and residential astronomers in the HET control room. Since this mirror is open to the atmosphere it collects debris, from dust particles and bat dropping. Hence the mirrors are cleaned with CO2 foam that washes the minor debris from the surface. At the moment the HET primary is undergoing a face-lift from its present silver coating to being aluminized. Hence as mirrors are collected for aluminizing they must have a place for security and safety from surface contact. In addition, there are five spare mirrors as well that need storage housing. The intended solution is the design and construction of a mirror storage unit. Since each HET mirror weighs about 315 lbs. the rigidity of the structure must be a factor and its overall function to install and remove the mirrors from the storage unit by means of an overhead ceiling hoist. Hence, this was our challenge that intended a functional solution.

The Mirror Storage Project

For my project I was assigned a mentor, Paul Peterson, a Mechanical Engineer from the HET facility. Mr. Peterson and I discussed all possibilities of potential projects that suited my particular knowledge and potential. From four project choices, all of which were dedicated to the HET, one was selected as most feasible. This project was the HET Mirror Storage Project. I was assigned to create a storage unit capable of housing seven hexagonal, 1-meter mirrors and two calibration plates. I was to apply the project management scheme set forth by the HET McDonald division to complete this project. In addition, I was to create concepts, design, build, install, and release my storage unit to the client by my completion of my term at the McDonald Observatory.

As I completed my project I would be assisted by my mentor and collaborate with optical and mechanical technicians. While my mentor assisted strengthening my fundamental concepts of mechanics and dynamics, I grew a deeper respect and understanding of the design of my project's potential, testing my design with free body diagrams and applying physics engines to my CAD models. Many technicians, such as machinist Robert Peonisch, contributed ideas and concepts that would make this project sensible to the reality of the facility's capabilities. I also consulted my client, Jerry Martin, optics specialist, to assist me in determining our requirements and factors of safety to take into consideration. In addition, I found financial assistance from an electrical engineer, George Damm, to place PO's and develop my bill of materials. While my sponsor, Bob Calder, gave me advice in preparation of my design, as it went public to the facility and our overseers in Austin. As a result, I attained not only a new level of understanding and respect toward engineering professionalism, but a new level of confidence to apply this experience toward my future goals in engineering.

Project Management @ the HET

As a progressed along with my project I learned to apply myself and develop into an engineering profession that elevated my potential. I attained the opportunity to work in an atmosphere immersed with professionalism. My work performance was motivated to work toward my goal. I found that the plan laid out by the Project Management HET staff was beneficial toward my development as an engineer and leadership roles. I not only learned from my colleagues, but found the motivation to contribute my knowledge for a solution. The day-to-day routine of the staff found my curiosity and questions, a time to share their knowledge of their experience and job duties for the HET. At times I got the honored opportunity to assist in the removal and installation of the HET mirrors and optics devices. I not only gained a deeper understanding for their duties, but a new level of respect for the purpose of the duties they were required to accomplish and maintain.

As a new work day dawned, a new challenge awaited me. The Project Management Plan of the HET follows certain guidelines, initially with a concept, where we determine our requirements and contacts. This leads on to a Concept Review, where I presented three potential designs to the facility for the Mirror storage unit. I consider all possibilities, from an in-house design that we would fabricate and construct, to a manufactured unit. Of these choices, my client chooses one that will become our concept. Thus, I enter the Design Stage. During the Design process I test the concept with free-body diagrams and apply Algor Fempro®, a physics engine to test the design to static and dynamic loads. We complete my CAD using Autodesk Inventor® and create the finished design, which bought my concept to reality.

After I complete my design, I arrange a formal meeting with my client and sponsor to a Design Review. At the design review, I present my analysis and data I have determined for the given loading. I explain the function and how the storage unit will operate, satisfying our given requirements. We discuss any modification and safety factors to consider. And finally, I present a bill of materials and an estimated cost for the project. Eventually, we come to an agreement that the design's potential can indeed become a reality, and we move toward our next phase- Construction.

During the construction phase, I collaborate with my welders, fabricators, and machinist to create my assembly drawings. I create individual components of each piece, and give descriptive instruction of its material composition, dimensions, quantity, and special considerations for fabrication and installation. We purchase our supplies and track our deliverables. As we await our order, we prepare the installation space for construction. Since this project requires mounting to our support beams and foundation, we start the boring and drillings for our anchor bolts. As supplies come in I assist the fabrication of jigs, templates to assist our welders in complex angle welds. Fabrication takes about one week to complete, and our welds take an additional 3 days. Once all components are complete, we machine and sand rough edges for our metallic coating. Once we have a complete shelf, we run a mock load test, to ensure that the shelf can hold the tolerated load we desire. We place 300 lbs of material onto the shelf and measure the deflection and compare that to our analyzed results. Once satisfactory, we are now ready for installation.

As we install the components, I direct the correct installation procedures for the support structure and installation of our shelves, which would be mounted by tapered pillow-block bearings. As we complete installation, we a ready for the release. During the release, I present the unit to my client and give all the necessary information of operating procedures and safety consideration for the storage unit. I also present the potential modifications that can be included, such as a housing for each mirror, a housing for the entire unit, and a locking device to prevent operation by those that may not specialize in optics. After the release, my job is now done and this project has attained all the requirements it set out to satisfy.

Project Management at the HET, follows a guide that not only makes the task easier as a guiding principle, but your appreciation to its completion and understanding of its structure and composition. Professional ethics such as, leadership, time management, critical thinking and organization all apply to a successful project. As my project developed, I developed to understand my capabilities and how my potential could contribute to the project's success. I learned to think critically and find solutions to the project by the fundamentals I applied from my education in statics, dynamics, mechanics, and basic calculus. In addition, technology, by CAD models and physics engines brought my designs to a new perspective of reality. In the end, I found success in a project that helped me mature and develop into my profession. In conclusion, The McDonald REU prepares the aspiring engineer for the concepts and reality of the professionalism in engineering.

McDonald REU Summery

The REU program is dedicated to engineers with a potential to contribute to the astronomical and aerospace industry. The program welcomes all engineering disciplines. The program last ten weeks to complete your specified project. There is a stipend of $325/wk. The Astronomers Lodge (AL) houses the interns during their ten week stay. Food is served at the AL at a faculty discount, with a buffet style. As you complete your project, you are given the opportunity to assist at public Star Parties, visit local Observatories (i.e. VLA, New Mexico), and experience research in a new perspective of science and technology. During my stay I applied my stipend into a college savings that I could apply to my future educational expenses and project developments. The McDonald REU program for engineers is the ideal choice to elevate the aspiring engineer into a professional reality.

