A P M
triplet apochromatic
Refractors
- Made in Germany -

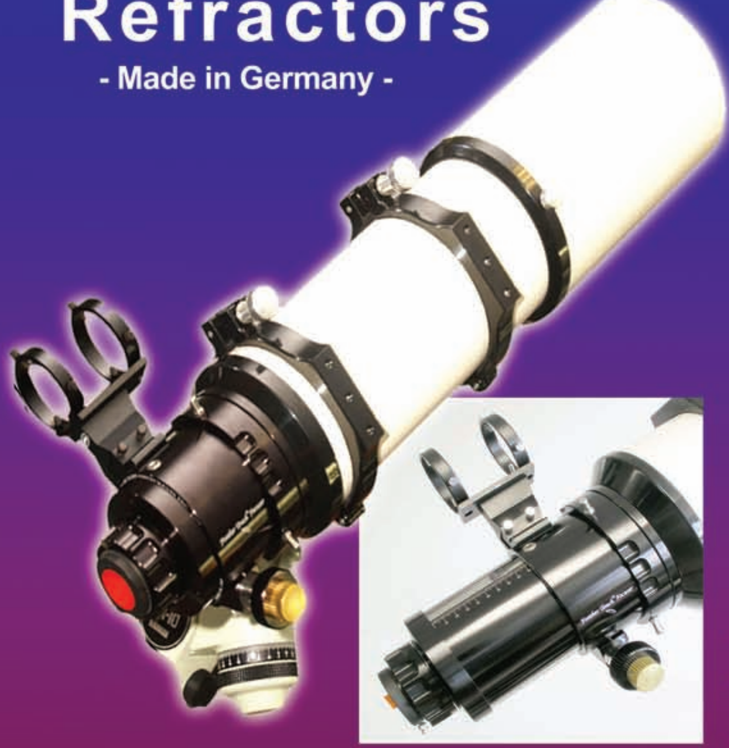
APM
TELESCOPES

www.apm-telescopes.de

Poststrasse 79
66780 Rehlingen

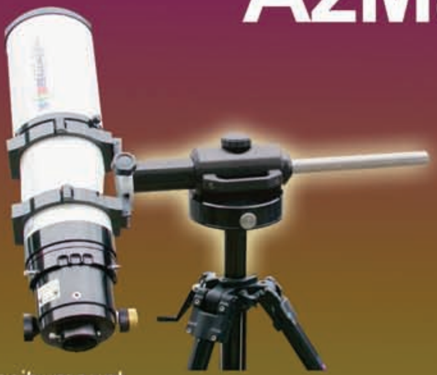
Tel.: +49 (0) 6835 - 500671
Fax: +49 (0) 6835 - 500673

anfrage@apm-telescopes.de



- Lens designs by TMB-Optical
- Ultra-smooth Feather Touch Focusers
- Lens diameters from 105MM to 530MM

AzMaxLoad Mount
- Made in Germany -



- New high-capacity mount
- Payloads up to 14" SCTs and 8" refractors (tripod/pier dependent)
- Weighs 17.93 LBS, including counterweight shaft

Our Price: € 835 + S/H

Our USA Dealers:

Teton Telescope
attn.: Mark Rieck
418 N 3826 East
Rigby, Idaho 83442
Phone: (208)403-4339
E-Mail: mark@tetontelescope.com
URL: www.tetontelescope.com

Oceanside Photo & Telescope
918 Mission Avenue , Oceanside, CA 92054
Toll-Free: 1-800-48-FOCUS (800-483-6287)
Local Calls: 760-722-3343 or 760-722-3348
24 Hour Fax: 760-722-8133 or 760-722-5819
E-Mail:opt@optcorp.com
URL: www.optcorp.com

What is a REVOLUTION?

The revolutionaries can be seen here in this team photo.

