Wide-field Infrared Survey Explorer (WISE)

WISE Science Data Center Functional Requirements Document

Version 2.1

18 September 2009

Prepared by: Roc M. Cutri

Infrared Processing and Analysis Center
California Institute of Technology

WSDC D-R001

Approved By:

Roc M. Cutri, WISE Science Data Center Manager

George Helou, IPAC Executive Director

Donald Royer, WISE Mission Operations Manager

Edward Wright, WISE Principal Investigator

Peter Eisenhardt, WISE Project Scientist

Revision History

Date	Version	Author	Description
4/8/2006	0.1	R.M.C.	Initial Draft
3/7/2007	**0.5**	**R.M.C.**	**Revised Draft**
5/30/07	**1.0**	**R.M.C.**	**Version 1**
11/25/07	**2.0**	**R.M.C.**	**Version 2**
9/17/09	**2.1**	**R.M.C**	**Version 2.1**

1. INTRODUCTION

The Wide-field Infrared Survey Explorer (WISE) is a NASA medium-class explorer (MIDEX) mission that will carry out a sensitive, digital imaging survey of the entire sky in 3.3, 4.7, 12 and 23 μm mid-infrared bandpasses. WISE will produce and release to the world astronomical and educational communities and general public a digital Image Atlas covering the sky in the four survey bands, and a reliable Source Catalog containing accurate photometry and astrometry for approximately 300 million objects. The WISE Catalog and Atlas will enable a broad variety of research efforts ranging from the search for the closest stars and brown dwarfs to the most luminous galaxies in the Universe. The WISE science data products will serve as an import reference data set for planning observations and interpreting data obtained with future ground and space-borne observatories such as JWST.

WISE will conduct its survey using a 40cm cryogenically-cooled telescope equipped with a camera containing four mid-infrared focal plane array detectors that simultaneously image the same 47'x47' field-of-view on the sky. The spacecraft will fly in a sun-synchronous 525 km polar orbit and use a near-zenith pointing telescope with freeze-frame scanning technique to obtain multiple, independent 8.8sec exposures of each point on the sky. The number of independent exposures is typically eight on the ecliptic equator and increases towards the ecliptic poles as the orbital scans converge. WISE is designed to achieve a minimum point source sensitivity on the ecliptic corresponding to flux signal-to-noise ratios $\geq$5 at flux densities of 0.12, 0.16, 0.85 and 4.0 mJy at 3.3, 4.7, 12 and 23 μm, respectively, in regions of the sky not confused by Milky Way stars and diffuse emission. The astrometric precision of the WISE Source Catalog and Atlas will be $\leq$0.5" with respect to the 2MASS All-Sky PSC.

WISE is scheduled for launch in December 2009 and will have an in-orbit checkout (IOC) phase of one month, followed by a six month baseline on-orbit data acquisition operations period. A preliminary Source Catalog and Image Atlas constructed from data acquired from the first 50% of the sky surveyed will be released six months after the end of the on-orbit operations phase. The final Catalog and Atlas will be released 17 months after the end of on-orbit operations. All WISE science data products will be distributed via the on-line and computer-compatible services of the NASA/IPAC Infrared Science Archive (IRSA).

The WISE principal investigator is Dr. Edward Wright (UCLA). Management of the WISE mission, mission systems engineering, mission assurance and mission operations are performed by JPL/Caltech. The Space Dynamics Lab. Utah State University is responsible for the WISE payload (telescope, optics, detectors, electronics). Ball Aerospace Corp. is responsible for the WISE spacecraft and will carry out system integration. Science data processing, archiving and distribution is performed by the Infrared Processing and Analysis Center, California Institute of Technology (IPAC). IPAC will serve as the WISE Science Data Center (WSDC).

1.1 Scope of this Document

This document describes the functional requirements for WSDC. These are "Level 4" requirements in the organization of the WISE project structure. The traceability to higher-level requirements is indicated for each WSDC requirement. In most cases, WSDC requirements flow from corresponding requirements in the Level 3 MOS Requirements

Document. A few WSDC requirement flow directly from a requirements in the Level 1 Project Plan or Level 1.5 Science Requirements Document if there are no corresponding requirements at Level 3. WSDC requirements that are self-derived are so indicated. Also indicated for each requirement are verification methods, as appropriate.

WSDC requirements are organized in this document as follows:

Section 2.1 Data Product Requirements
Section 2.2 Subsystem Functionality
Section 2.3 Operations Requirements
Section 2.4 Standards and Practices

This document does not directly describe implementation plans for the WSDC, or specifically how the WSDC Functional Requirements will be fulfilled. However, implicit assumptions are made to subsystem design in Section 2.2 that describes requirements on WSDC subsystems. Refer to the IPAC/WISE Implementation Plan (WSDC D-M001) for descriptions of the organization of the WSDC and the data system components.