The McDonald REU program is coordinated by Matthew Shetrone, (432) 426-4168, shetrone@astro.as.utexas.edu

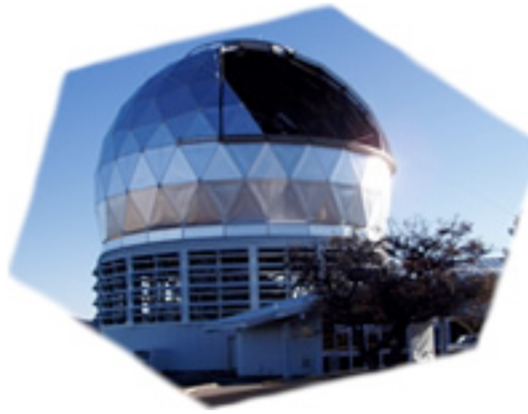
HET

NOTE: The following is a detailed account of the HET Mirror Storage Project; it follows the HET Project Management scheme and includes detailed analysis and assembly drawings.

HET Project Management

Project Management at the HET prepares the engineer the essential tools, necessary for professionalism.

- *Concept*
- *Design*
- *Build*
- *Install*
- *Release*



HET Facility Goals

- *Apply Science and Basic Fundamentals*
- *Establish Safety Guidelines*
- *Create a functional/operational ease*
- *Create Project Management Experts*

Concept

During the Concept phase we determine an idea for the solution at hand. This idea can be far-fetched, for we are brain-storming all possibilities to solve our problem. We initially identify who is our project sponsor/manager. We meet with our client to determine what requirements we must satisfy. We then take this data and acquire what techniques may need to be applied to the project, i.e.: CAD, Free-body diagrams, construction, fabrication, or welding We then research what existing systems or techniques can be applied to the design. We research the data and concepts that our manufacturers can supply for a solution. After all data is collected, we thus customize all our resources to satisfy the outlining function of the project. Before we start our CAD models, we test our concept with free-body diagrams. We can now determine our Reaction Forces and Moments that may occur during static and dynamics operation. Once we are comfortable with our results, we can create a CAD model of the design. For any project, it is reasonable to come up with three different concepts for the client to choose from, one is usually a manufactured unit, so we can compare our design to that on the market. In addition, an overall concept of how each concept will satisfy the requirement is essential. Be honest and give the pros and cons of each concept to the requirements. And finally, take into account Safety Factors, whether it be function to basic risk assessment of the designs. Now you are prepared to meet with your client and sponsor for a Concept Review and decide which concept satisfies the given requirements.

Design

After we have determined which concept is satisfactory, we can now get to work detailing our concept, through design. We initially take dimensions of our installation space and modify our concept to represent a fixture of reality. Based on our previous hand calculations we can compare our CAD models through a physics engine, which will test the stress and strain of our design. Algor Fempro is such an analyzer that can be applied to our design, after we indicate the applied loads and constraints design. You must never trust an analyzer until is agrees with the calculated results we determined. Many complications can occur during the analysis that are unseen by the user. This is software is used to mimic reality, not become reality. Once we establish our complete detailed design up to scale, we can determine the required materials that need to be purchased, customized, or supplied by our in-house unit or distributor. Research all the necessary information of your components, from composition to tolerances, which are compatible to the design and its function. Once complete, create your Bill of Materials, a list of all required components of the design and purchasing information from contacts, quantity, dimensions, and overall cost. During the Design Review, present the overall function and how this design satisfies the given requirements. Include its safety factors and operational use while in static and dynamic phases. Give the bill of materials to your sponsor to decide if this project has a feasible budget. Once this design attains satisfactory results, allow the project team to understand the construction and installation schedule and when deliverables will be achieved.

Build

We are one our way in bringing our concept to reality! During the Building phase we can now purchase all required supplies and await their arrival. During this time, prep the installation space for construction. Work collaboratively with your machinist, welders, and fabricators in determining the necessary information they will need in the assembly drawings. Create detailed assembly drawings that specify the dimensions, tolerances, and special requirements that are needed for each component that may need in-house fabrication and welding. Determine the special tools and jigs that may need to be supplied to help speed up the construction process. Once Materials are delivered, begin assembly of the components. After a section of the design can be assembled, plan a test to generate a mock load/operation of the design in the work shop. Test this design by means of loading the device to its maximum potential. Operate the device as it was to function. This test will ensure that our design meets the anticipated requirements, before we install the unit. Finally determine the installation team and date for which the unit will be installed to its destined location.

Install

If the installation process permits we may have to issue an installation plan that will assist us in the assembly of the unit. Once installed, we set the tolerances of any device that may need to be calibrated. Then we can ensure that the device is fully operational and ready for release.

Release

The Release is the final phase of our project. At this time we present the designed installed unit to the client and operational team that will be operating the unit. We give a brief demonstration of the unit's operation and function. We assist and train the client as they operate the unit for the first time. We then supply our client with any consideration to take into account, such as future modifications and applications that can help the present design's functionality. We then supply our sponsor with all data, from analysis, assembly drawings and instructions for future reference. Finally, we have met the requirements set forth by the HET Project Management and Development division to ensure a successful solution for our given requirement.

The Mirror Storage Unit

The Team

- Client: Jerry Martin, Optics Technician
- Sponsor: Bob Calder, Facility Mgr.
- Project Manager: Johnny J. Mendias, REU
- Welders: Jerry & Robert
- Fabrication: Johnny, Robert, & Paul
- Installation: Johnny & Robert

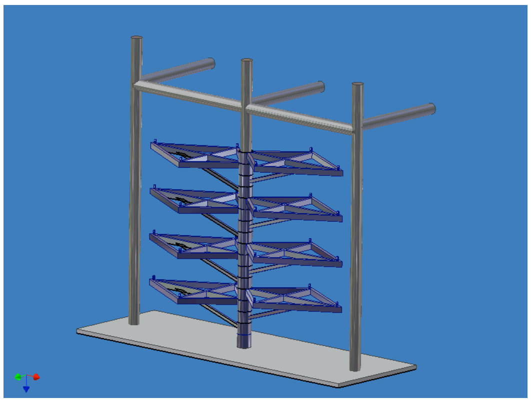
The Challenge

Create a Storage Unit to house 7 hexagonal mirrors with their mounts attached for the Optics Lab

The Requirements

- Create a functional, accessible storage unit to house a max. of 7 mirrors.
- Must tolerate a load of 315 lbs per shelf.
- Be accessible to hoist, for placement on each shelf.
- Be of rigid construction and minimize vibration.
- Must not obstruct access to exiting doorway
- Optional: Create storage for calibration plates.

