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Comparison of SOFA and NOVAS Astrometric Software Libraries

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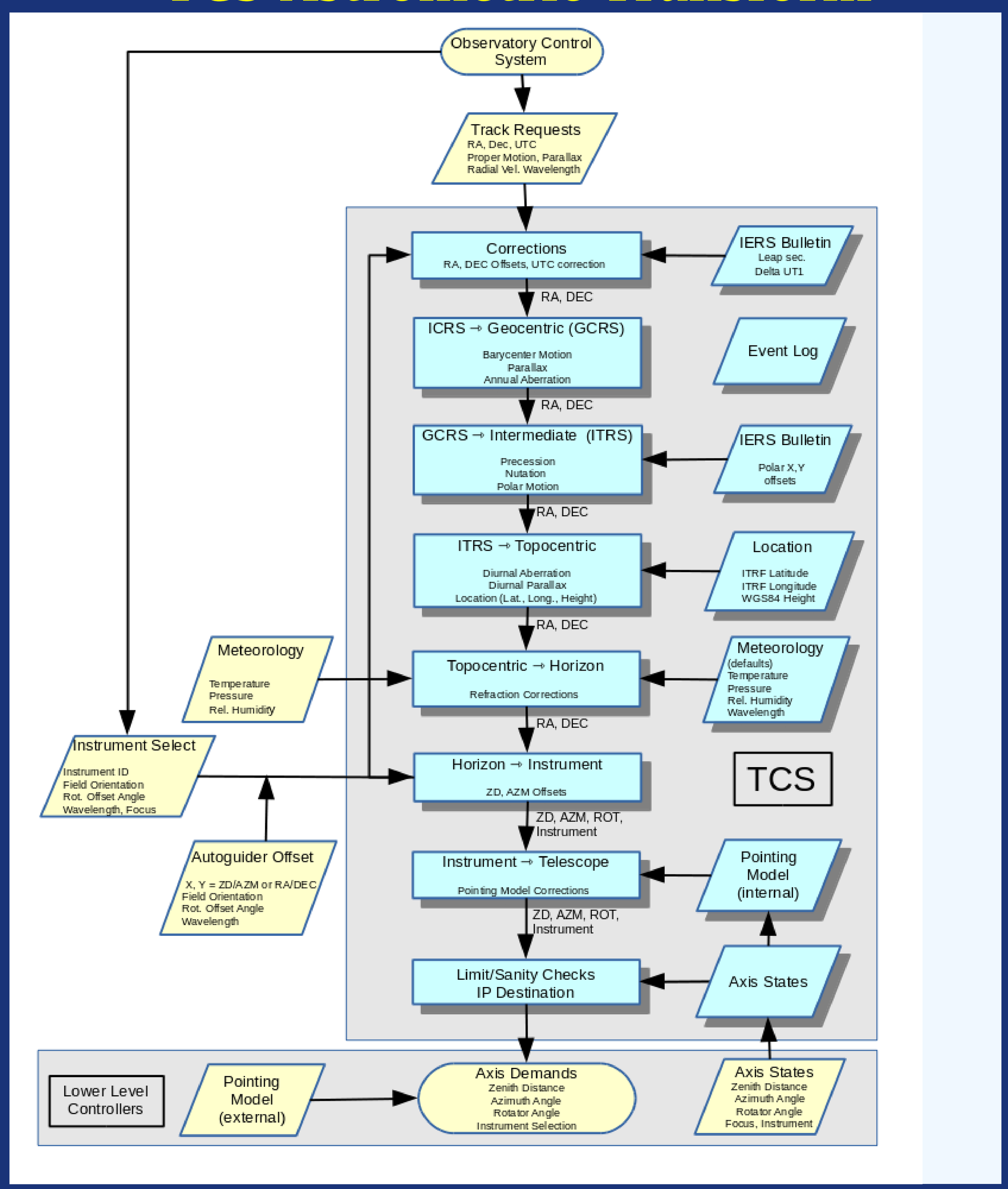
TCS Astrometric Transform



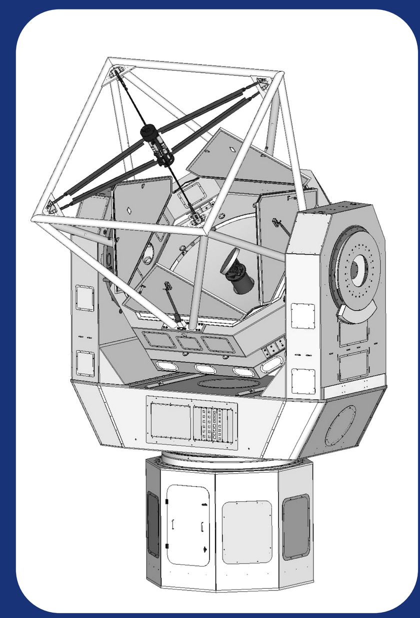
Dataflow Diagram

The AIM of the STFC's Newton Fund is to promote innovative scientific partnerships between countries. It supports this research programme in the development of a new Telescope Control System (TCS) by the ARI in collaboration with NARIT. The new TCS will be deployed to telescopes operated by both institutes.

