Wide-field Infrared Survey Explorer (WISE)

Position Reconstruction Peer Review Report

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WSDC D-A003

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1 INTRODUCTION

A peer review of the design of the Position Reconstruction module of the WISE Science Data System was conducted by the WISE Science Data Center (WSDC) on December 13, 2007. The Position Reconstruction module (PREX) is responsible for determining the transformation between instrumental pixel coordinates and J2000 equatorial coordinates in WISE image data. This transformation is used to assign equatorial positions to sources in the WISE Source Catalog and to provide World Coordinate System (WCS) information for images in the WISE Image Atlas. This review focused on the design of the single-frame component of PRex (SFPRex).

PREX functionality, design and algorithms are described in Position Reconstruction Subsystem Design Document. (WSDC D-D003).

1.1 Review Panel Members

Rachel Akeson (IPAC/MSC)
Gene Kopan (IPAC retired)
Amy Mainzer (JPL WISE Science Team
Bob McMillan (U.Arizona/LPL WISE Science Team)
Mike Rich (UCLA)

1.2 Instructions for Review Panel

The peer review panel was asked to comment on the following specific questions*:*

- Does the design of Position Reconstruction program address the requirements on the system?
- Are the Position Reconstruction algorithms suitable and appropriate to carry out the system functions?
- Is the design robust to circumstances that will be encountered with the WISE data?

In addition, comments on other aspects of the design we welcomed.

Written reports were received from Akeson, Kopan, and McMillan. These reports are provided below. Miscellaneous comments that were recorded by R. Cutri during the review are also summarized below.

1.3 Applicable Documents

WSDC Functional Requirements Document (WSDC D-R001)
WSDS Functional Design Document (WSDC D-D001)

2 PANEL REPORTS

2.1 Rachel Akeson

Overall the algorithm development looks excellent. A very valuable next step is to start working with realistic astrometric sets from 2MASS and plausible WISE fields. In particular, it would be helpful to know how difficult the error budget for this component is to meet.

RESPONSE: The error budget for astrometeric calibration is currently held in the project-level WISE Calibration Plan. For construction of that error budget, assumptions were made for various allocations within the position reconstruction system that were based on earlier experience with 2MASS. Once FSFitR is installed in SFPRex, which should be soon, we plan a series of tests using Monte Carlo generated simulation data. These tests should provide a good idea of the reconstruction accuracy SFPRex will be able to achieve and will allow updating of the error budget in the Calibration Plan.

On the astrometric input catalog from 2MASS, there are several avenues to vetting the input catalog to minimize problems during the mission, particularly with respect to proper motions. Some suggestions are:

- Consider using fewer bright stars, as these will statistically have higher proper motion and will be used first in the current matching scheme.

RESPONSE: Will provide the capability to reject 2MASS stars brighter than a specified magnitude from the FSFitR step.

- Use the 2MASS color info as well as the Kmag to pre-select for well-behaved stars likely to be present in WISE as well.

RESPONSE: This is highly desirable and will be implemented if resources allow.

- Use Hipparcos and other proper motion surveys to reject high proper motion stars from the input catalog. You could also use Hipparcos to generate proper motion statistics given a 2MASS color threshold and then scale for the appropriate distance given the average Kmag of the input catalog.

RESPONSE: See response to proper motion comments at end of report

- Have a good process to reject stars from the input catalog during the first processing run.

RESPONSE: Identification of rejects is currently on the SFPRex lien list. Flagging problem 2MASS stars will definitely be included.

- Have test fields such as the Hyades which can check for any latent systematics in the position reconstruction.

RESPONSE: Plan to compare reconstructed WISE positions with a large set of astrometric references not used in the reconstruction. This will include, but not necessarily be limited to, the UCAC catalog. Will look for all sorts of possible systematic errors.

2.2 Gene Kopan

1. how well the current design addresses the subsystem requirements

Very well. The current design should be sufficient to address all subsystem requirements.

2. Are the algorithms to be used are suitable and appropriate to carry out the subsystem functions?

Yes, the algorithms proposed are suitable and appropriate to carry out the subsystem functions.