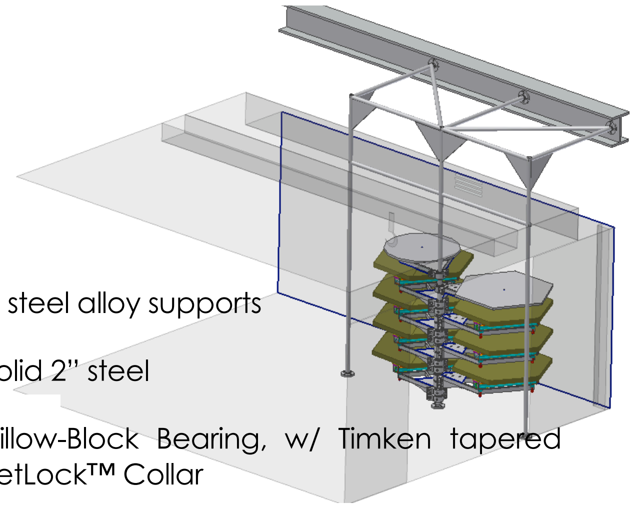
The Concepts



- **Solution A:** *The Mirror Tree*
- Rigid construction
- Houses 8 mirrors supported by a single post with bearing supports to each individual shelf.
- Rotational shelves satisfy our desired hoist location and provide min. vibration.
- Loading is distributed to longitudinal axis of post and supports.
- Installation space is kept at minimum requiring only 7.5' of space.
- Swivel arms do not obstruct access to exit, clearing at least 3'
- Installation is rigid and permanent.
- Meets all necessary requirements.
- Recommended Solution.

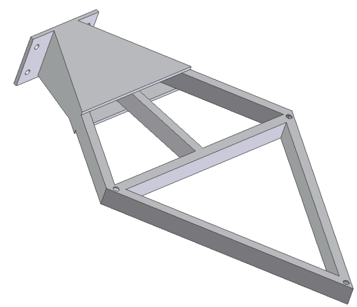
- **Solution B**: *The Mirror Rack*
- Design is compact and rigid.
- Swivel Shelves on either side of parallel poles.
- Internal load is distributed by supports
- Can house only 4 mirrors on each side.
- Must require more installation space (up to 12') and materials.
- Right mirror shelves could possibly obstruct exit.
- Permanent installation.

- **Solution C**: Manufactured Storage Unit
- *Material Handling Sales Inc*, High Density Storage
- Distribution center located in Maine.
- Can hold excessive loads, up to 3000lbs
- Unit may need modifying; drawer-type units are rare.
- 12" Clearance between each shelf
- Temporary unit, may be relocated



The Design

- *The Mirror Tree*
- Composed of structural steel alloy supports
- Single shaft support of solid 2" steel
- Mounted to Dodge Pillow-Block Bearing, w/ Timken tapered bearings, and locking SetLock™ Collar
- Mounted Skeleton Shelf Design
- Holds up to 7 HET mirrors w/ mounts
- Additional shelving for calibration plates



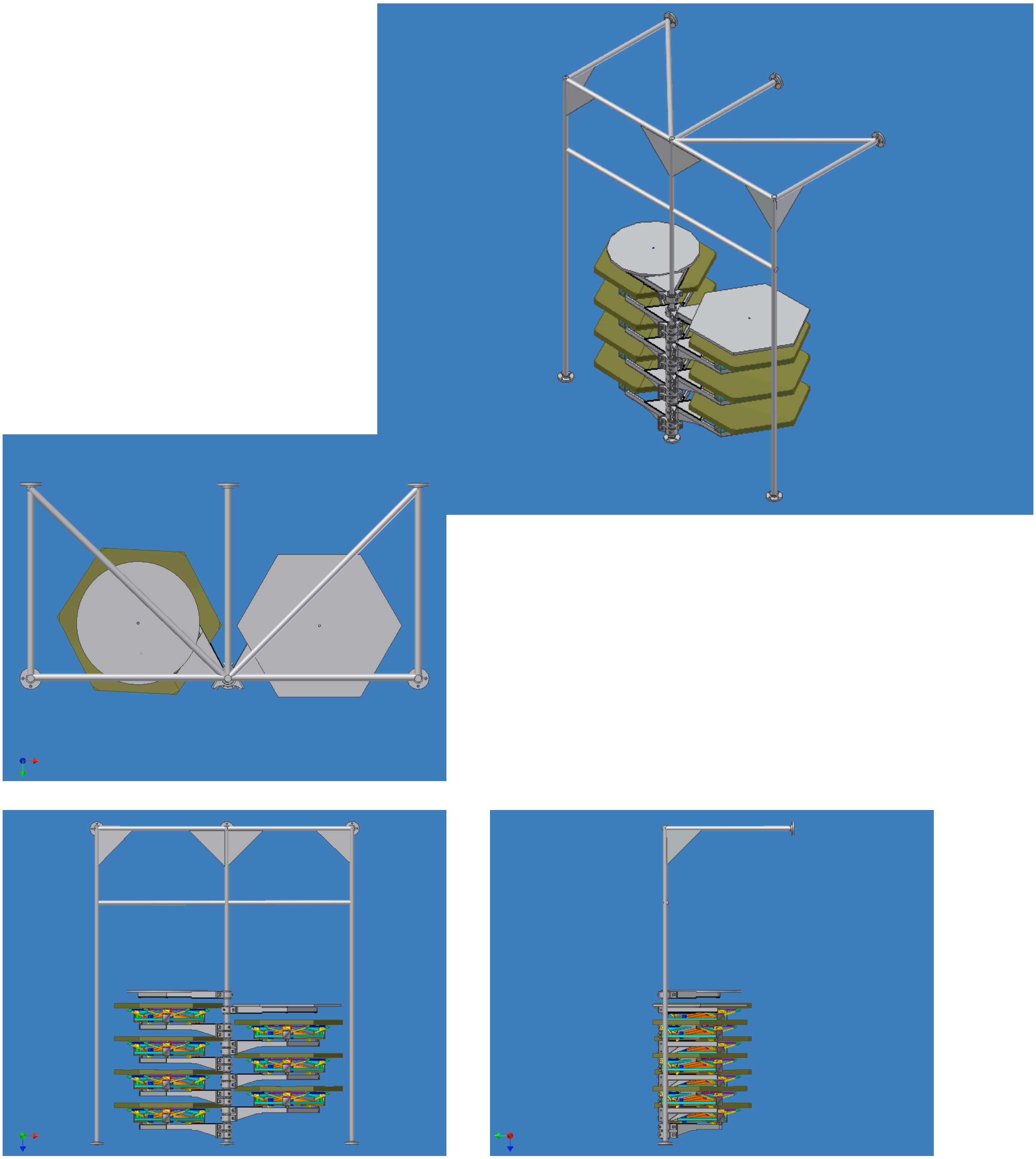
The Function

- Each mirror will be stored at a 30° from plane of rotation
- Establish a 120° rotational displacement for each HET shelf
- Shelf rotates out 90° to access hoist location at center of each shelf (appox. 22")
- Clearance of 14" between each shelf
- Access to top self gives 10" of clearance to hoist

