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Coordinate Transformation Service User Manual
Version 0.3

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Coordinate Transformation Service – User Manual
Version 0.1

Revision History

Version	Date	Released by	Detail
0.1	01/05/2012	P. J. Richards	Initial Draft
0.2	27/06/2012	P. J. Richards	Completed section 3
0.3	13/07/2012	P. J. Richards	Added reviewers' corrections

Note: Any notes here.

1 Introduction

The Coordinate Transformation Service (CTS) provides the capability to convert between the various coordinate systems used in HELIO (see Bentley,2010, for the coordinate systems used and diagrams showing the relationship between the coordinate systems). The CTS is built on the SPICE kernel files distributed with the SolarSoft package (Thompson, 2008). SPICE (Spacecraft, Planet, Instrument, C-matrix (pointing), and Events) is a software package developed by the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF)[1], and is used by many missions which navigate through the solar system.

The CTS utilises the capabilities provided by the SPICE kernels in SolarSoft, which were originally developed for STEREO but it also includes more generic kernels, such as a general solar system ephemeris, planetary constants and so on. The coordinate systems provided with this software are listed in the following section.

1.1 Coordinate Systems

The coordinate systems available are based on (Russell, 1971), (Hapgood, 1992) and (Fränz, 2002), and the descriptions are taken from (Thompson, 2008). The various coordinate systems are summarized below. Two axes are chosen to define each coordinate system, and the missing axis satisfies the right-hand rule.

GEI: Geocentric Equatorial Inertial. The *X* axis points toward the first point of Aries (i.e. the vernal equinox), and the *Z* axis is aligned with the geographic north pole. When expressed in terms of longitude and latitude, this is the well known celestial coordinate system of right ascension and declination. This is realized with the J2000 ecliptic.

GEO: Geographic. *X* is the intersection of the Greenwich meridian and the geographic equator, and *Z* is the geographic North Pole. This is usually expressed as geographic longitude and latitude.

GSE: Geocentric Solar Ecliptic. *X* is the Earth-Sun line, and *Z* is aligned with the North Pole for the ecliptic of date.

MAG: Geomagnetic. *Z* is Earth's north dipole axis, and *Y* is the intersection between the geographic equator, and the geographic meridian 90 degrees east of the meridian containing the dipole axis. In other words, the geomagnetic meridian containing *X* also passes through the south geographic pole. The dipole axis is defined as the centred dipole approximation to the International Geomagnetic Reference Frame (IGRF) model, as described in Fränz and Harper (2002).

GSM: Geocentric Solar Magnetospheric. This has its X-axis from the Earth to the Sun. The Y-axis is defined to be perpendicular to the Earth's magnetic dipole so that the X-Z plane contains the dipole axis. The positive Z-axis is chosen to be in the same sense as the northern magnetic pole.

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[1] http://naif.jpl.nasa.gov/naif/

SM: Solar Magnetic. *Z* is Earth's north dipole axis, and *X* is the projection of the Earth-Sun line. Although not evident in the name, this is a geocentric coordinate system. Users should be aware that the acronym SM has sometimes in the past been used for what is now referred to as GSM.

HCI: Heliocentric Inertial. *Z* is the solar north rotational axis, and X is the solar ascending node on the J2000 ecliptic.

HAE: Heliocentric Aries Ecliptic. *X* is in the direction of the first point of Aries, and *Z* is the ecliptic North Pole. This can be realized with either the J2000 ecliptic (default), or the ecliptic of date.

HEE: Heliocentric Earth Ecliptic. *X* is the Sun-Earth line, and *Z* is the North Pole for the ecliptic of date.

HEEQ: Heliocentric Earth Equatorial. *Z* is the solar rotation axis, and *X* is in the plane containing the *Z* axis and Earth, at the intersection of the solar central meridian, and the heliographic equator. When converted to longitude and latitude, this is known as Stonyhurst heliographic coordinates. In FITS files, this coordinate system is abbreviated as "HEQ", so that variation is also recognized by the software.

Carrington heliographic. *Z* is the solar rotational axis. The *X* axis is at the intersection of the Carrington prime meridian and the heliographic equator. The coordinate system rotates with a sidereal period of 25.38 days. This coordinate system is usually expressed in terms of longitude and latitude.

GRTN/RTN: Radial-Tangential-Normal. *X* axis points from Sun centre to the spacecraft, and the *Y* axis is the cross product of the solar rotational axis and *X*, and lies in the solar equatorial plane (towards the West limb). For the STEREO Ahead spacecraft, this is realized through the dynamic coordinate frame STAHGRTN, while for STEREO Behind it is realized through STBHGRTN. When the Sun is used as the origin, the designation is HGRTN—with the spacecraft as origin, it's simply RTN. RTN coordinates are closely related to helioprojective-cartesian coordinates (Thompson, 2006)).

2 How to Access the CTS

The CTS is one of several services available via the HELIO Context Service (CXS). At present this is not available via the CXS GUI.