3. if the design is robust to the circumstances that will be encountered with the WISE data.

The design should be robust to circumstances that will be foreseeably encountered. As noted by the presenters, the unlikely loss of both short wavelength bands would impact the ability to meet requirements, and would probably require a redesign and/or an additional reference catalog. It might be prudent to give some consideration to this contingency.

RESPONSE: Have given some consideration to the possible loss of bands 1 & 2. SFPrex can operate with any subset of bands. It is expected that the biggest problem will be getting enough reference stars. One possibility might be to modify how the 2MASS stars are selected. This would be a relatively easy change. Another thought would be to solve simultaneously for multiple frames along the scan, as we did in 2MASS. This would allow the use of far fewer reference stars, but would be much more drastic, requiring a total redesign of the software. Will continue to look for other options.

Addtional comments:

The SFPRex subsystem Cog E's demonstrated more than sufficient competence to accomplish this task in virtually any eventuality. A few minor (and possibly debateable) comments are listed below that might possibly improve an already excellent design.

One prior comment on Requirement L4WSDC-014: The rms position error requirement should probably specifically exclude moving objects (asteroids, proper motion) and confused or extended objects.

RESPONSE: This qualification of L4WSDC-014 is a good one. Pending discussion with the Project and Science Team, we will consider for the next revision of the WSDC Functional Requirements Document.

1. The scale factors may vary only on long time scales. Some thought might be given to updating the estimates of these parameters on longer time scales than per frame, such as per scan or longer.

RESPONSE: Current plans are to write scale factor solutions to the meta-data file. It should be possible to identify long-term trends from these data. The smoothed scale factors could be input to the reprocess as fixed parameters.

2. Additional thought and analysis could be put into choosing the WISE position reference catalog subset of the 2MASS catalog. The bright 2MASS stars (Ks<9) are more likely to have significant proper motion and also have somewhat larger 2MASS position uncertainties than the fainter set. This argues for lowering the bright limit for the reference subset, but in confused areas the fainter sources could be a worse problem. Some additional study of these problems may be warranted.

RESPONSE: Will look into your suggestions

Also, it may be good to retain the brighter sources for the pattern matching step, but not use them for the position estimation steps.

RESPONSE: Will provide the capability to drop 2MASS stars brighter than a specified magnitude from the FSFitR step.

3. Attention needs to be given to analysis of outliers and the tails of the distribution in general, and optimization of robust rejection criteria to remove the effects of proper motion (and other moving objects), confusion, artifacts, and dead pixels (the latter is probably covered by frame extraction uncertainties).

RESPONSE: Identification of outliers is currently on the SFPRex lien list. Will keep in mind the points mentioned during that task.

4. Due to the somewhat large focal plane, accurate determination of the distortion model will be necessary to achieve accuracy requirements. This will probably require a combination of optics modeling and IOC measurements.

RESPONSE: A preliminary distortion model will be measured during ground characterization at SDL, and will supplied to the WSDC prior to launch. Verification and updating of the distortion model is idientified as a key IOC task. Both external tools and routines within PRex are being developed to fit distortion during IOC and monitor periodically thereafter.

5. A plan will of course be needed in due time for IOC determination of initial parameters (scale factors and distortion, band offsets and relative band rotations about the optical axis, etc).

RESPONSE: The IOC plan will contain descriptions of these tasks and will identify procedures needed before launch to be ready to determine the various parameters. We expect that SFPRex can be used during IOC to get a handle on the parameters mentioned by simply operating with larger a priori uncertainties and computing band-to-band differences in MergeX prior to calling FSFitR. The Ref-vs-Band file generated will be used by an off-line program to fit the distortion.

2.3 Bob McMillan

PRex Subsystem Design Document Version 1.0 4-December-2007

Page 6:

>Twist,

"orientation" is the term used in other WSDS docs. And when I think of "twist", something much more horrible comes to mind: differential field rotation vs. radial position!