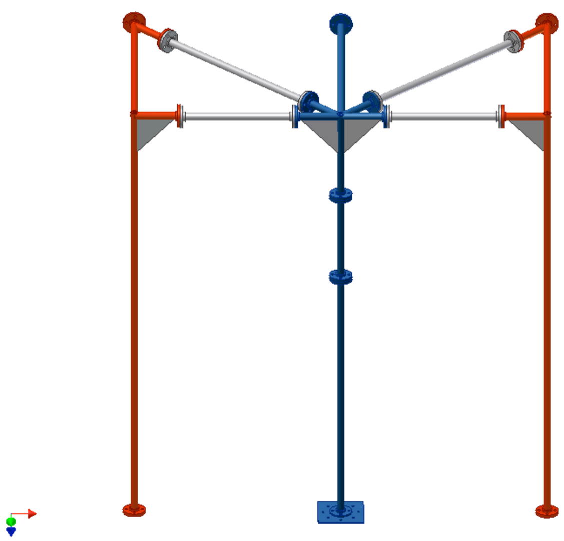
The Safety

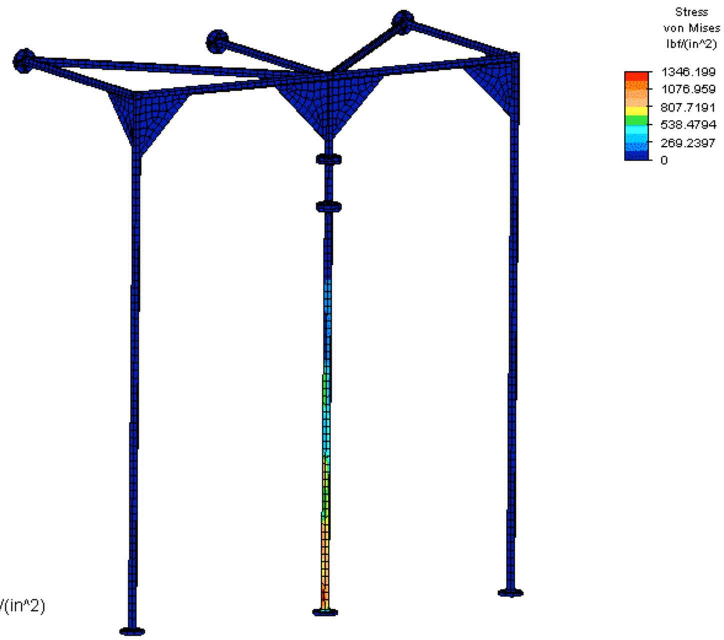
- When shelf is in use, clearance of 4' to exit
- Steel Retractable Spring Plunger w/ lock down nut will set the rotational displacement in storage and in use.
- Locking latch gives stability and security to shelf while in storage.
- Mounted locating pins on shelf prevent vibration and movement while in motion.

The HET Mirror Tree



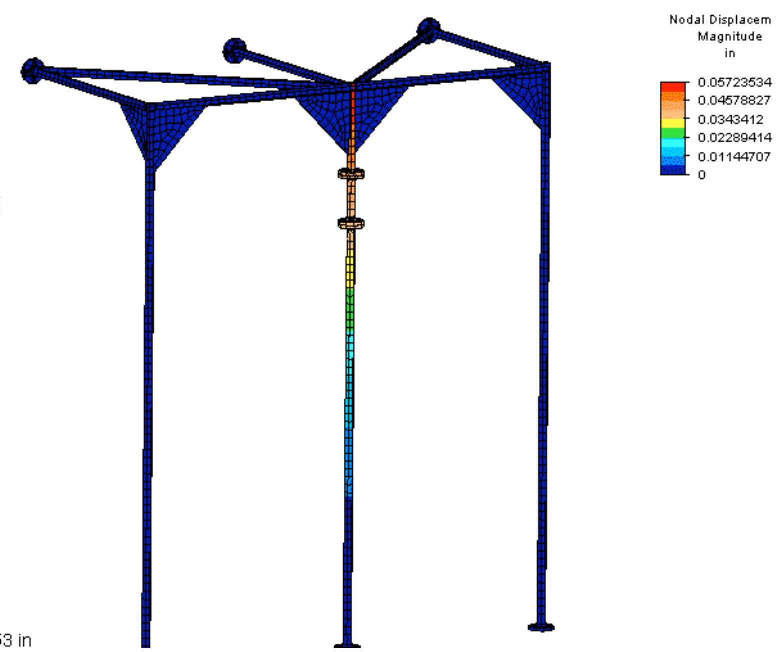
The Structure





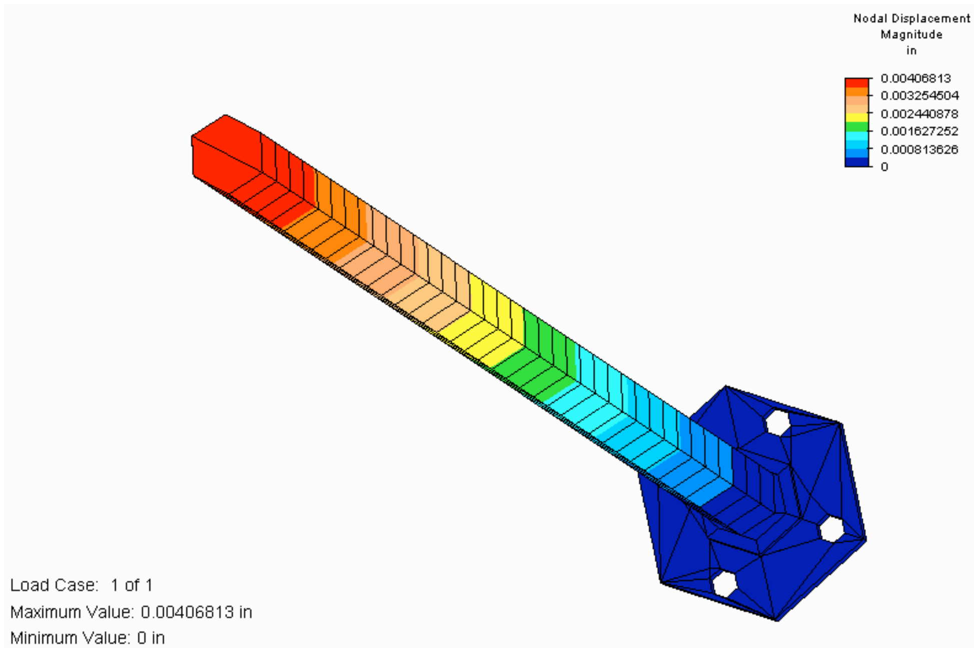
Load Case: 1 of 1
Maximum Value: 1346.2 lbf/(in^2)
Minimum Value: 0 lbf/(in^2)