Texas Astronomical Society of Dallas Hosts Advanced Alt-Az Telescope Workshop

By Max Corneau

Webster's Dictionary defines a revolution as a sudden, complete or marked change in something. What magnitude of change in telescope design would constitute a revolution during this first decade of the 21st century? On the last weekend in October, a group of nearly 30 scientists, engineers, industrialists, and amateur astronomers gathered for two days and nights in Dallas, Texas, to launch a revolution in telescope design. Hosted by the Texas Astronomical Society of Dallas (TAS), the event was billed as the "Advanced Alt-Az Telescope Workshop" (AATW).

Was this a "Vapor Ware" conference highlighted by self-promoting enthusiasts trying to make a name, a buck, or both? Or was this group gathered as a dedicated community of interest seeking to launch a true revolution in telescope design? Perhaps this topic is most appropriate for the *Astronomy Technology Today* Yahoo Group to discuss.

If you're not the "reading type" I'll cut to the chase: The bottom line results of the Advanced Alt-Az Telescope Workshop indicate that it is possible, by integrating a variety of advanced technology components, to construct a 20-inch Corrected Dall-Kirkham design telescope on an alt-az mount for approximately $13,000 (unassembled). Given the alt-az approach, the 20-inch design appears to be the smallest size that justifies this design. However, the alt-az approach scales upward in favor of the consumer, as many costs like encoders, motors, and bearings remain relatively fixed. Based on the workshop results, the bill of materials (BOM) is itemized in the **table (right)**.

How the Workshop Came to Be

The AATW was the brainchild of Russ Genet, Ph.D. Russ and I first met in 2003 and have remained friends since. After being elected as Vice President of TAS in September, I asked Russ to be my first guest speaker for the monthly general membership meeting program. My original request for an hour-long presentation on Russ's work with small telescopes in science evolved into a 40-minute presentation followed by a 20-minute panel discussion to our club on Friday night at the University of Texas at Dallas. Then on Saturday, at The Richardson Hotel, a group of 30 assembled all day to conduct a disciplined workshop.

After realizing that Russ was using the Dallas invitation's central location as a vehicle to launch his hoped-for revolution, the systems engineer in me surfaced and I questioned the "requirements" we were building this telescope to. Retrospectively, this was an extremely appropriate question, that was unfortunately, never answered. However the

20-inch Corrected Dall-Kirkham design telescope on an alt-az mount	
Finished Optics (primary, secondary, corrector)	**$5,000**
2 Encoders	**$1,400**
2 Motors (parts, not assembled)	**$600**
2 Bearings	**$1,000**
Carbon Fiber Truss Poles	**$700**
Truss Pole Connectors	**$400**
Mirror Cell including back plate (parts only)	**$1,000**
Spider and Secondary Holder (custom fabrication)	**$400**
Field de-rotator, OAG, focuser	**$1,500**
Material for forks and other structures (not assembled)	**$1,000**
Total Cost	**$13,000**

objective of the workshop, notwithstanding any specific science or user requirements, was to explore nine different areas:

1. Lightweight, affordable optics
2. Precision control systems and drives
3. Direct drive motors
4. Field de-rotation
5. Observatory automation and scheduling
6. Autoguiding
7. High natural frequency mechanical structures
8. Bearings for alt-az telescopes
9. Structural alternatives/Session Q&A wrap-up

Friday

Friday evening was billed as the "Kickoff" event to this revolution. Unfortunately (for my stress level), Russ Genet's first flight from the central California coast was cancelled and his next flight was delayed. Before 5pm, we knew that it was mathematically impossible for Russ to make his speaking engagement. However, Dave Rowe, designer of the Corrected Dall-Kirkham (CDK) telescope, became my new best friend and gave Russ's presentation without missing a beat; many thanks to Dave Rowe for running with the ball.

Dave's presentation addressed the limiting factors of equatorial mounts (size, weight, and cost) as they support larger aperture systems, then dealt with examples from major scientific, or "mountaintop" telescopes. The presentation transitioned nicely into the small telescope revolution, made possible primarily by fork-mounted Schmidt-Cassegrain Telescopes (SCT), pointing out that these are only upwardly scalable to a 14- to 16-inch design before the corrector plate becomes a limiting optical design factor. With the audience decisively engaged in the subject matter, Dave drilled into a potential convergence of the Dobsonian design and mountaintop alt-az systems. The convergence (and here's the revolutionary part so pay attention) is facilitated by lightweight aerospace materials, active control systems, and brushless motors.

