# The Portland III Alt / Az Workshop

**Article and Photos by Howard Banich, Russ Genet & Richard Berry**

**August 1-2, 2009, Portland, Oregon**
**Technical Marine Services**

The Alt-Az Initiative began two years ago to facilitate the development of low cost, lightweight alt-az telescopes in the 0.5 to 2.0 meter aperture range. Large telescopes at mountaintop observatories switched from equatorial to alt-az telescopes decades ago, and have partially inspired the continuing evolution of Dobsonian telescopes. Our goal is to selectively translate design concepts from the worlds largest and most sophisticated telescopes to affordable technologies that will transform amateur alt-az telescopes.

A new breed of modest aperture, hi-tech, computer-controlled alt-az telescopes is indeed emerging, and the Alt-Az Initiative is facilitating this emergence via workshops, conferences, a website (www.AltAzInitiative.org), and a Yahoo discussion group.

This article is an update of our progress and outlines our continuing efforts to make this new breed of large and affordable telescopes a reality. Our latest workshop was the third annual event in the Portland, Oregon headquarters of Dan Gray's Technical Marine Service, where he manufactures his Sidereal Technology products.

The Portland III Alt-Az workshop was held on August 1 - 2, 2009, preceded by the now annual BBQ on the evening of July 31. These dates coincided perfectly with a heat wave that brought temperatures well above 100 degrees Fahrenheit.

Portland III Alt-Az Initiative Workshop attendees stand in front of the TMS facility. Don't let our cool demeanor fool you, it was hot!

The presentations and discussions of the Portland III workshop detailed our


***Lou Boyd and Russ Genet stand by the "Fairborn 10" robotic telescope on Mt. Hopkins in 1986 The MMT can be seen at the summit in the background. The entire observatory was automated and eventually grew to 14 telescopes including a two meter automated spectroscopic telescope***

current progress but the selected summaries that follow are necessarily brief – for more information join the Alt-Az Initiative email discussion that can be found at ***http://www.altazinitiative.org/***.

### Automation History

Peter Abrahams gave an excellent and occasionally humorous talk on the history of robotic telescopes. A fair number of the people involved with automating amateur scopes are a part of the Alt-Az Initiative and many where present at the Portland III workshop.

### "What's the telescope for?"


Richard Berry asked this question at the start of the Alt-Az Initiative and continues to ask it at every stage along the way. This is the all important question to ask, and requires a detailed answer when designing and building a new scope – any scope, not just a relatively large one. It's equally important to answer well, whether the scope will be used for astrophotography, collecting data, for visual observing or all three.

For instance, a scope to be used for fast cadence, high precision photometry will have different optical requirements than one intended for astrophotography. Researching those requirements and how they translate into telescope design will play an important role in how successful the finished scope will be.

If data collection is the goal, knowing who will interpret the data is important because the data itself is useless unless someone can interpret, then work with it and use it for published work. Working with a professional astronomer from the beginning will help keep the science mission of the scope as the central design theme of the scope and help insure its ultimate success.

***Machined parts for the Jones near IR photodiode photometer. The vacuum cryostat allows low temperatures to be maintained with a multistage thermoelectric cooler, thus reducing detector noise, the major noise source for photometry in the J and H bands.***

Designing a scope that can be used for several missions is the more difficult and expensive path but probably the most tempting one. Most of us want a scope that's equally effective collecting data, taking photos or producing crisp images in an eyepiece. Many amateur and small professional scopes are made this way. Imagine converting a visual scope like a traditional Dobsonian so it can take good astrophotos or do high precision photometry. Although the basic design wouldn't change, the mechanical tolerances, stiffness and precision of the drive would need to be significantly upgraded.