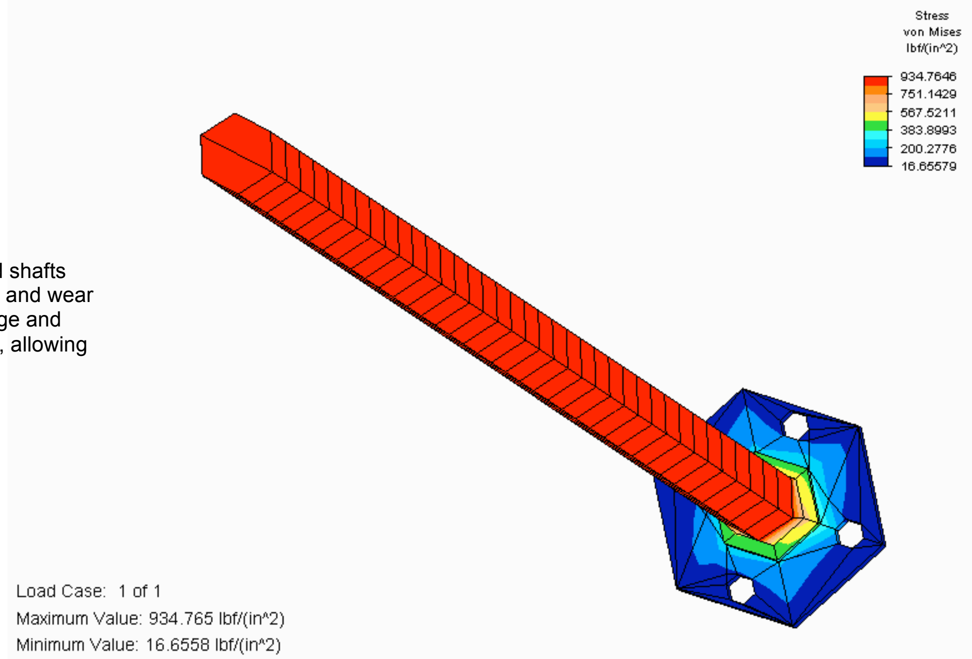
- Overall strain 1345 lbf/in^2
- Young's Modulus for ASTM A53: 297000ksi
- Thus Strain= .000046 in/in
- Overall displacement with full load of 2300lbf= .057"



Load Case: 1 of 1
Maximum Value: 0.0572353 in

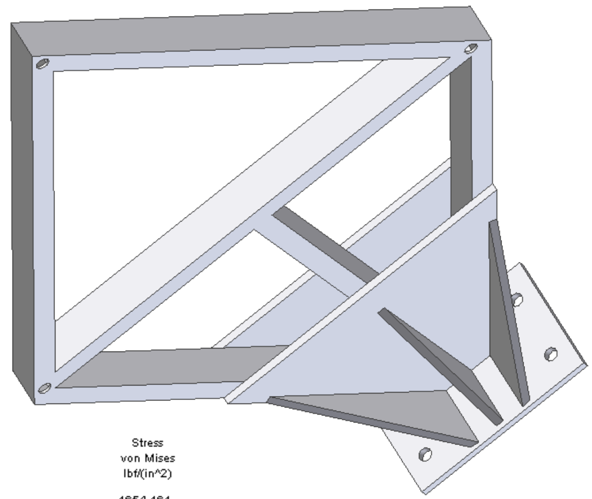
The Shaft

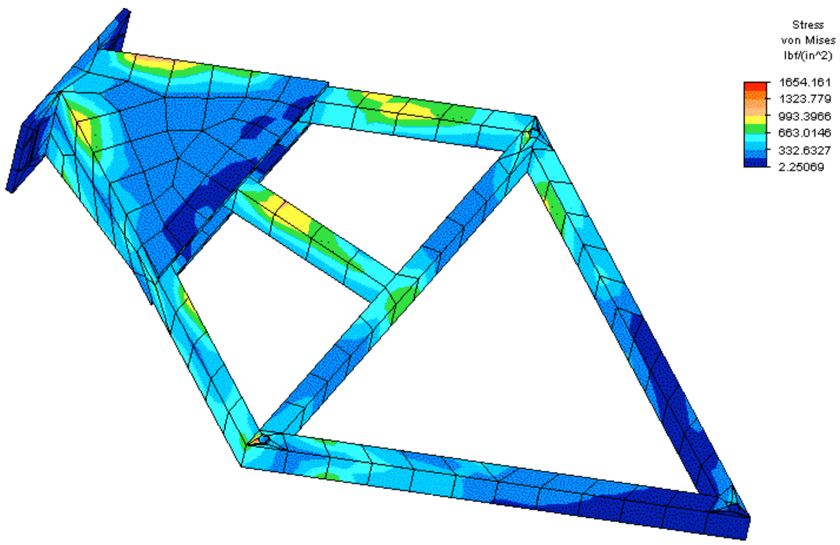




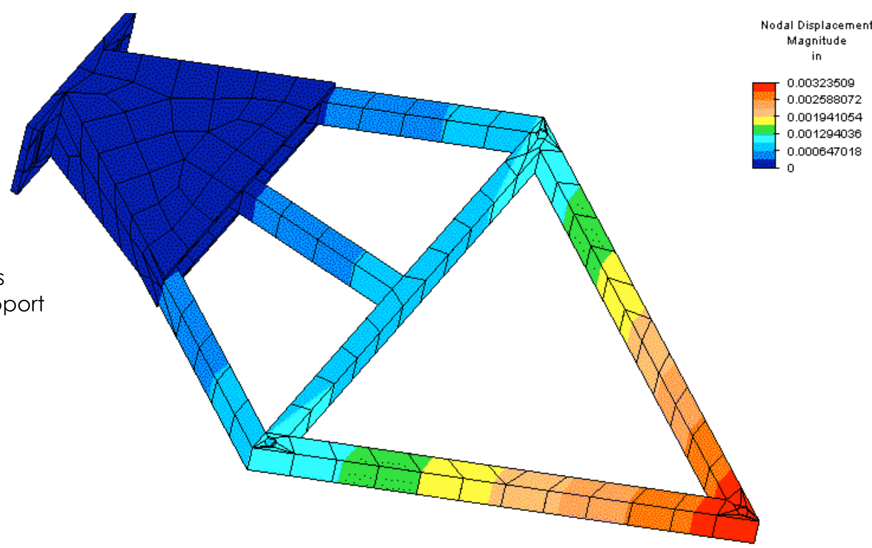
- Machined to precision steel shaft
- Shaft Tol: .0006 to .0013
- Applications include gears, pins, and shafts
- Low carbon steel, slow to expansion and wear
- Welded in place at base to floor flange and threaded into overhead flange union, allowing future removal of bearings.