1.2 Applicable Documents

WISE Project Plan (Level 1 Requirements)
WISE Level 1.5 Science Requirements Document
WISE MOS Level 3 Requirements Document
IPAC/WISE Implementation Plan (WSDC D-M001)

2 REQUIREMENTS

ID	Requirement	Traceability	Verification Method	Notes
	2.1 Data Products			
	2.1.1 Final Products			
L4WSDC-001	The WSDC shall produce a digital Image Atlas that combines multiple survey exposures at each position on the sky.	L1PP-8, L3MOS-366	Analysis	
L4WSDC-002	The WSDC shall produce a Source Catalog derived from the WISE digital Image Atlas.	L1PP-9, L3MOS-374	Analysis	
L4WSDC-003	The final WISE science product releases shall be accompanied by an Explanatory Supplement that provides sufficient documentation about the mission, spacecraft, instrument, operations, data quality, processing and characteristics of artifacts to allow their scientific exploitation by the astronomical community.	L3MOS-379	Inspection	
L4WSDC-004	The WSDC shall release the final WISE digital Image Atlas, Source Catalog and Explanatory Supplement within 17 months of the end of on-orbit data collection.	L1PP-34, L3MOS-366, L3MOS-374	Analysis	Need formal definition of end of on-orbit data collection.
	2.1.2 Preliminary Products			
L4WSDC-005	The WSDC shall generate a preliminary digital Image Atlas using data from the first 50% of the sky that is surveyed.	L1.5SRD-50, L3MOS-357	Analysis	
L4WSDC-006	The WSDC shall generate a preliminary Source Catalog derived from the WISE preliminary digital Image Atlas that contains sources detected in unconfused regions in the first 50% of the sky that is surveyed.	L1.5SRD-50, L3MOS-361	Analysis	
L4WSDC-007	The preliminary WISE science product release shall be accompanied by a preliminary Explanatory Supplement that provides documentation about the mission, spacecraft, instrument, operations, data quality, processing and characteristics of artifacts to allow their scientific exploitation	L3MOS-379	Inspection	

ID	Requirement	Traceability	Verification Method	Notes
	by the astronomical community.			
L4WSDC-008	The WSDC shall release the preliminary WISE Image Atlas, Source Catalog and Explanatory Supplement within 6 months of the end of on-orbit data collection.	L1.5SRD-50, L3MOS-355, L3MOS-359	Analysis	Need formal definition of end of on-orbit data collection.
	2.1.3 Catalog Specifications			
	2.1.3.1 Reliability			
	The final WISE Source Catalog shall have greater than 99.9% reliability for sources detected in at least one band with SNR>20, where the noise includes flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to sources that are superimposed on an identified artifact.	L1PP-10	Analysis	
	2.1.3.2 Completeness			
L4WSDC-009	The final WISE Source Catalog shall be at least 95% complete for sources detected with SNR>20 in at least one band, where the noise includes flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to sources that are superimposed on an identified artifact.	L1PP-11, L3MOS-TBD	Analysis	
L4WSDC-010	The final WISE Source Catalog shall include sources down to SNR=5 in any band, and the completeness and reliability of sources in the Catalog shall be characterized at all flux levels.	L1PP-14	Demonstration, Analysis	
L4WSDC-011	The preliminary WISE. Source Catalog shall be at least 95% complete for sources detected with SNR>20 in at least one band, where the noise flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to	L1.5SRD-51, L3MOS-363	Analysis	

ID	Requirement	Traceability	Verification Method	Notes
	sources that superimposed on an identified artifact			
	2.1.3.3 Photometric Sensitivity and Accuracy			
L4WSDC-012	Flux measurements in the WISE Source Catalog shall have a SNR of five or more for point sources with fluxes of 0.12, 0.16, 0.65 and 2.6 mJy at 3.3, 4.7, 12 and 23 micrometers, respectively, assuming 8 independent exposures and where the noise flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources.	L1PP-4, L1.5SRD-37, L1.5SRD-38, L1.5SRD-39, L1.5SRD-40,	Demonstration	Assumes a definition of absolute flux calibration. Assumes all other elements perform to specifications.
L4WSDC-013	The root mean square error in relative photometric accuracy in the WISE Source Catalog shall be better than 7% in each band for unsaturated point sources with SNR>100, where the noise flux errors due to zodiacal foreground emission, instrumental effects, source photon statistics, and neighboring sources. This requirement shall not apply to sources that superimposed on an identified artifact..	L1PP-12, L3MOS-376	Demonstration	
	2.1.3.4 Astrometric Accuracy			
L4WSDC-014	The root mean square (1σ) error in WISE catalog positions with respect to 2MASS All-Sky Point Source Catalog positions shall be less than 0.5” on each axis, for sources with SNR > 20 in at least one WISE band.	L1PP-13, L3MOS-370	Demonstration	
	2.1.3.5 Catalog Contents			
L4WSDC-015	The WISE Source Catalog shall contain the measured in-band fluxes or flux upper-limits in the four WISE bands for objects detected in at least one band in the WISE Atlas Images.	Self-derived	Demonstration	
L4WSDC-016	The WISE Source Catalog shall contain uncertainties in the flux measurements (one sigma) in all bands for which a source is detected.	Self-derived	Demonstration	Upper limits are not provided in bands in which source is not