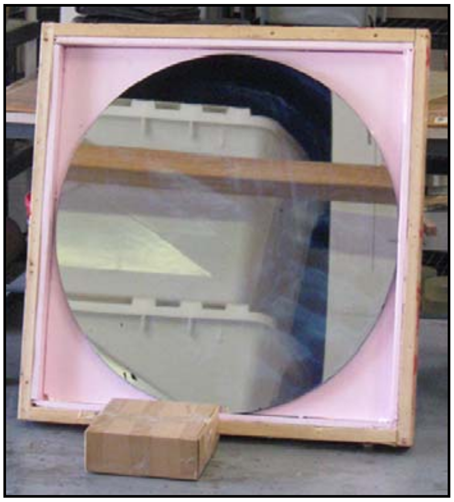
### Lightbucket Science

While most ATM's strive for optical perfection there are a few who purposely go the opposite direction. These contrarians prefer lightbuckets with an optical quality so poor one hesitates to refer to "images" at all. Unlike astrophotographers and visual observers who like crisp, sharply focused stars, stellar photometrists prefer somewhat fuzzy stars and may purposely defocus their telescopes to improve photometric precision and dynamic range - especially when observing brighter stars or fast paced events. They crave lots of cheap photons, preferring to spend money on larger apertures as opposed to higher optical quality.

During an Alt-Az Initiative workshop at the American Astronomical Society's summer conference in Pasadena in June 2009, Arne Henden, AAVSO Director, gave a talk, "1.5 Meter Lightbucket Science" that championed the cause of low cost, lightweight lightbuckets. Besides precision stellar photometry, lightbuckets are well suited to near IR aperture photometry. At the Portland III workshop Greg Jones described his work on a near IR aperture photodiode photometer housed in a cryostat. All the telescope's optical system needs to do is focus, on axis, most of the light from a star on a photodiode 1 mm or 0.5 mm in diameter. Off axis optical quality is of no concern. Near IR astronomical cameras are very expensive and difficult to support, while aperture photometers, such as the Optec SSP-4 and the Jones' photometer are affordable and relatively straightforward.

### Lightweight Meniscus Mirrors

What's a telescope without its primary mirror? A really cool tracking device that's no fun to look through and useless for gathering data. A traditional 1.5 meter mirror would weigh a ton



*Left, Thin 3/4" - 75 lb mirror from DOTI*
*Center: Joe Haberman testing the 1 meter meniscus mirror from DOTI*
*Right: David Davis with first attempt at Foamglas tessellation*

and cost a fortune so our group is exploring several non-traditional approaches.

Thin meniscus mirrors are lightweight, and if they are made from a slumped disk of ordinary soda lime float glass they can be quite inexpensive. Such mirrors are used extensively in less demanding optical applications such as flight simulators. Because they are so thin they're also very flexible, and the resulting optical figure can be of low quality unless steps are taken to apply corrective forces to the back of the mirror in a manner somewhat similar to large alt-az telescopes (but on a much smaller, simpler scale).

A similar approach was described by Russ Genet. He led a discussion on design options for a 1 meter lightbucket photometric telescope he plans to build as a technology demonstration project using a thin ¾ inch, 75 lbs mirror from DOTI Optical normally used for flight training simulators – see the photo above. This was a continuation of an on-line discussion he began a couple months prior to the workshop, so a good deal of progress had already been made deciding on the final design.

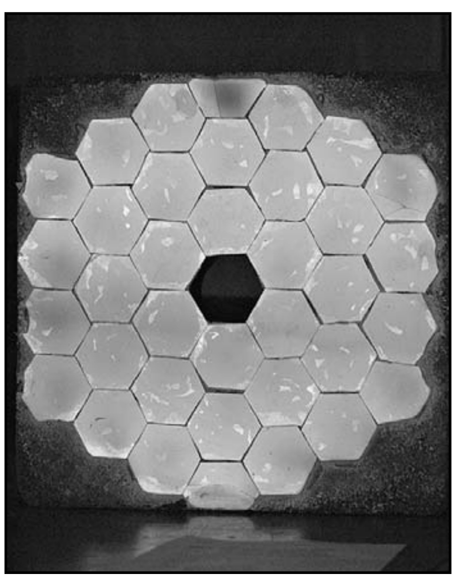
*Below: Russ Genet leads discussion on design options at Alt/Az conference*

*Right: Lightweight mirror using Foamglas tessellation. Octagonal pieces of soda lime glass mounted on a light weight substrate product by Corning*

A two element spherical aberration corrector will be used to improve the mirror's performance. The objective of the project is to show that high quality photometry can be done with a very lightweight, low cost alt-az 1 meter telescope—hopefully in an approach that could be scaled up to 1.5 or even 2.0 meters.