Preliminary telescope designs for our revolutionary telescope design considered the following systems and their pros and cons: The Hyperbolic Newtonian (HN) provides excellent wide-field optical performance and a convenient Newtonian focus, but requires an overcorrected primary. Another optical design, the Wynne-corrector plus parabolic mirror, provides an acceptable alternative to the HN in some situations, however is beset by a lack of back focus that seriously limits the variety of scientific instruments to be placed in the optical train. One additional negative for this design is the fact that the corrector is large, expensive and difficult to make. In a "saving the best for last" methodology, Dave showcased the Tertiary-focus Corrected Dall-Kirkham (CDK) large telescope design. The optics are less challenging to fabricate for this system relative to the Richie-Chrétien (RC) Cassegrain and provide the added, and very significant advantage of being easier to collimate than the RC and Newtonian telescopes.

Following the planned 40-minute discussion describing how the confluence of low-cost telescope control systems, affordable aerospace materials, and innovative optical designs enable a revolutionary new class lightweight, highly capable alt-az telescopes to emerge, we convened a panel discussion. Panelists included Tom Smith of the Dark Ridge Observatory, Tom Krajci, Dave Rowe of Sierra Monolithics, and Dan Gray of Sidereal Technology.

As the moderator, I asked a pre-planned question to jump-start the panel discussion: "How would you design a 20- to 25-inch advanced alt-az telescope for TAS?" Here, the requirements question that I had posed earlier to Russ et al in a collaborative thread, came back to roost as the panelists returned the question in terms of questioning the requirements. Dan Gray replied that the cost depends on the goals the club has in mind for the telescope. Tom Krajci echoed this comment with a 'what will it be used for' point, while Tom Smith, recognizing our potential student affiliation with the University of Texas at Dallas, wisely suggested that we consider what students might be able to use the telescope to accomplish. Dave Rowe wrapped up the panel by addressing the participatory aspect of an advanced alt-az design by suggesting that a one-meter triple truss CDK telescope could serve both visual and demanding scientific imaging given the following characteristics:

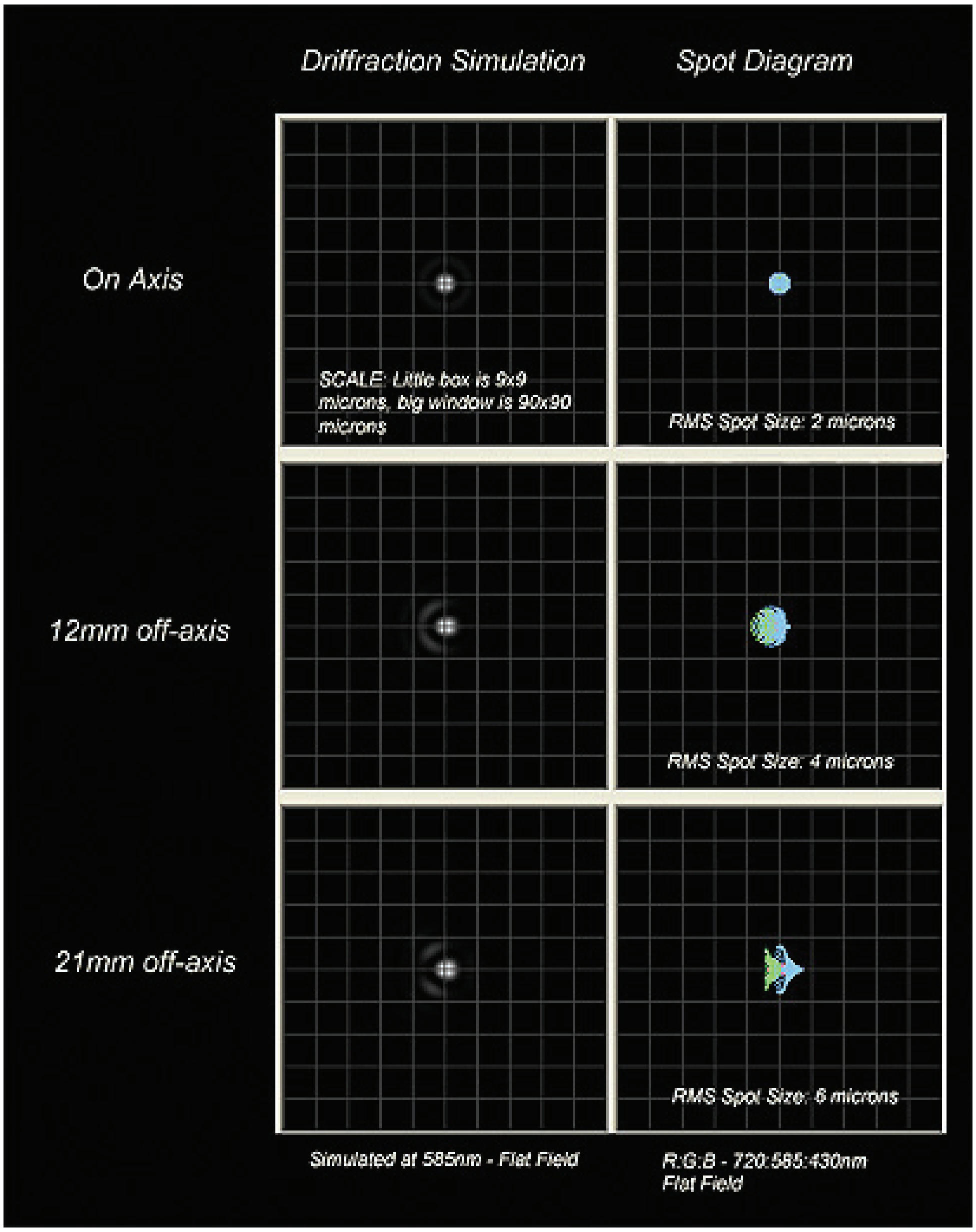
- Effective focal length = 5930 mm (f/5.9)
- Fully baffled over 55-mm image circle
- Flat field
- Geometric RMS spot diameter < 10 microns over full field
- Extremely well corrected from 375 nm to 1000 nm
- Eyepiece height less than 1.8 meters (70 inches)
- Back focus > 200 mm
- Spherical secondary is easy to collimate
- Much less expensive than other Cass alternatives

Ultimately, we settled on a "whiteboard derived SWAG" of around $20,000 for a 20-inch CDK telescope that could serve equally well in both visual and imaging roles and provide easy visual eyepiece access and uncomplicated collimation. The panel was very helpful and stimulated the assembled group of 100 or so members and visitors to think more deeply about the possibility of our Society obtaining a telescope capable of providing exceptional visual observations as well as doing hard science.

Saturday

With all scheduled presenters on station, except for Richard Kay, President of Impact Bearings, Inc., the workshop commenced its daylong effort at the Richardson Hotel. At the conclusion of the meeting, we dined at a newly discovered "astronomy restaurant," most appropriately named, Luna de Noche, on some of the finest Tex-Mex faire available in the Dallas-Fort Worth Metroplex.

Dave Rowe's initial presentation, titled "Lightweight Affordable Optics," set both the stage and the bar relatively high for those who would follow. Much to the satisfaction



Diffraction and Spot Diagram Simulations courtesy of PlaneWave Instruments Inc.

of my systems engineering "requirements approach" to doing things, Dave stated the requirements for his approach up front.

