The Two Micron All Sky Survey
Extended Mission

- Extended Mission Overview
- Deviations from Baseline Plan
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Extended Mission Overview

• **Motivation:** 2MASS External Review Board 2001 recognized the scientific value of the *Ancillary Data Products* drawn from data acquired during survey operations and recommended finding the resources to prepare and release them to the community. They also recommended finding a way to continue expert *user support* for 2MASS products beyond the end of FY02.

• Because the primary mission funding did not cover these activities, the Project submitted a proposal for an Extended Mission to the NASA MO&DA Senior Review Board in April 2002.

• Proposal for FY03-04 Extended Mission was approved and funded at near requested level. No further NASA funding for 2MASS as a Project will be available.
Extended Mission Activities

• **Objective:** To produce and provide the *best, most comprehensive* source and image databases and *value-added* features available from 2MASS by exploiting expertise and infrastructure from primary mission before that expertise is lost
  – Science oversight provided by 2MASS PI and subset of original Science Team
  – Bulk of pipeline and product generation work done at IPAC

• Carry out minimum level of data processing and validation to make *Ancillary Data products* useful to community

• Continue user support at IPAC (2MASS Helpdesk, science outreach)

• Deliver Products to and serve to community through *IRSA* by the end of FY04
  – Leverage IRSA expertise and existing Catalog and Image services to serve data
  – Possible bulk ftp and DVD distribution of Catalogs (probably not images)
Personnel

• Project Manager/IPAC Lead - R. Cutri (IPAC)
• UMASS Lead - M. Weinberg (U.Mass.)
• Science Team - M. Skrutskie (Chair - U.Virginia), C. Beichman (IPAC/MSC), J. Carpenter (Caltech), J. Huchra (CfA), D. Kirkpatrick (IPAC/SSC), S. Schneider (U.Mass.), M. Weinberg (U.Mass.)
  – staff names in red have now transitioned off project
  – remaining staff are all \leq\ half-time
Baseline Deliverables

- Working Survey and Calibration Source Databases
  - All point and extended source extractions, not included in PSC, XSC
  - Reliability confidence scoring for all extractions
  - All measurements of unique objects linked with time-tagging
- Long Exposure (6x) Scan Catalogs and Source Databases
  - Photometry and astrometry for point and extended sources
  - Merged with Survey catalogs in relevant areas
- Non-lossy-compressed Survey, Calibration and 6x Image Atlases
  - \(5.9\times 10^6\) calibrated FITS (1″/pix 512x1024) images (~12TB raw, 9TB gzip’d)
- Images and point and extended source lists from Combined Calibration Scans
- Explanatory Supplement Appendices describing Ancillary Products
- Released to community by the end of FY04
Changes from Baseline Deliverables

- Working Survey and Calibration Source Databases
  - Include all extractions, including those selected for Catalogs. Identify catalogs sources with cat flag

- Long Exposure (6x) Scan Catalogs and Source Databases
  - Will not merge with main Survey catalogs because of variables, proper motion objects, and complexity introduced by confusion
  - Will include identification of closest PSC, XSC sources with 6x Catalog

- Images and source lists from Combined Calibration Scans
  - Will produce single source catalog, without point/extended separation
  - Only aperture photometry will be performed on extracted sources

- LMC/SMC 6x Data Products will be released at end of CY06
  - All production work on 6x to be complete by end of FY04
Ancillary Data Sets: Working Databases (WDBs)

- WDBs contain positions, magnitudes and auxiliary information for all SNR>3 extractions from Survey, Calibration and 6x scans generated during pipeline processing.
- The All-Sky Release and 6x Point and Extended Source Catalogs are subset of WDBs that meet Level 1 reliability, completeness and uniformity requirements:
  - SNR>7 for reliability
  - One apparition of multiply-detected sources for uniformity
  - Artifacts removed using probabilistic algorithms

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<th>Data Set</th>
<th># Scans</th>
<th># Point Srcs</th>
<th># Extended Srcs</th>
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<td>6x Catalogs</td>
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<td>8,591,216</td>
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Ancillary Data Sets: Working Databases (WDBs)