The CXS manages the running of the service, which takes the form of a pre-compiled IDL runtime binary of the IDL procedure HELIO_CTS.pro. This procedure is run via a Service interface IDL procedure CALL_HELIO_CTS.pro.

2.1 Input Interface to CTS

The IDL procedure CALL_HELIO_CTS requires the following input parameters:

inp_votable : Path to a VOTable file (Ochsenbein, 2009) containing a time (in ISO 8601

format, e.g. 2005-01-01T00:00:00Z) and the coordinates to be transformed (an example of an input file is given in Section 3). One or more set of coordinates can be input. When the transformation involves a shift of origin, which would be the case when going from a heliocentric system to a geocentric or planetocentric system, then distances must be provided in km. (At present the software does not check the field names and assumes that the coordinates are in the order XYZ for a Cartesian representation and R, T(latitude), P(longitude) for a Spherical RTP representation.)

inp_coord : A string containing the coordinate system of the input data. Possible values for the string are:
'GEI','GEO','GSE','GSM','GAE','MAG','SM','HCI','HAE','HEE','HEEQ','Carrington','GRTN'
These correspond to the definitions given in section 1.1

outp_votable : Path to a VOTable file containing the time and the coordinates in the transformed coordinate system

outp_coord : A string containing the coordinate system of the input data. It can have the same set of values as the inp_coord parameter.

inp_rep : Set to 'RTP' if the input is in spherical representation. The T (theta - latitude) and P (phi – longitude) angles must be provided in degrees.

outp_rep : Set to 'RTP' if the output is in spherical representation. The T (theta - latitude) and P (phi – longitude) angles are in degrees.

2.2 Output from CTS

The output is a VOTable containing four columns which are the time and the three element positions in the converted coordinate system. The VOTable is annotated and the field elements have values for the name and datatype attributes.

An example of the output VOTable from a transformation from GEO XYZ to GSE RTP coordinates is given below.

```
<?xml version="1.0"?>
<!DOCTYPE VOTABLE SYSTEM "http://us-vo.org/xml/VOTable.dtd">
<VOTABLE version="1.0">
 <DESCRIPTION>
   VOTable file created by the HELIO Coordinate Transformation Service
   Created: Wed Oct 19 11:11:25 2011
 </DESCRIPTION>
 <RESOURCE>
  <DESCRIPTION>Transformed coordinate list</DESCRIPTION>
  <TABLE>
   <DESCRIPTION>Transformation from GEO/XYZ to GSE/RTP</DESCRIPTION>
   <FIELD name="TIME" datatype="char"/>
   <FIELD name="R" datatype="float"/>
   <FIELD name="THETA" datatype="float"/>
   <FIELD name="PHI" datatype="float"/>
   <DATA>
    <TABLEDATA>
```

```
    <TR>
      <TD>2005-01-01T00:00:00Z</TD>
      <TD>173205.</TD>
      <TD>54.7356</TD>
      <TD>45.0000</TD>
    </TR>
    <TR>
      <TD>2005-01-01T00:00:00Z</TD>
      <TD>173205.</TD>
      <TD>54.7356</TD>
      <TD>45.0000</TD>
    </TR>
    </TABLEDATA>
   </DATA>
  </TABLE>
 </RESOURCE>
</VOTABLE>
```
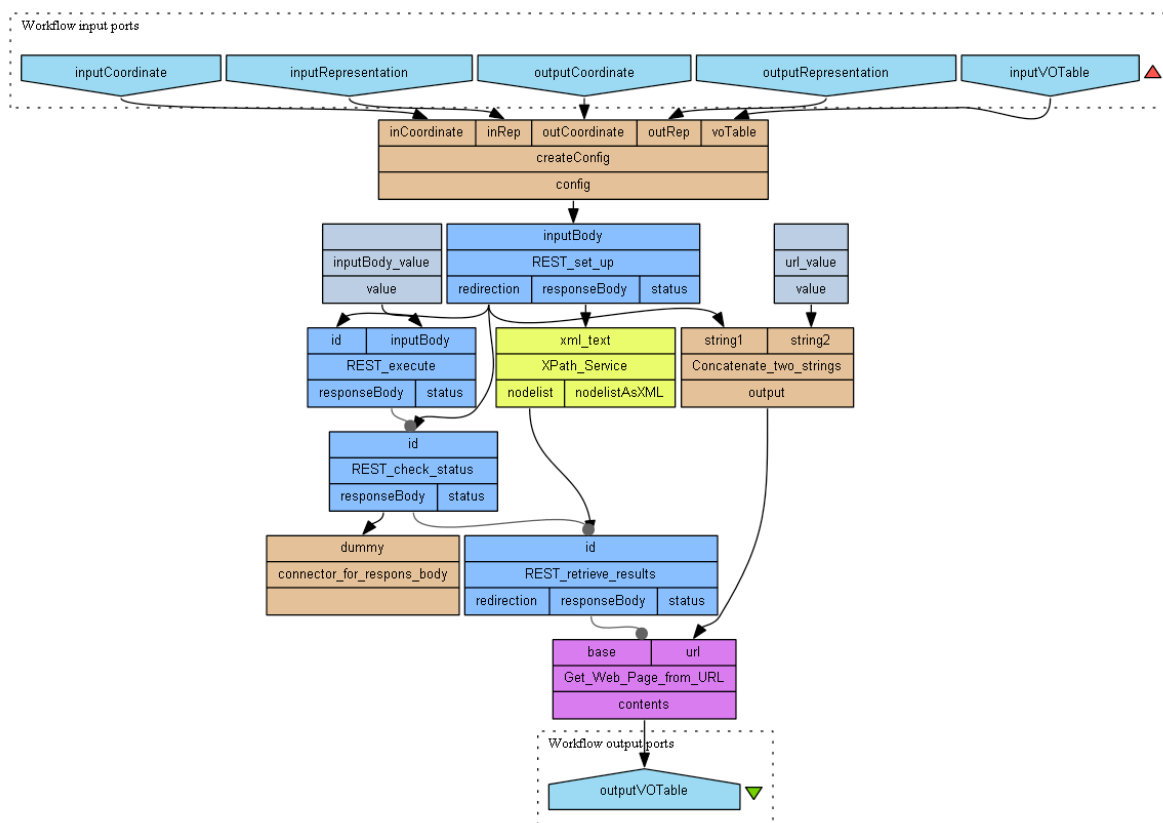
3 Sample Workflows