The Shelf





Load Case: 1 of 1
Maximum Value: 1654.16 lbf/(in^2)
Minimum Value: 2.25069 lbf/(in^2)

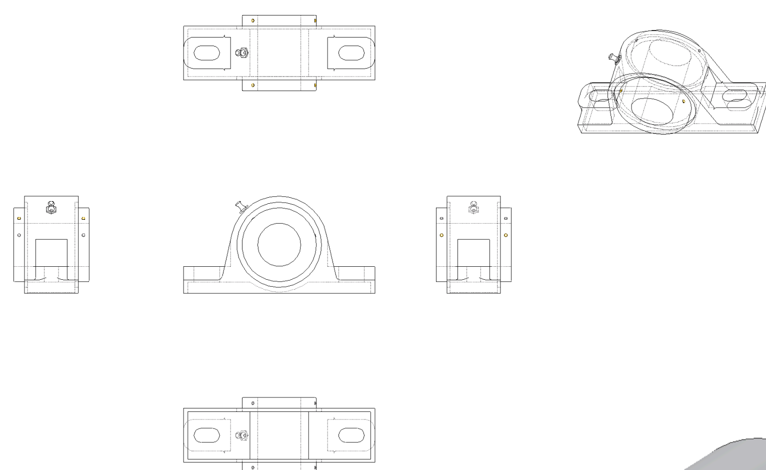


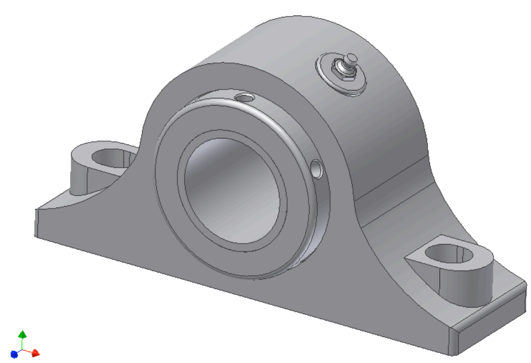
- We have a moment load of 8800 in-lbf
- Stress is distributed back to center supports, thus allowing our mount to distribute our loading support evenly among our two pillow-blocks
- Overall stress: 1654 lbf/in^2
- Moment of inertia: 49054.93 lbf/in^2
- Modulus of Elasticity: 29000 ksi
- Thus Strain: .0000367 in/in
- Overall Displacement: .0032 in

Load Case: 1 of 1
Maximum Value: 0.00323509 in
Minimum Value: 0 in

The Bearing

- Dodge Type E-Xtra Pillow-Block Bearing with 8" mount.
- Entirely sealed and assembled to mount
- Timken Tapered Bearings, w/ TDI arrangement, inner race movement on shaft
- Supports any to all moment loads
- Our set of 2 TDI's = modified TDO
- Holds trust load of 6908lbf, ours is max of 1500lbf
- Radial load of 16800lbf
- ASTM A48 Cast Iron Housing
- Set Screw Set-LOC™ Collar creates eccentric 360° hold up to 3500 lbf to our shaft
- Two Bearings per shelf will satisfy our loading and prevent misalignment of bearings
- Most economical solution to our loads and reverse engineering application.





The Flange

Support flange:

- Will hold 300 psi,
- Total area: 28.27in^2
- Total loading potential: 8482.30 lbf
- Our foundation will hold up to 150psi = 4240 lbf (see structural design S1 in blueprints)
- Our intended load w/ mirrors = 4046.83 lbf

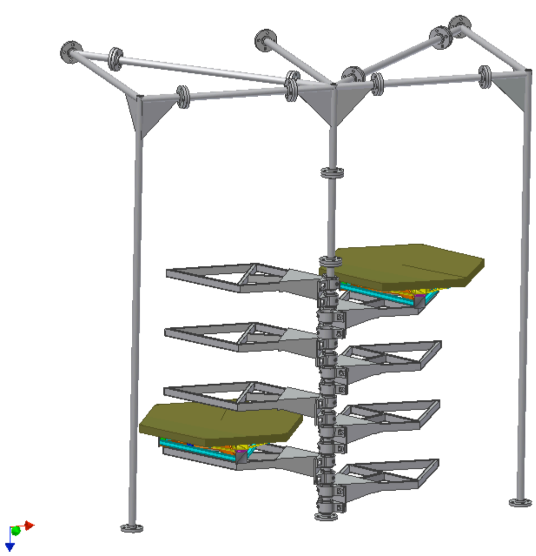
- Note: This will be welded to our machined shaft and anchored to foundation by WeJ-It anchor bolts

Steel Weld Fitting
Raised Face
Class 300 Socket-weld Flange

Union flange:

- Will hold 150 psi,
- Total area: 28.27in^2
- Welded to our steel shafts
- Bolted by 5/8” bolts with lock washers and nuts
- Note: One union flange will be threaded to our machined vertical shaft, for removal of bearings and collars.

Union Flanges
Weld Neck Class 150
Raised Face



The Instructions

The following is detailed instructions of the HET Mirror Tree Storage preparation, construction, fabrication, installation, and operation.