In order to be useful, the system must afford convenient access to instruments and eyepiece. This requirement can be achieved through a Newtonian focus or tertiary Cassegrain focus. The explosion of low-cost, large-format CCD chips and arrays dictate that the system provide excellent images over a large, flat field. Specifically, the instrument should be able to support 37-mm x 37-mm CCD formats across 400 nm to 850 nm of the spectrum. Most importantly for scientific applications, the system should provide for adequate back focus for imager, filters, off-axis guider (OAG), and deviator. Specifically, he adopted a baseline requirement of greater than 90-mm back focus. Finally, the three factors that can justify the moniker of revolutionary for such a system are that these requirements are to be met in an affordable, compact and lightweight, package that offers ghost free images. Right on Dave!

Rick Hedrick, formerly of Celestron, and most recently a 2006 co-founder of PlaneWave Instruments, Inc., provided an excellent embellishment on several concepts addressed by Dave Rowe in his presentation on "Corrected Dall-Kirkham Telescopes." From Rick's perspective, a primary driver for the CDK design is to support the 42-mm to 52-mm (diagonal) CCD chips with an affordable system. Primary drivers addressed by Rick also included a large, flat, coma free field that must be less expensive than a traditional Ritchey-Chrétien design and easier to collimate.

Rick's PlaneWave website articulates the advantages of the design extremely well (www.planewaveinstruments.com). In the **graphic (left)**, the small squares in both simulations are 9x9 microns, about the size of a common SBIG science CCD pixel. In the diffraction simulation the star images on axis and off-axis are nearly identical. In the spot diagram 21-mm off-axis the spot size is an incredible 6 microns RMS diameter. This means stars across a 42-mm image circle are going to be pinpoints as small as the atmospheric seeing will allow.

Both of the simulations take into consideration a flat field, which is a more accurate representation of how the optics would perform on a flat CCD camera chip. For visual use some amount of field curvature would be allowed since the eye is able to compensate for a curved field. The diffraction simulation was calculated at 585 nm. The spot diagram was calculated at 720, 585, and 430 nm. Many companies show spot diagrams in only one wavelength, but you cannot see the chromatic performance with only one wavelength.

Given the relative advantages of performance, cost, and ease of use articulated by both Dave Rowe and Rick Hedrick on the CDK design, the logical follow-up question asked by one of the workshop attendees was, "how scalable is this design?" The simple answer is that the low end of the CDK design is about 20 inches and it scales upward to about two meters. And, according to Rick, the cost will likely increase as the cube of the diameter.

Following Rick Hedrick's presentation, the workshop took a decidedly esoteric and less practical, if only from an Earth-based perspective, turn. Dr. Peter Chen of the NASA Goddard Space Flight Center shared both his vision and daily challenges developing a telescope for use on the Moon in his presentation titled, "Carbon Fiber Mirrors." Peter is truly on the cutting edge, far ahead of programs and funding, forced to use tremendous ingenuity and creativity to make his dream of a telescope on the moon a reality. Peter's major accomplishments include inventing a lunar telescope using ultra lightweight replica optics and high temperature superconductors for which a U.S. Patent was issued in April of 1993 and co-inventing new processes of making ultra-lightweight optical telescopes by composite replication for which several patents are currently pending. Peter stated his objective to the workshop as wanting to develop telescopes to put on the Moon, which he immediately clarified, is a topic that only recently could be discussed in polite company. Dr. Chen's thesis statement to the workshop was that carbon fiber composite laminates offer unlimited size whereas beryllium optical surfaces have only been made up to four meters. In his design, a simple laminate substrate stiffens and supports a pure resin optical surface. In this modality, Peter has built a 36-inch mirror that weighs only nine pounds.

Unfortunately, Dr. Chen's early composite mirror designs encountered what NASA refers to as a "show-stopper" problem. Given differential coefficients of thermal expansion (CTE) whereby the laminate = 0 and the resin = 60, when subjected to thermal cycling, the mirror underwent a host of unacceptable changes including buckling, wrinkling, and de-lamination. The undesirable characteristics were ultimately attributed to the differential CTES between laminate and substrate. This problem can be solved, according to Peter, by graduating the differential CTEs through additional layers, or by modifying the fiber resin using carbon nanotubes.