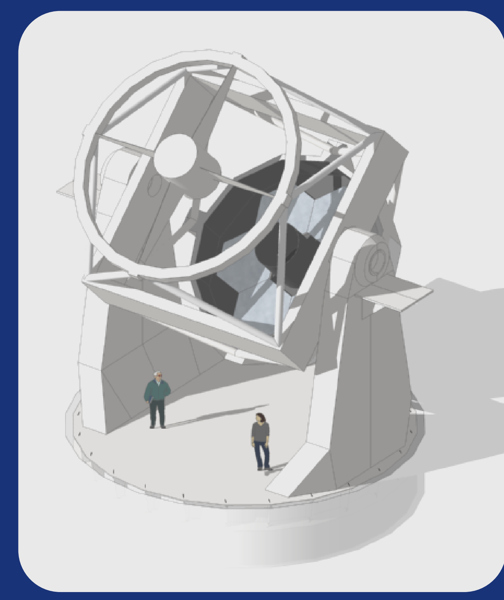
A TCS converts celestial co-ordinates to physical telescope axis demands to accurately maintain a target on a desired location and orientation on a detector. The astrometric to physical transform is accomplished in several stages and must be achieved in real-time. Target coordinates and proper motion are first converted into an idealised sky position for the current epoch and geographic location. Sky position adjustments are successively applied for atmospheric refraction, autoguider corrections plus any instrument offset and orientation to produce idealised axis position demands. Finally a pointing model is applied to minimise the effects of mechanical flexure and drive train harmonics to produce physical axis demands sent to motor controllers.

Evaluation of several open-source astrometric software libraries was performed to establish their suitability for developing a platform independent TCS with common code and build environment on the two target systems.

Host Telescopes



Thai National Telescope



Liverpool Telescope 2

A common TCS is under development for use on the 2.4m Thai National Telescope (TNT) located at Ban Luang near Chiang Mai, and for the ARI's new 4m Liverpool Telescope 2 (LT2) on La Palma in the Canary Islands.

The TNT uses MS Windows® and is manually operated whereas the LT2 will be Linux based and fully robotic.

The new TCS software is designed to operate on these two disparate telescope systems with minimal changes.

Survey of available open-source astrometric libraries and programming language support generated a set of initial candidates. Python and C were selected as possible languages for coding, FORTRAN was discounted as obsolete. ERFA and PAL are ports (marked =) from the other libraries and so were discounted. Native programming language support is only available for C and FORTRAN. Only support for Python 2.7 is available via wrapper functions. SOFA and NOVAS are actively supported and being developed and so were selected for comparison by function features and code execution efficiency.

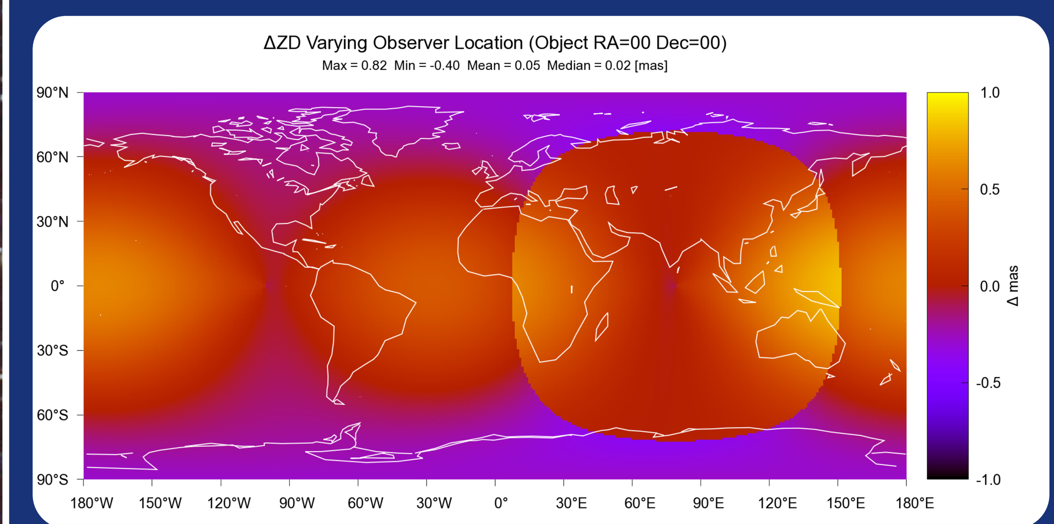
Name	Library	Native Language Support	Python Wrapper
SOFA	Standards of Fundamental Astronomy	C, FORTRAN	pysofa 0.1.1
NOVAS	Naval Observatory Vector Astrometry Software	C, FORTRAN	NOVAS_Py
ERFA	Essential Routines for Fundamental Astronomy = SOFA	C	erfa_python
SLALIB	Classic astrometric library by Patrick Wallace	C, FORTRAN	pySLALIB
PAL	Positional Astronomy Library = SLALIB	C	n/a
LIBNOVA	Part of NOVA project	C	n/a

Feature Comparison of NOVAS and SOFA transforms were done using C and Python test code under both Windows and Linux. Although Python permits platform independent builds, wrappers proved ~5 times slower and lacked features available in the C libraries.