Joe Haberman tested the 1 meter meniscus mirror from DOTI Optical in the shop at PlaneWave Instruments in Torrance, California, right after the Portland III Workshop. (photo above)

## Foamglas Tessellation

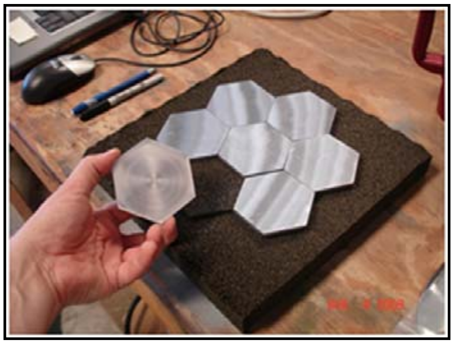


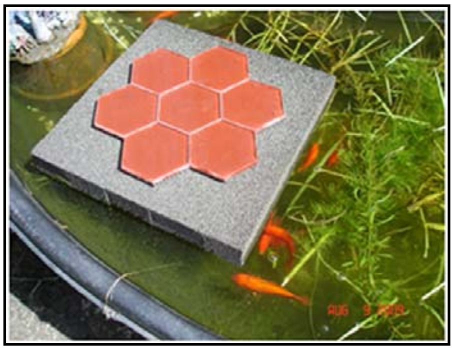
One of the more innovative approaches to a large, lightweight primary mirrors is Foamglas tessellation. This approach uses small hexagonal mirrors that when combined make up one large mirror.

Dave and Andrew cut hexagon shaped pieces of soda lime glass which they glued to a piece of glass foam with the desired f-ratio curve ground into it. Foamglas, a product made by Pittsburgh Corning, is so lightweight it floats but it's exceptionally stiff and has nearly the same temperature expansion characteristics as soda-lime glass.

This idea is essentially a low tech takeoff of the Keck and TMT primary mirror strategy that uses many small hexagonal mirrors that fit together to make one large mirror. In our case the small glass hexagons are glued to a Foamglas substrate and then ground, polished and figured just like a monolithic mirror. This in contrast to the high tech approach of using actuators, edge sensors and computers to keep the individually made tessellations working as one optical surface similar to the Keck and TMT telescopes.

The first attempt was an 18" mirror with 3" tessellations of 1/8" thick glass adhered to a chunk of foam glass with Gorilla Glue. David Davis was able to achieve a rough figure on the combined tessellations but a few of them were out of alignment. Even so a star test was able to form two arc minute sized star images. That's Dave in the photo holding his 18" tessellated prototype mirror. Joe Garlitz looks on





***Top: Thicker glass, and larger hex shapes that fit into individual pockets CNC'd into the glass foam***
***Lower image: Foamglas-tessellated blank floating in a fish pond.***

with understandable skepticism.
The main problem with this first attempt was that the glass hexes ended up being only 1mm thick as a result of the optical work. Also, the hexes didn't fit flush to the glass foam because they had flat backs and the Foamglas was curved, causing an unequal distribution of adhesive.

The next attempt used thicker glass, and larger hex shapes that fit into individual pockets CNC'd into the glass foam that still follow the overall curve of the desired f-ratio of the completed primary. Andrew Arigema used Milbond optical adhesive this time, which is more stable than Gorilla Glue. Note the photo showing this Foamglas-tessellated blank floating in a fish pond. Optical work by Dave is progressing as this article goes to press.

To follow the latest developments join the Yahoo email list "AltAzInitiative". Or start holding your breath.