Nanotechnology expands the potential for Dr. Chen's composite mirror technology. Effects of wind loading on a terrestrially based composite mirror probably requires

active mirror control. This apparent limiting factor actually drives a deeper design evolution. Already on the books, United States Patent 7064885 (http://www.freepatentsonline.com/7064885.html) describes a lightweight active mirror where the first layer has a front side and a backside. A second layer has a front side and a backside and the backside of the second layer faces the front side of the first layer. A reflective surface is on the front side of the second layer. The reflective surface is operable to reflect desired wavelengths of electromagnetic radiation. A plurality of electroactive actuator strips arranged between the first layer and the second layer are utilized to alter the curvature of the mirror. A plurality of stiffening elements interconnected with at least one of the first layer and the second layer are used to stiffen the mirror. A plurality of shape retaining elements attached to at least one of the first layer and the second layer are used to control the mirror and to bias the mirror in the desired position.

In his discussion, Dr. Chen addressed a revolutionary, embedded active mirror design whereby carbon nanotubes are laid up and aligned in the mirror such that they can be used as actuators when a voltage is applied to them. This design concept appears to evolve "smart" mirror technology to the level of "brilliant mirror technology."

Dan Gray of Sidereal Technology, Inc., provided the next presentation titled "Precision Control Systems and Drives." Dan's philosophy regarding precision telescope control is refreshingly straightforward: Step 1 – acquire the object; step 2 – stop the telescope. Dan's presentation provided an excellent historical context of mechanical telescope control whose origins date back to the University of Wisconsin's work with synchronous RA motors in the 1960s. Notably, Dan cited Russ Genet's work in this domain, including the text, *Real Time Control with Microcomputers* by Russ Genet and Lou Boyd in 1982, and the first operational implementation at the Fairborn Observatory in 1983. Another one of Russ's co-authored publications, *Microcomputer Control of Telescopes*, this time with Mark Trueblood in 1983, remains a sought after publication today.

The presentation transitioned smoothly to a comparison between servo and stepper systems that described the wider dynamic range afforded by servos as well as greater angular accuracy while tracking. The downsides to stepper motors include mechanical wiring differences, magnetic hysterisis, and torque error. Advantages to servos include lower current consumption and greater torque per cubic inch. Dan's presentation noted that small servos can control telescopes up to 41 inches. Additional advantages of servos is their tolerance to resonant frequency effects and providing continuously accurate step data. Servos, as opposed to stepper motors, will never miss a step and lose position information. Given the balance of advantages and technology, it is not surprising that the cost of a stepper system is less than a servo system. However, Gray indicated that his company has managed to converge the two price points. Finally on the topic of drive systems, Dan articulated the virtues of brushless D.C. motors versus brush-type D.C. motors. His assertion was that brushless motors are more efficient and require less maintenance, but are more expensive.

Again, the demands of tracking and pointing are determined by the telescope's primary role. Photographic operations impose stiffer requirements for both cases. Precision requirements in this case can be met by closed loop systems such as SiTech according to Dan. After describing significant considerations of sky and telescope system, Dan Gray introduced a software application developed by Dave Rowe called *PointXP*. This application accounts for telescope modeling in terms of hub, axis perpendicularity (Z1), cone, collimation error (Z2), forward/reverse and left/right axis imbalances and the sin and cosin of declination droop. Applying the best practices described, Gray stated his personal goal of precision in unguided tracking is 10 minutes with a 14-inch telescope and SBIG ST8

camera. This particular use case establishes maximum drift of one arc second per ten minute period.

In another easy transition, Gray's presentation turned to gears versus rollers and the pros and cons of each. Of course, gears offer no slippage. However, they will always induce backlash, windup error, non-periodic and periodic errors. On the other hand, rollers offer little or no backlash and periodic error, but slippage can be a huge problem according to Gray. To eliminate adverse roller characteristics, Gray offers two options: tick management, and closed loop high-resolution encoders. Gray asserts that using an inexpensive 10,000 tick encoder can effectively eliminate aforementioned adverse characteristics. The most common downside is encoder runout on this type of system. Closing the feedback loop with high resolution encoders provides the main advantage of countering wind gusts.