- WDBs contain detections of real astrophysical sources:
  - Multi-epoch detections of sources in Tile overlaps and repeated observations (30% of sky observed $\geq 2$ times)
  - Sources fainter than SNR limit of Catalogs (reliability drops off rapidly below SNR~7, though)

- WDBs also contain spurious extractions of:
  - Low SNR noise events (~50% of extractions in low source density regions)
  - Artifact detections (<1%)
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Extended Mission Tasks: Preparing the WDBs

• Generate “value-added” columns for each entry to bring into compliance with All-Sky Release Catalogs
  – Corrected photometric uncertainties, photometric quality flag, Julian date tags

• Estimate reliability of each extraction and assign reliability “score”
  – Reliability score based on bands-detected, SNR thresholds, artifact identification
  – Additional reliability info provided from confirmation statistics and correlation with USNOA-2.0 and Tycho catalogs (non-uniform)

• “Merge” multiple detections
  – Autocorrelate source databases (1.5” match radius, confusion handling)
  – Generate cross-reference index for all apparitions of the same source in WDB
  – Derive confirmation statistics (#possible sightings, #detections)
  – Derive merged source properties (variance weighted position and brightness, updated uncertainties, magnitude and position chi-squared statistics for variability and motion diagnostics)
WDB Preparation Status and Schedule

- Pipeline data processing complete. Source and Image databases in-place (Survey and Calibration since March 2002, 6x since Nov. 2003

- Value added columns:
  - Calibration and 6x WDBs complete and validated
  - Survey WDBs in progress, complete by May 30

- Reliability flagging
  - Algorithms in test, final versions by June 10
  - Reliability flag application June 11-30
  - Analysis and validation July 1-30

- Multiple source merging
  - Autocorrelation software (WAX - S. Monkewitz) complete
  - Merged source statistics in test, final versions by June 15
  - WDB merging and merged source list generation June 16-July 31
  - Analysis and validation July 15-August 20
Ancillary Data Sets: Long Exposure (6x) Scans

- Observations made at **6x normal survey exposure** during “filler-time” at end of survey
  - Special “campaigns” on specific regions such as the Pleiades, ρ Oph, Chameleon II, IC1396, LMC, SMC, M31, M33, 15 nearby Abell galaxy clusters and the Lockman Hole
  - ~580 deg$^2$ ~1 mag deeper than nominal survey depth

- “R2” exposure increased to 7.8s (1.3s for main survey), but “R1” exposure time not changed (0.05s)
  - Resulted in **sensitivity gap** between “R2” saturation and “R1” detections limit (10.5-11.0 mag)
  - Low SNR “R1” sources (flux overestimation), partially saturated “R2” sources (small flux bias)
Ancillary Data Sets: Long Exposure (6x) Scans

Regions covered by photometric Long Exposure (6x) observations
Ancillary Data Sets: Long Exposure (6x) Scans

Standard 6x processing QA output showing difference between 6x and All-Sky Release PSC magnitudes for sources measured on 30 May 2000 UT from CTIO (mostly LMC and SMC scans)
Extended Mission Tasks: 6x Scan Processing

• Tune 2MAPPS pipeline for optimal handling of 6x data
  – Adjustments for longer exposure time (calibration, artifact ID, R1/R2-R1 merging)
  – Handle higher frame background level and airglow structure (image construction, source detection, extended source processing)
  – Derive astrometric calibration fields from 2MASS PSC
  – Develop calibration sequences from 5 special Cal Fields in LMC and SMC

• Process 6x data
  – Conduct Quality Assurance - update quality metrics for 6x data characteristics
  – Load Source and Image Working Databases

• Generate Point and Extended Source Catalogs
  – SNR thresholds, duplicate source resolution, artifact ID, etc (modeled on ASR)
  – Identify Catalog-subset of 6x WDBs with cat flag
  – Generate “value-added” source parameters (designations, Julian dates, corrected photometric uncertainties) - done in pipeline processing
6x Catalog Generation Status and Schedule