## Direct Drive

Gears, belts, friction, drive rods, servo motors, stepper motors – who needs them? Anyone with a drive on their scope, that's who, but very likely that won't have to be the case for long. Direct drive does away with all the mechanical parts of a telescope drive that we've become accustomed to by essentially integrating them as part of the telescope itself. It would be just as accurate to think of the telescope becoming part of the direct drive motors (DDM). Many large professional scopes use direct drive motors on both the azimuth and altitude axis.

In 2008 Dave Rowe came up with the idea of making a direct drive motor, which was purposely less energy efficient so it would be easier and less expensive to fabricate. The first rough prototypes worked so well that the 18"Cal Poly student project scope incorporated upgraded versions made of machined aluminum.

Essentially a DDM consists of a series of coils and permanent magnets set up on opposing rings. Add current – and a DDM controller - and you have a telescope motor. As you can see from the photos below, a high precision DDM can be made with common materials. This one has a material cost of around $300.

PlaneWave Instruments is now producing its CDK700, a 28 inch alt-az corrected Dall-Kirkham Nasmyth focus telescope with direct drive motors and plans to produce the CDK1000, a 1 meter scope. Direct drive motors will soon become familiar as they are integrated into modest aperture, top end telescopes.

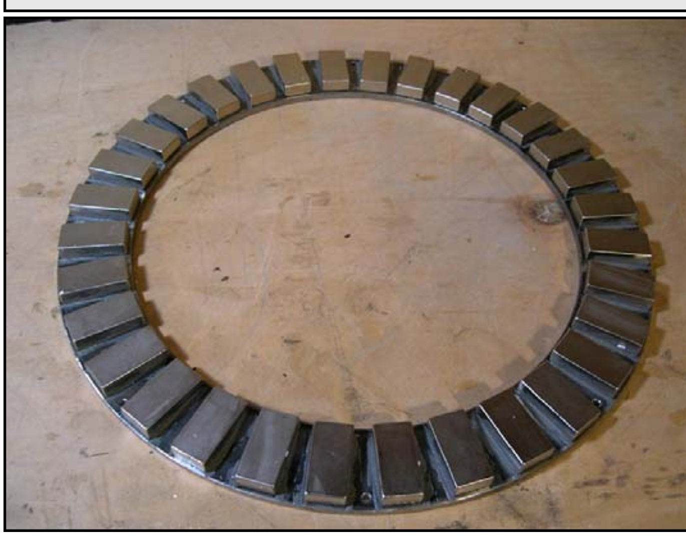
There's more to direct drive as a high precision telescope drive than just the motors. Also required to complete the system are super high resolution encoders and a controller to handle the encoder and control the speed of the DDM.. Dan Gray of Sidereal Technology is completing work on a DDM controller as this article goes to press. Once it's available the amateur telescope DDM revolution will begin.

The metal disks on top of the prototype DDM in the photo on page 63 is a super high resolution encoder with a prototype of the SiTech DDM controller placed on top for display purposes. Don't let the plywood disks the prototype is made from fool you, this thing works.

## Wheels

Large alt-az scopes need smoothly

***Direct Drive motor prototype, which consists of coils and permanent magnets set up on opposing rings.***



rolling wheels, especially in azimuth, to insure the scope moves with as little friction as possible so the motor can move the scope efficiently. Although the size and material of the wheels are important considerations their profile is also an important design element.

Consider a wheel rolling on the flat, circular track of an observatory dome or the azimuth axis of a large telescope. A wheel with a flat profile – meaning the contact area of the wheel – wants to roll in a straight line and so sets up a problem because the wheel will start to bind and skip at times. If the forces are high enough the flat wheel may eventually tear itself or its circular track apart. This has happened at the professional level on the dome wheels of a major observatory (that will remain nameless). Even though amateur scopes are not likely to be heavy enough to tear themselves apart in this fashion, a mismatch between the wheel geometry and the radius of the track they turn on can cause binding.

This means a wheel that turns on a circular track should have a conical profile. To imagine what a conical wheel looks like, imagine a paper cup turned on its side. When given a little push to roll on a table, the cup naturally traces an arc – that's what a conical wheel does. Matching the radius of a conical wheel to the radius of the circular azimuth or dome track will guarantee the minimum of rolling resistance.