After thoroughly examining many aspects of precision telescope control, Gray steered the workshop back to the comparison between equatorial versus alt-az platforms. Echoing his predecessors, he extolled the stability and cost-effectiveness of alt-az mounts, while addressing the inherent problems associated with field rotation. Field de-rotation is necessary to support autoguiding, flat fielding (near field) and to a lesser extent cable management. Gray again admitted to one of his life goals, that of making an affordable alt-az telescope a better decision than a comparably sized equatorial. He believes strongly that the crossover price point lies at the 20-inch range.

Gray made the case that all three major problems associated with alt-az field rotation are solvable through a variety of techniques. In terms of guiding, there are four potential solutions: (1) don't guide, (2) guide with a dual chip system such as SBIG, (3) use one or two off-axis guiders, or (4) use a guidescope that hands off the guide star to different pixels, which requires plate solves to find the exact radius and angle on the guide chip. Another guiding issue associated with alt-az systems is alt-az inputs versus RA/Dec inputs which are normally given in alt-az if controlling an alt-az scope. There are four solutions to this problem according to Gray: (1) re-calibrate often, (2) rewind the rotator, and (3) change firmware to guide in RA/Dec, or (4) use wireless guiding.

A ten-minute unguided image on an alt-as scope passing near the zenith by Dan Gray

Gray offered several solutions to flat fielding: either eliminate system vignetting or center the vignetting, model the vignetting, or take flats at all angles and interpolate using software.

Astronomy is, after all, a practitioner's undertaking. Dan Gray is a true practitioner who established goals and decomposed them into requirements. The ten-minute unguided image **(shown above)** provided courtesy of Dan is indeed worth a thousand words.

Tom Krajci of the Astrokkolkhoz Observatory at 9,440' in Cloudcroft, NM, introduced the next session on "Autoguiding" in Russian and would have continued on his linguistic excursion had the workshop attendees not requested English as the preferred language. Tom's presentation addressed the historical context of traditional autoguiding, followed by faster tip-tilt correction methods, requirements that must be met to abandon autoguiding, and optical/mechanical design considerations. As one who has manually guided a massive 12-inch Clark refractor at the U.S. Naval Observatory, I can attest to the rigors of this technique on the observer compared to using my dual-chip SBIG camera or piggy-back autoguiding system.

Kraji's approach to non-traditional autoguiding leverages the fact that software can be used to perform astrometric calculations on the main CCD image and issues subsequent commands to recenter the primary image at a user-defined interval. What the user defines depends on a variety of factors, including tracking performance, centering accuracy, and driver errors. A step beyond non-traditional autoguiding employs tip-tilt systems such as the SBIG AO-8 and AO-L which can correct at rates up to 10Hz. These systems, according to Krajci, work best on smaller apertures and can counter the effects of mild breezes.

In a clever way to talk himself out of doing an autoguding presentation, Krajci offered an excellent primer on why we autoguide and what must be done before we can do away with autoguiding. Tom asserted that autoguiding is used to counter the adverse effects of polar axis misalignment, periodic and random drive errors, long term RA drive rate drift, mount/telescope flexure, and wind. In order to abandon autoguiding, we must use a very stiff system that incorporates two high resolution encoders and that is accurately aligned and able to counter wind gusts through a fast-reacting drive. It's that simple and a most appropriate topic for the attendees at an advanced alt-az telescope workshop.

Next on the agenda, Tom Smith, assisted by Tom Krajci, provided an excellent presentation on "Observatory Automation and Scheduling." Smith, now the Director of his own Dark Ridge Observatory just down the hill from Tom Krajci, is in the process of automating his systems and obviously knows the subject material inside and out. Smith began the presentation by defining automation and distinguishing the three types thereof, followed by explaining how to automate with the various software and hardware components that must be integrated. The presentation then logically trailed into scheduling time and targets. He wrapped up the effort by cementing the concepts of remote observatory site selection.

