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The IAU SOFA Initiative

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Abstract. The International Astronomical Union (IAU), at its 1994 General Assembly, resolved to introduce new arrangements which will establish and maintain an accessible and authoritative set of constants, algorithms and procedures that implement standard models used in fundamental astronomy. A single center will, under a worldwide reviewing board, manage and distribute the set, which is called SOFA (Standards Of Fundamental Astronomy). The initiative is the responsibility of the Working Group on Astronomical Standards (WGAS), part of Division 1 of the IAU.

1. Introduction

New techniques such as VLBI, observations from space and lunar laser ranging have brought about rapid advances in fundamental astronomy. The existing mechanisms for agreeing and promulgating revised constants and computational procedures were never intended to cope with the present flow of results. Fortunately, new methods of information exchange, in particular through global computer networks, are becoming available, and might offer more responsive alternatives to traditional channels such as IAU Bulletins and paper journals.

A related problem is the simultaneous need for (a) an interlocking and self-consistent set of *canonical* constants and procedures and (b) the current *best estimates* of individual constants and procedures such as planetary masses and precession/nutation models.

Against this background, the Subgroup on Standard Procedures (SGSP) of the IAU Working Group on Astronomical Standards (IAU/WGAS) was in 1991 asked to prepare a report on standard procedures needed in fundamental astronomy, which (a) should have a maximum degree of compatibility with the International Earth Rotation Service (IERS) standards, (b) should include the implementations of procedures in the form of tested software and/or test cases and (c) should be available both in written and machine-readable form (IAU 1991). After preliminary discussions, the Subgroup issued a questionnaire (IAU 1992), followed by a campaign to compare five independently-developed implementations of the IAU precession formula. The WGAS concluded that it was both desirable and feasible to establish a mechanism to provide such procedures to the astronomical community, named it "SOFA" (Standards Of Fundamental Astronomy) and made detailed recommendations to the IAU describing how

the SOFA service should be managed and operated. This led to a formal IAU resolution (IAU 1994) which recommended that:

1. the IAU Working Group on Astronomical Standards (WGAS) continue permanently and assume the responsibility for establishing and maintaining a set of constants, algorithms, and procedures,
2. the IAU WGAS identify single center at a suitable institution, under a worldwide reviewing board, to organize, maintain, and distribute electronically the set of constants, algorithms, and procedures, and
3. the center, and the IAU WGAS coordinate their activities with the IERS and the IAG.

See also Fukushima (1995).

2. Management of SOFA

The service will emanate from the *IAU/SOFA Distribution Center,* the location of which has yet to be determined, and will be operated according to advice from three panels:

- 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 **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 **Relativity Subgroup**, which reviews the definitions of certain units and astronomical constants to ensure consistency within the framework of General Relativity.

The present status of the scheme is that membership of the Reviewing Board is being decided, and preparations are being made to allow potential sites for the SOFA Distribution Center to bid for this role.

3. Electronic Access to SOFA

Although the Distribution Center will be able to supply the SOFA products in hardcopy form or on magnetic/optical media (the recipient paying handling and shipping costs), the principal and preferred mechanism will be via the Internet. At least three methods of obtaining information electronically will be supported:

- **Listservers:** Files will be obtainable through e-mail, transmitted automatically on receipt of specially-formatted messages.
- **World Wide Web:** Web pages will describe the products that SOFA can offer, and the user's choice of files retrieved by "point and click" actions.
- **Anonymous FTP:** Files may be transferred directly to the user's computer system without intervention from SOFA staff. No prior permission will be required, but accesses will be recorded.

In addition, the technique of *mirroring* may be used to provide access to SOFA products at sites in different parts of the world, to ease problems caused by congested international links.

Overall, the emphasis will be on automatic operation, with minimal load on the staff operating the SOFA service.

4. Standard Procedures

The intention is for SOFA to offer a group of relatively small standard procedures, rather than any large, all-embracing software packages. Each standard procedure will correspond to a specific computation in fundamental astronomy, and will be canonical in nature, uncolored by purely practical issues such as efficiency, user-interfaces or input/output. Making full use of machine precision will, however, be a consideration.

The great care with which the procedures 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:

- 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.

5. Software Issues

Although one of SOFA's key roles will be to provide access to canonical procedures, many users of the service will be looking for practical software that they can use directly or build into application programs. Indeed, there is a large audience for whom the fine distinction between a canonical procedure and a merely accurate and reliable one is of no importance, as long as whatever is supplied can be used without undue difficulty.

In general, there are two types of software which SOFA needs to address: (i) individual functions (subprograms, subroutines, etc.) and (ii) executable programs offering multiple facilities. Items of Type (i) form the basis of SOFA, but it is less clear that it is appropriate to include items of Type (ii), especially early on. Whatever software is provided, users will expect the following characteristics (in no particular order):

- free of charge
- network-accessible
- authoritative
- reliable
- easy to use
- efficient
- no copyright strings attached
- maintained
- source code available (and comprehensible)

Therefore a particular challenge faced by the SOFA Reviewing Board is to provide software which not only implements the fundamental-astronomy models definitively but also satisfies the above requirements, especially in being straightforward to use and efficient in execution. One possibility that may be considered, especially in the short term, is a two-tier system where a core of key, canonical algorithms is supplemented by packages which are richer and more practical but of lesser status. The SLALIB library (Wallace 1994) is an example of the sort of package that might fulfill such a role.

References

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