A crowned wheel is also recommended so that the edge of the wheel (and thus it's high contact stress) does not make any contact with the rail. Allowing this contact stress to occur can lead to cataclysmic failure of either the wheel or the rail. If failure does not occur, excessive wear is a sure result. Care has to be taken that both the crowned wheel and the surface of the curved track it rolls on are firm enough to not distort.

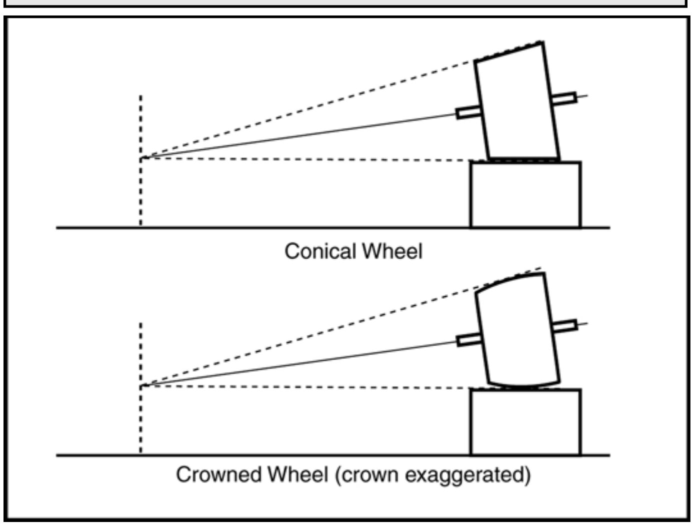
## Scope structures

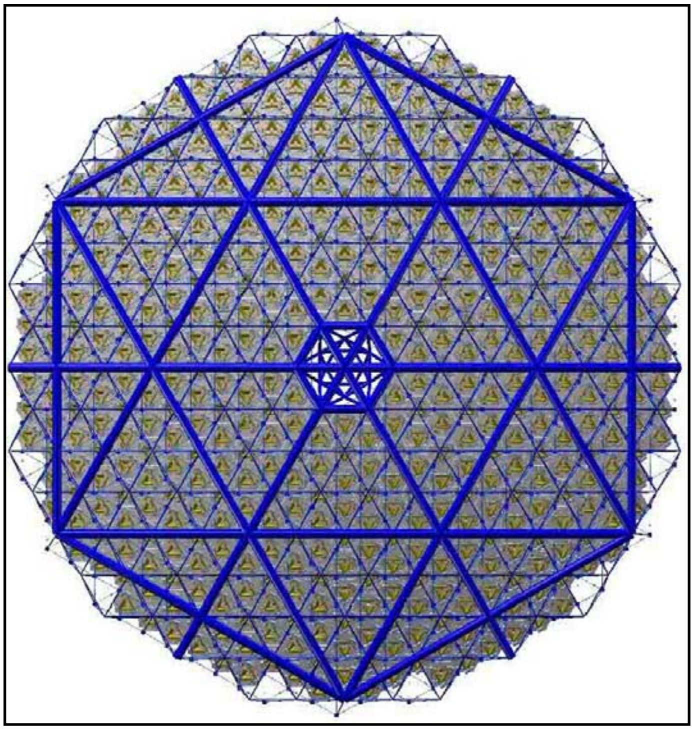
It's easy to imagine a 1 to 2 meter alt-az telescope as a scaled up Dobsonian, but rather than scaling up, let's look at scaling down – down from the worlds largest scopes that is. If a telescope structure is strong and stiff enough for an 8 to 30 meter scope, it should work beautifully for a 1.5 meter scope.

For instance, look at the use of truss elements throughout the 30 meter (TMT) telescope design. Mirror cells are an excellent area for a multi-truss structure, as is a non-flexible ground ring support and a stiff rocker structure.