RESPONSE: The traditional JPL spacecraft terminology for spherical angles has been for many years "clock, cone, twist". Since PRex deals internally with true Euler angles, we need to use a definition with a clear distinction from traditional left-handed and/or celestial-zero-point angles defining rotation about the telescope optical axis. "Twist" has been the best choice for numerous missions, and so we propose to use it for WISE.

>The MFPRex module is called by the WSDS Multi-Frame Pipeline and
>operates on multiple framesets corresponding to overlapping coverages
>of a specified area on the sky. It also uses matched sets of sources
>and the 2MASS astrometric reference data to refine the registration of

>the frames relative to each other. It employs an interative method that
^^^^^^^^^

iterative or interactive?

RESPONSE: It was meant to be "iterative", and the SDS will be corrected. However, given the long run times associated with an all-sky solution, it might be prudent to make it somewhat "interactive" as well. We could place pauses at the end of specified iteration steps, where user input could be accepted.

>It has not been determined how to handle 2MASS position errors due to
>accumulated proper motion.

See my comment below.

>Page 9:
>
>2.1.2 SFPRex Namelist Parameters
>The SFPRex module optionally reads a NAMELIST file. The name of this
>file must be given on the command line via the ,~@~\-n,~@~]
>option. The name of the NAMELIST is sfprin. The parameters defined in
>the NAMELIST are as follows.

No correction delta-T = VTC minus UTC info provided?

RESPONSE: SFPRex doesn't currently do anything with the time tags, other than pass them along to the meta-data file. Presumably they will be used later on for working with asteroids. We could easily add an adjustment to the time tags if deemed useful.

>Page 13:
>
>Unfortunately, proper motions are correlated due to solar motion through
>space,

differential galactic rotation, and the population-dependent kinematics of stars, ...

I think these corrections to 2MASS positions could be done by cross identifying 2MASS objects with the USNO-B catalog and deriving proper motions from the 2 positions.

RESPONSE: See response to proper motion comments at end of report

>WISE Science Data Center Functional Requirements Document
>Version 2.0 25 November 2007
>

>L4WSDC-077
>All data products and operations reporting shall contain
>Coordinated Universal Time (UTC) time-tagging with an
>absolute knowledge of +/-0.6 seconds.

Is +/-0.6 sec an rms or a hard limit?

RESPONSE: This requirement is a direct flowdown from the Level 3 MOS Requirements. The WISE MOS is interpreting this as a hard limit. The conversion coefficients will be updated frequently enough that every timestamp on the data falls within the 0.6 sec accuracy (*response provided by Beth Fabinsky (JPL))*

>L3MOS-121 Analysis
>Inspection
>Demonstration
>
>WISE Data Processing Overview
>R. Cutri and the WSDC Team @ IPAC
>
>6.1.1 Execution Wappers (WRAP)
^^^^^^^
Wrappers

RESPONSE: The correction is noted.

>6.1.3 Ingest Pipeline Executive (INPIPEX)
>
>VTC
>Vehicle Time Code. The time stamp marking frame data and ancillary data
>generated on-board the S/C.

How do we know the VTC is correct? Is it tested on the ground? Should we devise a check in flight using a fast-moving asteroid with a really well determined orbit?

RESPONSE: The key element in the VTC->UTC conversion is the spacecraft clock accuracy. Non-spacecraft components of the timing will be calibrated during IOC. Everything else (signal delays within the spacecraft, TDRSS, White Sands) is measured at various points and provided to the MOS. The spacecraft clock accuracy will be determined during ATLO. It is expected that the VTC->UTC correlation can be maintained to within 0.1 sec.

As part of the standard output from the solar system association module (SSOID), ee will have the information to test for systematic offsets between predicted and observed positions of bright asteroids that could indicated VTC->UTC offsets.