Figure 1: Sample Workflow to call the CTS via the REST interface

CTS is an asynchronous service, therefore it requires several steps. The first sets up the job on the server by providing the required input in a XML file. Here is such an file as example:

```
<?xml version="1.0" encoding="UTF-8"?>
<tool xmlns="http://www.ivoa.net/xml/CEA/types/v1.2"
```

```
      id="ivo://helio-vo.eu/cxs/CTS" interface="simple_rep">

 <input>
    <parameter id="InputVotable" indirect="false">
       <value>
<![CDATA[<VOTABLE version="1.1"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://www.ivoa.net/xml/VOTable/v1.1
http://www.ivoa.net/xml/VOTable/v1.1"
 xmlns="http://www.ivoa.net/xml/VOTable/v1.1">
<RESOURCE>
<TABLE>
<FIELD arraysize="*" datatype="char" name="time"/>
<FIELD datatype="float" name="x"/>
<FIELD datatype="float" name="y"/>
<FIELD datatype="float" name="z"/>
<DATA>
<TABLEDATA>
  <TR>
    <TD>2005-01-01T00:00:00Z </TD>
    <TD>-132645.54</TD>
    <TD>-93817.847</TD>
    <TD>60028.106 </TD>
  </TR>
  <TR>
    <TD>2005-01-01T00:00:00Z </TD>
    <TD>-132645.54</TD>
    <TD>-93817.847</TD>
    <TD>60028.106 </TD>
  </TR>
</TABLEDATA>
</DATA>
</TABLE>
</RESOURCE>
</VOTABLE>]]>
</value>
    </parameter>

    <parameter id="InputCoordinate" indirect="false">
       <value>GEO</value>
    </parameter>

    <parameter id="OutputCoordinate" indirect="false">
       <value>GSE</value>
    </parameter>

    <parameter id="OutputRepresentation" indirect="false">
       <value></value>
    </parameter>

 </input>
</tool>
```

Note the embedded VOTable with the values to transform. At present the order of these values is significant and the fieldnames are not.

In a second step the CXS server is instructed to execute the submitted job by setting the phase to the state 'run'. The third step is checking the execution status. Last step is to call retrieve results. Note this does not return a link to the results. But the results can be

downloaded from:
`http://msslkz.mssl.ucl.ac.uk/cxs/jobs/{job-id}/output.vot`

3.1 How to Use the CTS

The CTS is called as a web service via the CXS. For more information on how to run a service via the CXS see the CXS – User Manual (Benson, 2012). See also Section 3.

3.2 Submit the Transformation

The input required for the transformation is submitted to the CTS service according to the interface described in the CXS – User Manual. See also the description in Section 3.

3.3 Get Transformation Results

The results are written to a file 'output.vot' in VOTable format. An example of the contents is given in section 2.1.

References

Bentley, R.D (Ed) (2010). Coordinate Systems. HELIO-UCL-N3-003-TN.
Benson, K. (2012). CXS – User Manual, *HELIO document TBD*.
Fränz, M. (2002). Heliospheric coordinate systems. *Planetary and Space Science* , 50, 217–239.
Hapgood, M. A. (1992). Space physics coordinate transformation: A user guide. *Planetary and Space Science* , 40, 711–717.
Ochsenbein, F (Ed) (2009). VOTable Format Definition Version 1.2, http://www.ivoa.net/Documents/VOTable/
Russell, C. (1971). Geophysical coordinate transformations. *Cosmic Electrodynamics,* , 2, 184-196.
Thompson, W. T. (2008). *Reading STEREO ephemerides as SPICE kernels.*