Taking cues from non-optical telescopes is helpful as well. Looking at the truss structures that hold the receivers above the main dish in radio telescopes show that three or four truss elements can hold a prime focus instrument package precisely in place. This could be a perfect solution for the low optical quality fast cadence, high pre-

***Below: Illustration of conical wheels. Top shows an exagerated design of a conical wheel to better illustrate the principle and the lower shows an example of a "crowned" conical wheel. Right: Photo of conical wheel from drive on Howard Banich 30" scope.***



cision photometry scope that doesn't require high quality optics and doesn't need to worry about the possible extra diffraction caused by these truss structures where they cross into the light path.

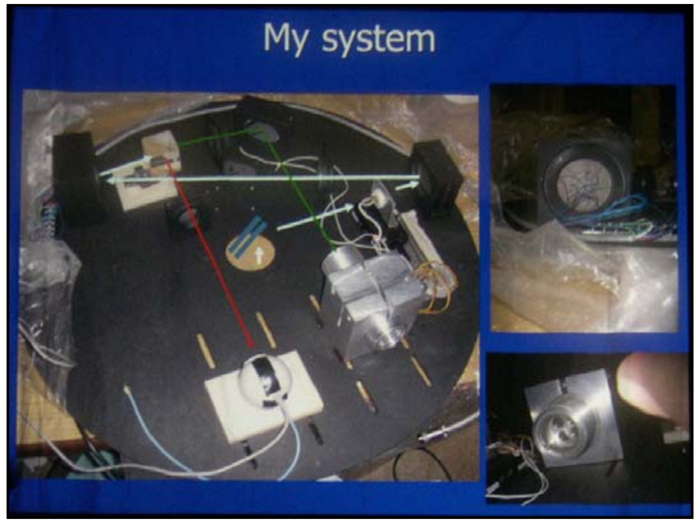
The long and the short of it is that 1 to 2 meter alt-az scope design is wide open to using design influences from the world's largest optical and non-optical scopes. It's tempting to dismiss these designs as too complicated for amateurs to build, but the traditional wooden Dob reaches its limit right around 1 meter. Building successful alt-az amateur scopes larger than 1 meter will require a different approach, especially if they're meant to be transportable.

While the genesis of professional telescope design requires exacting engineering processes, amateurs can approach the design process somewhat differently. Fast prototyping can be more efficient than a specification process, so simply trying something new can be highly successful, especially when playing around with structures originally engineered by professionals. That's not to say that a careful design analysis isn't useful, only that trying something new by just building it will often provide useful information and empirical testing more quickly.

No doubt, some exciting amateur telescopes will come from creative use of professional telescope design concepts. Combined with direct drive motors, a typical amateur alt-az scope 10 years from now may more closely resemble the 10 meter Keck telescopes or the 8 meter Gemini telescopes – and in many cases will be considerably larger than the average Dobsonian of today.

## Adaptive Optics (AO)

Greg Jones is constructing an adaptive optics system for his 20 inch Cassegrain by following the basic design of professional AO systems. Nearing completion, his system is




straightforward and promises to produce a small corrected field of view. Although the corrected "isoplantic patch" is small, it is large enough for small objects, such as Pluto and its moons of close double stars, or for concentrating light from a star for high resolution spectroscopy or similar tasks.

For now amateur AO isn't promising a magic bullet to create Hubble-like sharp images but Greg's efforts do point the way for its use on specific science missions on amateur scopes that are large enough to make the technology practical.

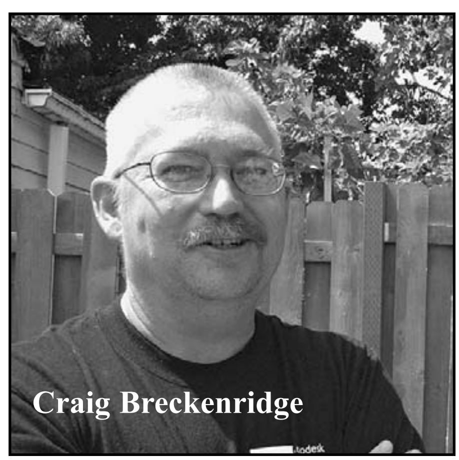
## The Future

Construction on the Thirty Meter Telescope (TMT) scope will begin in the near future and the European 42 meter OverWhelmingly Large (OWL) scope isn't far behind, so the size of the world's largest optical telescopes is currently undergoing a revolution.

