

Telescope Performance and Telescope Upgrades

Telescope upgrades should enhance existing capabilities or add new ones. The first result is probably more important to the observatory if the telescope is already oversubscribed, the second if the current demand for observing time is modest. Ideally, telescope upgrades should increase both the short and long term rates at which the instrument can gather useful information although some may be necessary just to maintain current levels of performance. Improvements are significant to the extent that peripheral instruments - and their users - can take advantage of them. We consider possible modifications to the telescopes, their support systems, and their operation modes. Which might produce the greatest benefits given current use patterns? Which might offer new capabilities or possibilities? What instrument additions or upgrades might motivate or justify particular telescope upgrades?

- Time on Target

We would like to maximize the amount of time actually spent accumulating data. This might be done by extending observations into daylight hours, reducing target acquisition time, providing off-line calibration, or minimizing the observing hours lost to system failures, weather, or devoted to engineering and maintenance tasks. (There are 8766 hours in a year. In 2004 we scheduled about 3200 of them, including 260 hours, or 8%, for engineering purposes. Of these 3200 hours, 61% were usable, 35% were lost to weather, and 3% to instrumental failures.)

- Throughput

We could increase the effective light gathering power of the telescope by increasing its throughput and broadening the wavelength range over which it can effectively operate. This is largely a matter of optical coatings and their maintenance, but might also involve the fabrication of new optical elements. Possibilities include a secondary optimized for infrared observations and correction optics which would enable wide field imaging or multi-object spectroscopy.

- Image Quality

Image quality can be described in terms of some measure of the image resolution such as the size of the point spread function. Image size is largely determined by atmospheric effects, but mechanical motions of the telescope, limitations imposed by the design and fabrication of the telescope optical systems, and errors in collimation or focus also contribute. The most significant atmospheric effect is turbulence induced seeing. Differential atmospheric refraction can be a concern at large zenith distances. Air temperature fluctuations in the immediate vicinity of the telescope ("dome seeing") can also be problem. Adaptive optics systems can partly compensate for seeing effects - and for image motions induced by telescope motions. Local seeing can be reduced by control of airflow and temperatures in the vicinity of the telescope. Optical system limitations can sometimes be addressed by masking, corrective optical elements, or replacement of imperfect components. Collimation and focus can be monitored, and errors corrected by controlling the placement of the principal optical components.

- Sky Background and Scattered Light

A "natural" sky background will present at the focal plane. The undesirable effects of this can sometimes be reduced through improvements image quality. Artificial contributions to the sky background can be addressed through regional light control legislation. Filtering at the telescope might be useful in some instances. Light scattered into the optical path from telescope and observatory structures might be reduced by shields, baffles, and suitable coatings. Telescope enclosures can effectively exclude some external light and cleaning of optical components can reduce the scattering of what remains.

- Sky Coverage

The accessible portion of the celestial sphere is largely determined by our latitude, the time, and the weather. A portion close to the horizon is excluded by mechanical considerations mainly related to the support and safety of the optical components. A small area near the zenith is also excluded; that area might be somewhat reduced by enhancements of the drive and control systems.

Some Specifics

Windscreen

A suitable windscreen could

1. reduce wind-induced vibrations and thereby improve image quality,
2. permit observing in higher wind conditions,
3. reduce stray light from outside sources
4. provide an added telescope safety factor
5. provide a convenient location for a flat-field screen (mirrors covers preferred for this?)
6. do service as a sunscreen during daylight observing

Consider a two-part (top and bottom) screen of low thermal mass and emissivity. Something simple and robust. Downsides are that the screen might well be a high maintenance item and introduce undesirable thermal fluctuations in the ambient airflow. (Does UW still have the model used for airflow studies? Did those studies consider the effects of a windscreen?)

Adaptive Optics

A fairly basic tip/tilt adaptive optics ("fast guiding") system operating to ~100 Hz would

1. address the principal contribution to atmospheric image degradation
2. remove essentially all of the image blurring caused by telescope vibration
3. address the seeing component which is most correlated over a larger field (imaging)
4. be the essential starting point for the next level of AO.

Concept at present is a quad cell device with avalanche diode detectors to sense image motion. This would be fed by a pickoff mirror or pellicle downstream of the correction optics. Correction ("fast guiding") could be accomplished by a moving reflecting or transmitting flat. Latter is the simplest "straight through" system but introduces some achromatism and astigmatism. Ideal system would mount just upstream of the (Nasmyth) instrument and be carried by the instrument rotator.

Field Correctors

With suitable correction the 3.5 meter telescope could provide a 30' diameter useful field at the Nasmyth focus. Uncorrected aberrations at the edge of this field are about an arc-second. A single-element Gascoigne corrector can remove essentially all of the residual aberrations leaving only field curvature (with $R = 1.75m$) as a problem. This would be suitable for, say, multi object fiber-fed spectroscopy. There is also a preliminary design for a three element corrector which provides a flat 30' field suitable for imaging. There is space "allocated" in the altitude fork for placing a corrector. Worry about repositioning of the focal plane.