1. Follow Bill of Materials to purchase the required components,

   Venders include:
   - Alamo Iron works, El Paso, TX (915) 593-5885, Rep. Benito
   - McMaster Carr, (800) 834-9427
   - Applied Technologies, Odessa, TX (432) 332-6417, Rep. Bobby Mariott

2. Deliverables of supplies is as follows:
   - Alamo Iron works: Place order by Fri., Delivery to Ft. Stockton by Mon. (You may deliver to Triple J Services HQ, 2 miles South HWY 385, right at intersection with Alamo Rd, Address: 1266 W. Alamo Rd.) please inform upon delivery: (432) 336-6863
   - McMaster Carr, ships US Ground, 3 day delivery
   - Applied Technologies, takes 2-3 working days for receiving, 1400 W 2nd St., Odessa, TX 79763

3. Installation space has been prepared. All insulation for the second floor can be located above the maintenance closet on the second floor.
4. Follow assembly drawing 1.0 to determine the location of bores for the overhead I-beam and floor bores.
5. Construct jigs for shelf units, follow assembly drawing 1.9
6. When steel arrives start fabrication of shelves follow assembly drawings 1.3-1.8
7. Construct Steel support arms, assembly drawing 1.0
8. Weld union flanges to support arms.
9. Complete welds on shelves, unions, and support arms.
10. Weld all required plate ribs to support arms
11. Grind down all welds to smooth finish
12. Coat entire structure with black HET paint to preserve from rust.
13. Paint all shelves and lower support arms (110" from base) with silver hammered Rust-Oleum Paint, give two coats as needed.
14. Machined Shaft:
    - Weld class 300 socket flange to end of shaft
    - Weld Base plate to 300 psi flange(assembly drawing 2.4)
    - Thread other end 11 thread/in for union flange
    - Bore 3/8 holes as in assembly drawing 2.1

15. The LOAD TEST:

- Mount one completed shelf to two pillow-block bearings and insert over a 2” shaft (Located in Machine Shop) which will be welded to a 2” ID flange at base.
- Load the shelf with 100lb weight on each corner of shelf.
- By using a distance stick (like that used for a transet) Mark the distance from the level ground to the top surface of the shelf
- After the weight is added, mark this new distance, compare this results with those on pg 16, under shelf displacement.
- If this surpasses load requirements, add a load of 500lbs at each corner, this should reach our max displacement, since we have a safety factor of 5 that should hold this load.
- If it remains within Max displacement, The shelf will hold a MAX load of 1500 lbs and passes our reality test.
- Continue to the installation

16. Install the assembled components
17. Bolt the two side supports into the foundation with Wej-It Anchor Bolts (four Bolts each)
18. Bolt all overhead flanges to I-Beam (Note: as one person screws the hex bolt from the first floor, the other installer can reach from the side wall of the second floor to secure the lock washer and nut next to Bob’s Office)
19. Install center overhead support to I-beam (hold this unit up by bailing wire supported to truss.
20. Input all union inserts of overhead supports together by lock washers, nuts and bolt fasteners, (4 bolts each)
21. Before drilling into our foundation determine where rebar lies. From SPECS: Rebar 12” apart, 1.50” from surface. Bore holes for Wej-It Bolts.
22. Attach center Shaft to foundation by 8 Wej-it Bolts into class 300 flange and eight Wej-it Bolts into base plate
23. Slide bearings and collars in this order: Bearing/Collar/Bearing/Bearing/Collar/Bearing/Bearing/etc…

24. You should have 16 bearings and 9 collars inserted
25. Place threaded union onto threaded vertical shaft, should be 72” from base.
26. Insert last vertical union flange support into place and bolt(4 bolts per union)
27. Position each pillow-block bearing as shown in assembly drawing 3.1

28. lock all collars into place
29. Space each collar 1/8" clearance and lock into place
30. Set tolerances on bearing torque as specified in Dodge P2BE200R specs on pg.
31. Install mirror shelves
32. Place shelf mount over pillow-block mounts and bolt with 4 5/8" bolts, lock washers, and nuts
33. Insert Locating pins into shelf corner bores.
34. Continue until all shelves have been installed in proper order and arrangement, assembly drawing 3.1
35. Position all shelves in their storage positions 30° to receding wall
36. The Mirror Tree is now ready to load with the HET mirror
37. Rotate a shelf out 90° to installation position.
38. Mount HET mirror to hoist supports on hoist.
39. Lift to designated height and position hoist over mirror shelf.
40. Lower HET mirror until locating pins acquire their designated positions in the Mirror Mount Bores.
41. Lower HET mirror onto shelf.
42. Remove hoist equipment and raise hoist
43. Rotate Shelf with HET Mirror slowly into storage position and lock into place at bored pin.
44. The installation and storage of a HET mirror is complete!
45. NOTE Calibration plates are placed on the upper shelves and may require a custom hoist supports to place at this level and height. The round calibration plate is placed on a shelf that is mounted to two dampened u-bolts in a storage position of 30°, therefore this shelf does not move and must be placed onto its storage shelf by hand.

Special considerations:

- **Only those specializing in Optics Care and Handling should operate this Mirror Storage Device.**
- Always check the tolerances of the bearings interference to the shaft initially once a week, then twice a month. See attached Dodge Tolerance Sheet for more information.
- Make sure no leakage occurs around bearing seal, if so, this is a manufacture default, return and replace
- Check the deflection of each shelf once a month as we did in previous loading test.
- If removing a bearing or collar, **remove all HET mirrors from the unit,** this union prevents moment loads to occur.
- This unit can be modified for future potential projects, like an enclosed housing, **only mount to side supports**, center support is needed to constrain our union to shaft and must not vibrate or increase deflection.
- Operational Animations and Project's Progress Located on HET MIRROR STORAGE PROJECT CD 1 in PowerPoint Presentations.
- For more information, refer to CAD drawings on HET MIRROR TREE/MIRROR rev 2.0/ CD 2 in Bob's Office (Inventor Ver. 8)