- Pipeline tuning **complete**
- Pipeline processing **complete** (twice, as for main survey)
- Catalog generation **complete** (“cat” flag set in WDB)
- Validation and Analysis **in progress**, scheduled completion August 1 (except LMC/SMC)
- Documentation **scheduled** for July 15-August 20
Ancillary Data Sets: Combined Calibration Scans

- **40** 8.5’x60’ fields scanned 6-18 times/night for 2MASS photometric calibration
  - Each field observed **600-3500** times over the course of survey (LMC/SMC Fields observed 150-470 times)
  - Time sampling from ~1 minute to 3 years
  - Broad range of environments (galactic poles to plane)

- “Stacking” Calibration Field Images yields deepest 2MASS data set
  - SNR=7 down to $K_s \leq 18.5-19.5$ mag over ~5deg$^2$
  - Dynamic range in images of ~11- 12 mag
Ancillary Data Sets: Combined Calibration Scans

Composite JHKs image of 2MASS Calibration Field 90009 (in ρ Oph); (top) from stack of ~780 scans, (bottom) from single calibration scan
Extended Mission Tasks: Calibration Scan Combination

• Combine Images
  – Calibration Scan Atlas Images registered and sampled on common pixel grid during pipeline processing
  – Filter 5% noisiest scans, and scans with high SNR artifacts detected on residual images
  – Combine images using sensitivity weighting (zero-point, seeing, background)
  – Quality verification done visually and with image stats (only 40)

• Extract Sources
  – DAO-find SNR-thresholded detection (conservative SNR~5 limit)
  – Aperture photometry, normalized to standard stars in each scan
  – Bandmerge

• Artifact Identification
  – Use north/south-going scan extractions to identify non-positional repeating artifacts (latent images, diffraction spikes, bright star halos)
  – Use bright star positions and Survey artifact detection algorithms to flag fixed artifacts (dichroic glints)
Combined Calibration Scan Status and Schedule

- Image stacking:
  - 35 Survey cal fields complete
  - 5 Special (LMC/SMC) cal fields in progress, scheduled for completion by May 25

- Source extraction software in test, processing scheduled for June 15-July 15

- Analysis and Validation July 1 - July 31

- Documentation in progress, scheduled for completion August 20
Atlas Image Status and Schedule

- Nexan ATABeast 12TB disk system acquired and installed
- Image loading from tape archive in progress, complete by July 31
- Modification to IRSA/2MASS Image Services scheduled for June 15-June 30
- Service testing scheduled for July 1-July 31
Extended Mission Tasks: Common Functions

• Final product validation and analysis
  – Goal is to release all data, so fundamental task is to characterize products rather than assure that they satisfy specifications
  – Relying on significant assistance from Science Team

• Integrate Catalog and Image products into existing IRSA services
  – Products developed within IRSA infrastructure, so “delivery” is implicit
  – Leverage interoperability offered by all IRSA services
  – Discussing development of one new interface to take advantage of merged WDB tables, but not required for release

• Documentation for new Products
  – Appendices to Explanatory Supplement (exploit existing project descriptions)
  – Document 6x observations, new processing, product generation, product characteristics
Extended Mission Resources

- All-Sky Release delay resulted in 1-4 month delay in start of some tasks
  - Mitigated by retaining staff longer followed by steeper roll-off
  - Consequence is minimal staffing now
- Funding $3.8M ($2.4M/$1.4M FY03/04)
  - $0.2M U.Mass.
  - $0.1M U.VA
  - $0.2M overrun payback
- $350K remaining in IPAC/2MASS budget
  - Projecting ~$40K reserve
  - Requesting no cost extension FY05-06 to manage U.Mass. Contract, and to maintain low level of user support
Summary and Concerns

• Main concern is small workforce and short time remaining before scheduled data releases.
  – Some descoping of effort, primarily on Combined Calibration Scan source extractions
  – Level and detail of analysis and documentation of Ancillary Products will not be as thorough as for primary mission products

• Ancillary Data Product generation tasks on schedule to be completed by end of July

• Validation and Analysis underway and will be on-going through end of August. *Relying heavily on Science Team support*

• Documentation to be finalized by end of August. *Level of detail likely will not be as good as for All-Sky Release*

• Release readiness review to be scheduled for early September