Differential atmospheric refraction (chromatic dispersion) can be significant even at moderate zenith angles. Unless the chromatic interval is constrained by filters or by the detector response, images will be appreciably elongated in the altitude direction; this can amount to several arc-seconds in very broad band applications. Field rotation at the Nasmyth focus will further distort the image for longer exposure times. Compensation can be accomplished by crossed-prism correctors upstream of the instrument mount. (The above three-element field corrector design includes such a dispersion corrector.) Note that full utilization of a 30' field would necessitate changes in the present system of baffles.

Telescope Drives

Direct drive drive boxes should

1. give fewer failures (shutdowns) and maintenance problems and might
2. allow improved position resolution (pointing & tracking)
3. allow higher frequency (>20 Hz) updates (*cf.* vibrations and image quality)
4. permit higher slewing (and tracking) speeds

..the first item being the most important. The current system uses servo motors with an analog tachometer to close the servo loop. That tachometer would turn too slowly for stable control in a direct drive system. (The current system employs a 35:1 reduction *via* the drive boxes.) The torque requirements would be also be higher. On the other hand the direct drive system on the 2.5 meter seems to have few problems. We'd probably want to change or upgrade our position encoding system as part of a drive upgrade.

Improved Ventilation and Thermal Controls

Adding a cooling unit to the existing Pace pressure fan/filter system (or separately mounting them) would help cool enclosure prior to (late night) opening. The benefits would be a faster thermal equilibration of the telescope with the ambient environment upon opening. In operation the cooling units might provide a modicum of dehumidification. This issue might become more important if the telescopes see increasing use during daytime hours.

Shorter and Less Frequent Shutdown Periods

Aside from the possibility of daytime observing programs, this offers the greatest potential for increased time on target astronomy. Scheduled shutdowns ("Engineering Time") currently represents about 8% of the time potentially available for astronomy.

More aggressive preventative maintenance program

- Reduce incident of events which require interrupting observations

- (Observing time lost to "equipment failure" is presently about 3% of the available total.)

Reduce shutdown task list

- Only tasks requiring shut down to be done during shutdown period

- More rigorous shutdown planning

Acquire more manpower for shutdown tasks

- To allow more tasks do be done in parallel rather than in serial fashion

- Temporary /short-term support personnel from ARC institutions

- Other part time hires. Local hires, SPO support,....

- Scheduling telescopes for non-overlapping shutdown periods

And Some Fragments:

The Infrared

- An IR secondary

- Associated A/O?

- Re baffling requirements

Daytime Observing

- Mainly infrared observing

- Thermal controls. A/C, sunscreen

- Manpower: An additional Observing Specialist?

Calibration Systems

- Calibration lamps: LEDs as continuum lamps?

- Flat field screen: Pupil defined by mirror covers (See Marshall & DePoy, asto-ph/0510233)

Performance Enhancements

(Check items)

Optical Performance

- Increase field size
 - Field correctors/flatteners for imaging
 - Field correctors for multi object spectroscopy (multi slit systems, fiber feeds)
- Increase optical throughput
 - Mirror coatings and overcoatings; recoating intervals
 - Cleaning methods and frequency
 - Reduce obscuration or vignetting
- Increase wavelength coverage
 - Mirror coatings (ultraviolet and infrared)
 - Baffling changes (infrared)
 - IR secondary
- Improve image quality
 - Optical figures (as-built) and optical supports (gravitational and wind loading)
 - Thermal controls (thermal effects on collimation and focus, structure-induced seeing)
 - Focus and collimation (pointing model)
 - Vibration reduction (windscreen, drives,...)
 - Adaptive optics (tip/tilt, ...)
 - Corrective optics
 - Atmospheric refraction correction (chromatic dispersion)
- Scattered light reduction
 - Baffling (and structural coatings)
 - Windscreen (stray light)
 - Cleaning (of optics)
 - Environmental controls (lights, moths, dust, moisture,...)

Mechanical Performance

- Increase sky coverage ($W/2p$)
 - Optical supports (near horizon)
 - Drive and control system enhancements (near zenith)
- Improve target acquisition (pointing)
 - Drive speed enhancements (slewing)
 - Encoding
 - Pointing models
- Improve tracking (guiding)
 - Drive resolution and encoding
 - Guiders
 - Windscreen (wind induced motions)

Scheduling

- Increase useful time on sky
 - Daylight and twilight observing (IR astronomy)
 - Broadened environmental limits (wind, dust, humidity,..)
- Reduce acquisition and setup overheads
 - Faster target acquisition (see above)
 - Service calibrations
 - Checks on observer data
- Reduce shutdown time
 - Aggressive maintenance
 - Maintenance/shutdown planning and scheduling
 - Manpower assignments
 - On site aluminizing facility

Operations

- Improve scheduling efficiencies
 - A new scheduling algorithm?
 - Requirements of observers (preparation, training, hand-holding,...)
 - Observatory time (ARC programs)
- Use quick change capabilities
 - Target of opportunity programs
- Service observing
- Systems information
 - Extinction
 - Sky brightness
 - Image size
 - General meteorology (pressure, humidity, temperature, wind, cloud cover,)

Calibration systems

- External flat field screen
- Mirror cover flat field system
- Calibration lamps
- Wavelength calibration lamps