The requirements on the spacecraft's Internal Crystal Oscillator are:

a) **Initial Accuracy: 25 ppm**
b) **Temperature stability: 100 ppm (-55 to +125 deg C)**
c) **Aging, 30 days: 1.5 ppm**
d) **Aging, 1 year: 10 ppm**
e) **Aging, 8 years: 25 ppm**
f) **Long term stability: The long term (one year) stability shall be less than 10 ppm at room temperature and less than 30 ppm over the specified temperature range.**
g) **Short term stability: The short term (one second) stability shall be less than 1.5 ppm**

Response provided by Don Royer and Beth Fabinsky (JPL)

2.4 Miscellaneous Comments Recorded During Review

Peter Eisenhardt – Who has the responsibility for determining updates to distortions and skew during IOC and prior to final processing?

RESPONSE: The responsibility of updating the distortion model during IOC is actively being discussed by the Project. The final update of the distortion model prior to final data processing is the responsibility of the WSDC.

Peter Eisenhardt – In what format would we like the distortion model to be provided?

RESPONSE: We would like to receive distortion vectors (dx:dy) for each point in a grid spanning the focal plane. We'll use these to do our own polynomial fit. That way we can chose the order which works best for us. For data coming from an optical simulation such as CodeV, it would be nice to have a fine grid with about 100 pixels (10x10) in each grid point, That would give us a grid of 102 by 102. For data coming from optical bench measurements, we'll settle for the finest grid that's reasonable to generate.

Peter Eisenhardt – If skew is added to the fitting solution, is there anything else to be solved for?

RESPONSE: Fitting for skew would be done off-line in conjunction with the distortion fitting

Peter Eisenhardt – Consider weighting sources differently depending on focal plan position because of the influence of distortion.

RESPONSE: If after processing a large quanity of data through SFPRex, chi-square analysis indicates that the extraction uncertainties are systematically incorrect as a function of focal plane position, the uncertainty modeling could be modified to correct the problem. This would change the weighting and could account for unmodeled distortion. The best point to do this would probably be prior to the reprocess.

Peter Eisenhardt – Leverage the stability of the band-to-band offsets.

RESPONSE: This should happen as a result of the fact that the a priori values included in the system have uncertainties that naturally shrink as a function of time. Trend monitoring is needed to prevent these uncertainties from shrinking too much to allow tracking of an actual variation. This is a well known feature of sequential estimation of parameters that are not expected to change but may somehow drift anyway, i.e., some supervision is needed to prevent the algorithm from eventually in effect ignoring measurements.

Gene Kopan – Do the position reconstruction accuracy requirements apply to non-intertial sources?

RESPONSE: See response to your requirement change suggestion in the review board comments

Amy Mainzer – Can motion in reference catalog be imprinted on WISE catalog, in particular for regions where there may be many stars with the same motion (e.g. the Hyades)?

RESPONSE: Yes, it is possible if the reference stars in a small area have systematically moved since the epoch of 2MASS. We should probably give special attention to areas where this is known to occur when doing the checks against external reference catalog(s).

Amy Mainzer – The WISE payload is going into the first round of image testing. What is the most critical aspect of optical performance that could threaten ultimate performance of PRex?

RESPONSE: Unmodeled distortion would probably have the greastest effect. Not necessarily on the PRex band-frame reconstructions themselves, but rather on the downstream source position accuracy.

Bob McMillan – Is the scan mirror position commanding dithered? If so, will it affect the accuracy of the vehicle time code?

RESPONSE: The scan mirror position commanding is not dithered. Scan mirror positioning should have no impact on vehicle time accuracy, or the correlation between vehicle time and knowledge of the observation time.

Mike Rich – Consider using the all-sky catalog of high proper motion stars being compiled by Sebastien Lepine to filter reference catalog, and to test impact of proper motion in regions known to have many stars with coherent motions (e.g. the Hyades).

RESPONSE to multiple comments on PROPER MOTION from various reviewers and audience members:

It's obvious from the number of comments received on this subject that it needs to be considered carefully. An analysis of how to best handle the lack of proper motions in the 2MASS catalog has been identified as a necessary task with a need date specified in the SFPRex development schedule. An effort will be made to determine the best solution that can be achieved within time and budget constraints. All recommendations received will be factored into the analysis.