- **Original Concept and Design by:**
  Johnny J. Mendias III, REU
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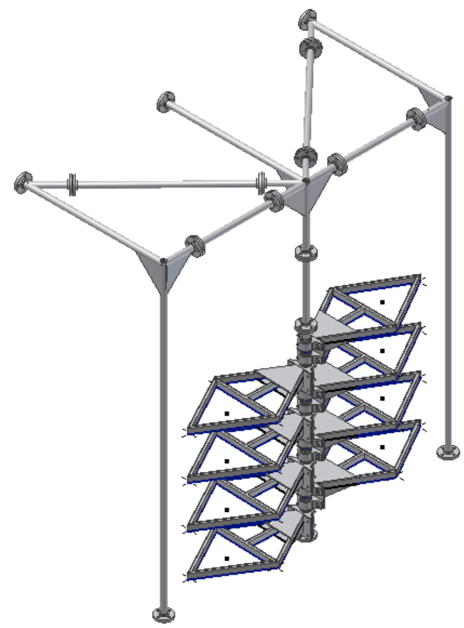
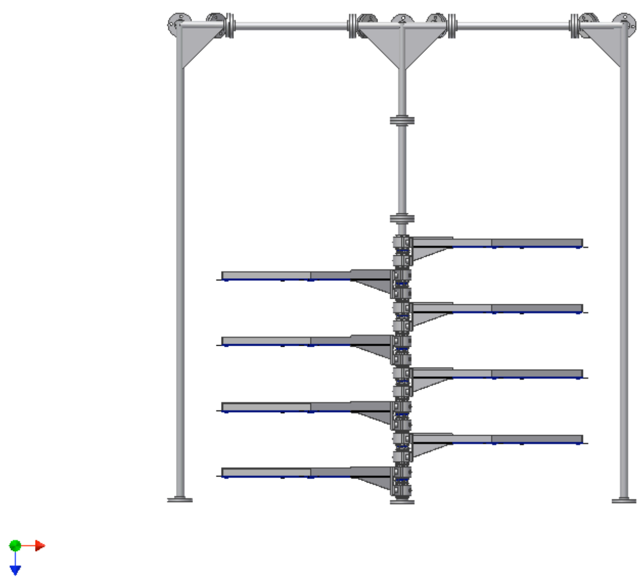
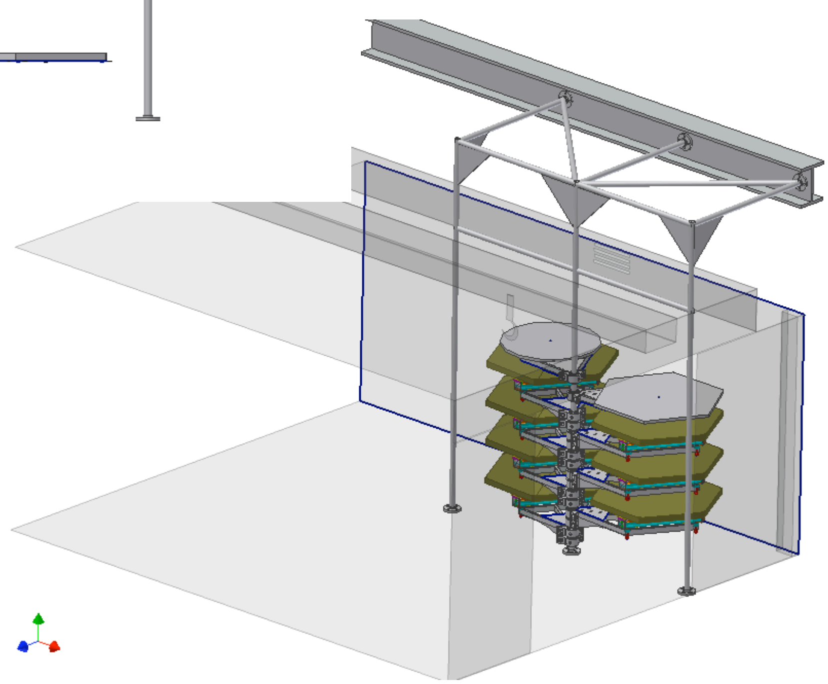
Bill of Materials

Item	Description	Distributor/ Location	Phone	Item #	Quantity	Cost
Dodge Pillow Block Tapered Roller Bearings	Cast Iron housing, Timken TDI Tapered Bearings, Set screw locking collar	Applied Industrial Technologies, Odessa, TX	(432) 332-6417	DODG P2BE200R	16 @$160.41 ea.	$2566.56
2" X 21' Continuous Weld Steel Pipe	Black Standard, Sch. 80, beveled end .154 wall thickness	Alamo Iron Works, San Antonio, TX	(800) 292-7817	948414	5, 104' @ 74.80 each	374.00
3/8" Hot Roll Plate	4'X10' ASTM A36 hot rolled plate	Alamo Iron Works, San Antonio, TX	(800) 292-7817	922658	1	271.50
2"x1"x24' Rectangular Tubing	ASTM A513, .120" wall thickness	Alamo Iron Works, San Antonio, TX	(800) 292-7817	937508	7, 165' @ 29.42 each	205.94
Flange bolts	5/8"-11 UNC	Alamo Iron Works, San Antonio, TX	(800) 292-7817	145540	13 sets @2.34/ set of 4 bolts and nuts	30.42
Steel Paint	Silver Rust-Oleum Enamel Hammered Metal finish	Alamo Iron Works, San Antonio, TX	(800) 292-7817	1691041	5, @37.35/gallon	
Threaded Flange	2" ID x 6" OD raised neck/ 150psi	McMaster Carr		68095K125	3 @ 14.42 ea.	43.26
Socket weld Flanges	2" ID x 6" OD floor and union flanges, socket weld neck w/ raised face	McMaster Carr	(630) 834-9600	68095K145 6806K145	24, @ 14.04 each 3, @ 17.33 ea.	336.96 51.99
2" X 6' Precision Steel shaft	AISI 1566 steel	McMaster Carr	(630) 834-9600	6061K98	1	338.67* Price may vary
5/8" Bolts	Heavy Hex Bolts, 5/8-11 UNC x 3"	McMaster Carr	(630) 834-9600	91571A274	150 @ 14.92/pk of 25	89.52
5/8" Nuts	5/8-11 tuff-torq hex nut	McMaster Carr	(630) 834-9600	90499A832	150 @ 10.05/pk of 50	30.15
5/8" Washers	5/8 SAE tru-torq flat washer	McMaster Carr	(630) 834-9600	90108A035	195 @12.99/pk of 65	38.97
5/8" lock washers	5/8 SAE lock washer	McMaster Carr	(630) 834-9600	91104A035	200 @14.95/pk of 100	29.90
5/8 Anchor Bolts	5/8"x3.5" Wej-It Bolts	McMaster Carr	(630) 834-9600	94475A295	16 @4.86 ea.	77.76
¾" Locating pins	Locating pins for mounting shelf to mirror mount	McMaster Carr	(630) 834-9600	8472A18	27 @ 4.06 ea.	109.62
Collar	One piece Clamp-on Shaft Collar, Chrome-plated	McMaster Carr	(630) 834-9600	9959K44	13 @ 12.11 ea.	157.43
2" U-Bolt With Collar	Vibration damping U-bolt Holds 1050 lbs	McMaster Carr	(630) 834-9600	3176T16	2 @ 19.73	39.46
Spring Plunger	Hand Retractable Spring Plungers w/ locknut	McMaster Carr	(630) 834-9600	8480A1	9 @ 15.90 ea.	143.10
					TOTAL	**$5197.20**

The Assembly Drawings







Credits

I would like to recognize the following individuals for making this project a success:

Paul Peterson, Mechanical Engineer, HET

Jerry Martin, Optics Technician, HET

Bob Calder, HET Management, HET

George Damm, Electrical Engineer, HET

Robert Peonisch, Technician, HET

Dr. David Corbin, Astronomy and Physics, SRSU

John J. Mendias, Contractor, Triple J Services

This was an REU Project for the HET, McDonald Observatory

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BRINGING CONCEPT TO REALITY

Johnny J. Mendias III, REU