Three types of observatory automation were addressed in Smith's presentation:

- Manual observatory startup with telescope and CCD operating under scripted control for the night's observations, followed by a manual observatory shutdown and subsequent manual data analysis.
- Remote, fully automated observatory operation with manual remote observation.
- Robotic remote observatory operation with scripted observatory operation and telescope and CCD scripted operations.

Of these three automation types, the first is the most common and easiest to implement, but requires an on-site presence. The second type of automation enables multiple users to select and dynamically interact with their targets such as the modality of commercial observatory sites used by subscription. Finally, the remote fully automated observatory is the most efficient and least error prone, thus most commonly used for scientific applications.

After establishing the type of automation schemas, Smith explained how to make control systems accomplish basic tasks in terms of data, monitoring and safety. A good automation system plan should begin by considering: weather data as part of the control plan, data flow (cabled or wireless), protective sensors and features to prevent damage to people and equipment, system monitoring schema, integration of software and hardware to make it all work, and building a bullet-proof emergency shutdown plan.

After an excellent discussion of the various software integration methods and options available, Smith addressed target scheduling in terms of easy and difficult scheduling. He asserted that easy schedules include time-series and single set deep imaging, whereas difficult schedules include supernova patrol or many target field images. Considerations when developing a scheduling plan include: length of target observations and time visible, target queue ordering to maximize photons captured and minimize scope movement, concurrent study target observation overlap, target prioritization schemes and weighting targets of opportunity: GRB Alerts, AAVSO Alerts and outbursts. Given the nature of weather (pun), anyone controlling a schedule must understand the difference between static and dynamic schedules and be able to respond to weather effects by either accepting a loss or re-prioritizing targets.

Unfortunately, I missed Russ Genet's short presentation on "High Natural Frequency Mechanical Structures" while I stepped out to coordinate a phone patch to Richard Kay for the alt-az bearing discussion. However, immediately following Russ, Richard Hedrick provided an outstanding presentation "The Structural Alternatives." Rick addressed four topical areas: the motor/encoder/bearing, optical design, mount materials, and optical construction. One of the most useful discussions of the day, Rick led the group to reach a participatory conclusion on the best type of design for an advanced alt-az telescope. In order to maximize both instrument placement and eyepiece accessibility, we assumed a CDK tertiary system on a ground plate constructed of advanced aerospace materials. In this case advanced aerospace materials include honeycomb structures bonded with structural adhesives, fabricated by smart machines. Given that stiffness increases as the third power of honecomb depth, honeycombs are indeed the honeypot for this design.

The workshop wrapped up with a "Bearings for Alt-Az Telescopes" discussion led by Richard Kay, President of Impact Bearings, whose point of presence was actually in San Clemente due to another air travel debacle. Of course the bearing discussion was not about traditional radial contact bearings. Richard Kay led the workshop through his product line including four point contact face-to-face and back-to-back bearings. In the b2b design, the outer rings abut and the inner rings are drawn together. The converse of this is true for f2f bearings. Additionally, we addressed Richard's apparent favorite design, the Gothic Arch. The Gothic Arch contains half the amount of roller balls and maintains a longer life.

The Results

The AATW hosted by the Texas Astronomical Society of Dallas indeed launched a revolution in telescope design. The availability of low cost materials, control technology, and optical designs mean that it is possible today, using mostly simple hand tools, to assemble a large, highly capable telescope for a fraction of the cost seen a decade ago. This revolution will only come to fruition if the "visioneers" are steadfast in their ideals and control design, development, material, and production costs such that this system does not evolve into a would-be mountaintop telescope. Should the project remain true to its roots, Albert would indeed be proud of us. The image **(below)** is scaled to the size of our proposed telescope.

For more information on the Texas Astronomical Society of Dallas and its programs go to www.texasastro.org.