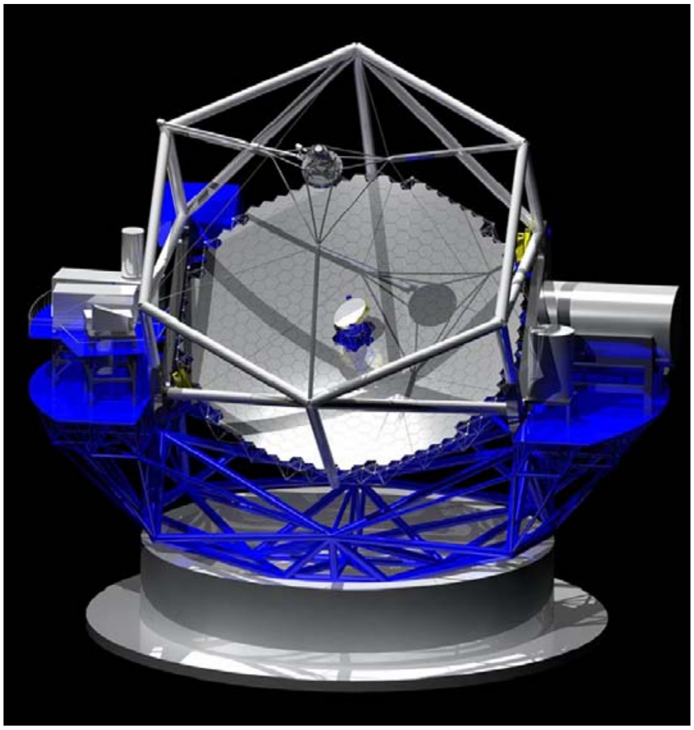
Craig Breckenridge of Dynamic Structures, the company that will build the TMT, gave us a preview of the design. As thrilling as that was even more interesting was discovering that Craig is just as much an amateur telescope maker and observer as he is a professional telescope engineer.

The 30 meter telescope and dome will be about the size of a football stadium and at first blush feels like a bit of science fiction. How can a telescope possibly be that big?

But getting used to a new idea or sense of scale can spark a paradigm shift and hopefully kick-start new ways of thinking. What's possible for amateurs to build? As new mirror technologies are developed, professionally inspired telescope structures, drives and possibly AO will find their way into amateur telescopes



Craig Breckenridge



***Left: General design principles applied to computer model of proposed Alt /Az scope discussed at the conference gives an idea of what the final product might look like. Exciting to think that you might be able to carry a 1 meter model to a remote site.***

considerably larger than 1 meter. The efforts of our informal group have produced some impressive results so far, but we've only scratched the surface.

Even so, let's imagine what all this might lead to in the next 10 years if our efforts continue to be successful. There are many variables at this point, but for fun let's say we meet our performance, price and weight goals. A 1.5 meter (60 inch) alt-az telescope will not only be possible for amateurs to build but they will likely lead to even larger amateur instruments. These will likely be multi-purpose telescopes so they will be capable of collecting high quality data, produce beautiful astro images, and also be killer visual scopes.

But will amateurs really build 60 inch alt-az scopes that weigh only 300 pounds and are as easily transportable as a current 30 inch truss tube wood Dobsonian? If the optics become even remotely affordable the answer is most definitely yes.

All are welcome to the February 2010 Hawaii II Workshop and the Mauna Kea tour afterwards. See www.AltAzInitiative.org for details. The Alt-Az Initiative's Portland IV Workshop is scheduled for Saturday/Sunday, July 31/August 1, 2010. Please join us, including the Friday evening BBQ immediately preceding the workshop, as ATMs fearlessly push onwards towards feasible 2.0 meter telescopes.

**Article and Photos by Howard Banich, Russ Genet & Richard Berry**