

SOFA: STANDARDS OF FUNDAMENTAL ASTRONOMY

PROGRESS AND PLANS

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1. Introduction

At its 1994 General Assembly, the International Astronomical Union resolved to introduce new arrangements to establish and maintain an accessible and authoritative set of constants, algorithms and procedures that implement standard models used in fundamental astronomy. The initiative was the responsibility of the Working Group on Astronomical Standards (WGAS), part of Division 1 of the IAU, and the set of procedures and constants was named SOFA, for “Standards Of Fundamental Astronomy”. The background to the IAU Resolution is given by Fukushima (1995) and Wallace (1996).

The proposed scheme includes the following elements:

- The **Maintenance Committee**, whose initial tasks are to:
 - establish a revision mechanism;
 - begin the continuous revision of the “best estimates”;
 - discuss the possible revisions of the astronomical constants (in particular the precession constant);
 - assess the possibilities for coordination with other fundamental-astronomy and geodesy activities, for example IERS and IAG (International Association of Geodesy).
- The **Relativity Subgroup**, which reviews the definitions of certain units and astronomical constants to ensure consistency within the framework of General Relativity.
- The **SOFA Reviewing Board**, whose initial tasks are to:
 - invite bids from institutions willing to operate the IAU/SOFA distribution center;
 - assess the bids and nominate a center;
 - start reviewing algorithms, procedures and software.
- The **SOFA Center**, located at a suitable institution. The Center organizes, maintains, and distributes the SOFA algorithms and procedures.

The present status of the SOFA scheme is that the Reviewing Board has been set up, the site for the Distribution Center has been identified, and preliminary software work is underway.

2. The SOFA Review Board

In 1995 February, the author was invited by the WGAS to chair the SOFA reviewing board (which has since become known as the “SOFA Review Board”). A process of consultation then took place, clarifying various aspects of the SOFA initiative itself and the role of the Board. This led to an announcement inviting the nomination of candidates for Board membership, in *IAU/WGAS Circular 104*, 1995 November. By 1996 February, the Board’s membership had been agreed, and ratified by the WGAS and its Advisors. The current Board membership is as follows:

Wim Brouw	Australia Telescope National Facility
Anne-Marie Gontier	Paris Observatory

Catherine Hohenkerk	Royal Greenwich Observatory
Wen-Jing Jin	Shanghai Observatory
George Kaplan	United States Naval Observatory
Zinovy Malkin	Inst. Appl. Astron., St Petersburg
Dennis McCarthy	United States Naval Observatory
Jeffrey Percival	University of Wisconsin
Patrick Wallace	Rutherford Appleton Laboratory

As a by-product of the trawl for Board members, a number of individuals were identified who were prepared to act as "reviewers" of new SOFA products.

With no independent funding, the SOFA Review Board relies on the host institutions of its members to provide the necessary resources. SOFA's needs in terms of computer facilities have, at least up to now, been modest, and easily met by existing equipment. Effort is, and is likely to remain, the most serious bottleneck. A further constraint is funding for travel. The bulk of the Board's work so far has been carried out by electronic mail, and this will continue. However, two meetings have also taken place, and most Board members were able to attend at least one of them. The first meeting was at United States Naval Observatory (USNO) in 1996 September, followed a month later by one held at the Paris Observatory.

In the months leading up to the Washington and Paris meetings, discussion via electronic mail had produced a measure of agreement on various matters of detail, and a draft Fortran coding standard had been prepared. The meetings allowed this work to be consolidated, and significant further progress was made. Among the decisions reached were:

- The SOFA Collection will, to start with at least, consist only of callable subprograms, as opposed to freestanding applications. All such items are to be called, simply, "routines", ignoring distinctions such as function *versus* subroutine.
- No existing package (SLALIB (Wallace 1997) and NOVAS (Kaplan 1996) were among those considered) fits the requirements of SOFA, though such packages are important sources of code and test examples.
- Before work on the fundamental-astronomy routines themselves could begin, a **toolkit** of vector/matrix routines would have to be provided. Once they were in place, the first tranche of **canonical** SOFA routines could be developed. These would comprise the established IAU standards, supplemented by *de facto* standards where necessary to fill in gaps. Later, alternative algorithms and packagings would be developed, to suit the needs of general users. These would include **manager** routines, which would string together SOFA calls to provide higher-level capabilities, giving non-specialist users easy access to correct procedures.
- On programming languages, it was recognized that SOFA must address all users and cannot, for example, afford to provide only Fortran code or C code. This diversity would be managed by regarding SOFA algorithms expressed in different languages as independent products, with packaging and interfacing optimized for the language concerned.
- With several levels of SOFA routine and multiple programming languages, it was recognized that it would be necessary to proceed in stages. The toolkit would be developed first, initially in Fortran 77, followed soon after by ANSI C. This would then allow canonical SOFA products (precession and nutation models, timescale conversion *etc.*) to be developed in Fortran and C, in parallel. The high-level manager routines could then be developed, probably only in C. Throughout the process, the object-oriented principle would be kept in mind, with the possibility in the long run that C++, Java or some other OO language would take over completely.

3. The SOFA Center

The Announcement of Opportunity for institutions to bid to become the SOFA Center was published at the beginning of 1997, in *IAU Bulletin 79* and elsewhere. By the 1997 April 30 deadline, two bids had been received, from Rutherford Appleton Laboratory (RAL) and the United States Naval Observatory (USNO) respectively. In 1997 June (with representatives of the two bidding institutions excluded from the voting) the Board endorsed RAL as the SOFA Center.

The SOFA Center will be operated in parallel with the Starlink service and will employ the same techniques as Starlink's "Software Store". This is a self-service facility, enabling enquirers to obtain software and documentation directly through the World Wide Web. The Web is expected to remain the principal medium for disseminating SOFA products; however, supplementary distribution services using magnetic, optical or printed media may also be introduced if there is a demand.

It is intended that the service provided by the SOFA Center will be monitored by a management board. This board will present reports and assessments at each triennial General Assembly of the IAU. The management board will initially be the WGAS. Because IAU Working Groups exist only for a limited period, it will be necessary in due course to establish a permanent SOFA Management Board, perhaps in the form of a new IAU Commission. Steps to bring about this change will be taken prior to the IAU General Assembly in 2000.

4. The First SOFA Algorithms

Apart from the "toolkit" routines, the following set of algorithms will be the first SOFA products to appear:

- IAU 1976 precession.
- IAU 1980 nutation.
- UTC/TAI transformation.
- TCB/TDB/TT transformation.
- UT1/GST transformation (mean and apparent).
- Closed-formula planetary ephemerides.
- Star-catalog-entry to space-motion transformation.
- Catalog transformation from B1950 to J2000.
- Solar-system barycenter coordinates of an Earth-based observer.
- Apparent/topocentric/observed star places for an Earth-based observer.

The great care with which the SOFA routines will have to be designed and evaluated means that rapid progress cannot be expected, and it is likely to take several years to provide even this basic set. However, successive refinements of existing models, such as new precession and nutation series, will be relatively easy to introduce quickly. Selection of new models will, of course, involve full consultation with the specialist community, and great care will be taken to ensure consistency with other standards and conventions, such as those of the International Earth Rotation Service.

An important feature of the SOFA software will be the accompanying documentation. This will include test examples, allowing other implementors of the same algorithms to check for consistency and accuracy, something which is very difficult to do at present.

References

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