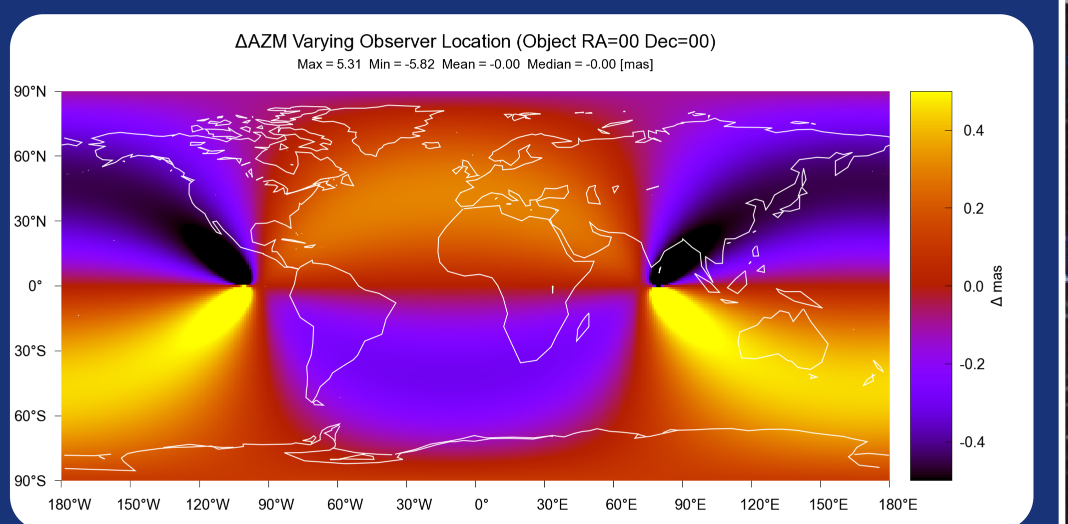
	NOVAS	SOFA
Latest Release Date	2011-03-01	2018-01-01
Transform C Functions Set	High/Medium level	Comprehensive
Transform ICRS to Axes	Requires 3 function calls	Single call
C Transform Rate[1]	64.1 kHz (low accuracy) 44.7 kHz (high accuracy)	1.2 kHz
Python Version Support	Python 2.7	Python 2.7
Python C Wrapper Support	Some differences from C	Incomplete wrapper set
Python Transform Rate[1]	11.8 kHz (Low accuracy) 12.2 kHz (High accuracy)	No equivalent function
Refraction Corrections	Altitude, temperature, pressure	Altitude, temperature, pressure relative humidity, wavelength

[1] Compiled code running under 64-bit Ubuntu on a 2.4GHz CPU

Astrometric Transforms were evaluated for test target objects using SOFA and NOVAS libraries and the results between the two compared. Shown here are the variation in evaluation of Zenith Distance (ZD) and Azimuth (AZM) angle for a target at the sample position, RA=00:00:00 and Dec=0.0 degrees, on UTC date/time 2016-01-01T00:00:00. The difference is evaluated for an observatory placed at every geographic location to a resolution of 1 degree.



Zenith Distance Variation < 1.0 mas



Azimuth Variation < 6.0 mas

The target RA and Dec position was varied and other parameter spaces evaluated including observing time and atmospheric refraction corrections. The maximum difference in evaluation of ZD and AZM between NOVAS and SOFA was ~50 mas.

Conclusions

SOFA was selected as the astrometric library for the TCS. It provides a more extensive function set than NOVAS. The atmospheric correction model additionally corrects for humidity and wavelength . Although SOFA execution time was significantly slower (~50x) than NOVAS, a 1.2 kHz sample rate is sufficient for the intended telescope control systems (400 Hz maximum).

C was chosen as the programming language over Python. The third party Python wrapper routines do not yet fully provide equivalent functions, and even when compiled, proved slower to execute than C.

Cygwin was successfully used to fully emulate a Linux-like build environment under Windows 10 Pro. All source libraries and test executables were compiled using common code and scripts. All executables produced identical numerical results on both target platforms.

Python is the preferred language for NARIT software. However the astrometric library wrappers are slower and provide a limited level of support compared to C.

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Liverpool Telescope
http://telescope.livjm.ac.uk