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				detected.
L4WSDC-017	The WISE Source Catalog shall contain equatorial (J2000) coordinates for objects detected in at least one band.	Self-derived	Demonstration	
L4WSDC-018	The WISE Source Catalog shall contain uncertainties in the coordinates measurements for each object.	Self-derived	Demonstration	
L4WSDC-019	The WISE Source Catalog shall contain one or more quality flags for each object entry that indicate if a flux measurement may have been contaminated due to the proximity of the source to an image artifact or another nearby source.	Self-derived	Demonstration	
L4WSDC-020	The WISE Source Catalog shall contain one or more quality flags for each object entry that indicate if the detection of that object may be a spurious detection of an image artifact or transient event.	Self-derived	Demonstration	
	2.1.4 Image Atlas Specifications			
L4WSDC-021	The images in the final WISE Image Atlas shall be re-sampled to a common pixel grid at all wavelengths.	L1.5SRD-42, L3MOS-368	Analysis Demonstration	
L4WSDC-022	The photometric calibration of the final WISE Image Atlas shall be tied to the photometric calibration of the final WISE Source Catalog.	L1.5SRD-43, L3MOS-372	Analysis	
L4WSDC-023	The WSDC shall make all WISE image data available in accordance to the Flexible Image Transport (FITS) astronomical data standard	L3MOS-381	Inspection	
	2.1.5 Ancillary Products			
	2.1.5.1 Single Frame Products			
L4WSDC-024	The WSDC shall generate and maintain an archive of the calibrated, single epoch WISE images for the duration of the project for the purpose of quality assurance, transient analysis and moving object identification.	Self-derived	Demonstration	Define duration of project.
L4WSDC-025	The WSDC shall generate and maintain a database of source information extracted from the calibrated, single-epoch	Self-derived	Demonstration	Define duration of project.

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	images for the duration of the project for the purpose of quality assurance, transient analysis and moving object identification.			
	2.1.5.2 Coverage Maps			
L4WSDC-026	The WSDC shall generate and archive coverage maps that show the number of independent observations that go into each pixel of the Image Atlas images in each band. The coverage numbers shall take into account focal plan coverage and losses due to poor data quality, low responsivity and/or high noise masked pixels, and pixels lost because of cosmic rays and other transient events.	Self-derived	Demonstration	
	2.1.5.3 Solar System Object Identification			
L4WSDC-027	The WSDC shall identify and compile a listing of known solar system objects that are positionally associated with source extractions in the WISE single-epoch image frames.	L1PP-TBD, Self-derived	Demonstration	
L4WSDC-028	The solar system objects associated with WISE single-epoch extractions shall include asteroids, comets, planets, and planetary satellites.	Self-derived	Demonstration	
	2.2 Subsystem Functionality			
	2.2.1 Ingest			
L4WSDC-029	The WSDC shall generate level 0 image data out of the raw science data stream from the MOS High Rate Data Processor (HRDP). This involves de-packetizing, removing the lossless Rice-compression, assembling into FITS format images and correlating it with the appropriate spacecraft and instrument engineering data. It is assumed that the science data packets from the HRDP have the convolutional and Reed-Solomon encoding removed.	L3MOS-265, L3MOS-280	Demonstration	
L4WSDC-	The WSDC Ingest system shall be able to accept compressed	Self-derived	Demonstration	

ID	Requirement	Traceability	Verification Method	Notes
030	science data packets at an average rate of 21GB/day sustained during IOC and on-orbit operations period.			
L4WSDC-031	The WSDC Ingest system shall be able to accept compressed science data packets at a peak rate of up to 43GB/day for at least 3 consecutive days.	Self-derived		Rate is defined by capacity of single 4Mbps transfer line. Duration is defined by ~3 day on-board storage plus sustained transfer rate.
L4WSDC-032	Within 24 hours after receipt, the WSDC shall ingest at least 3% of the science data from each downlink, and process it through a quick turn-around version of the WISE pipeline. It shall produce processing reports and quality summaries to a WISE internal web-site, and stage sample fits data to a WISE ftp site at the same time, from which the other MOS partners can fetch the data for evaluation.	L3MOS-272	Demonstration	
L4WSDC-033	The WSDC shall ingest WISE engineering telemetry that is sent by the MOS. This shall include but may not be limited to spacecraft ephemeris data, spacecraft pointing data, vehicle time-to-UTC conversion data, stored state-of health data, orbit events files and sequence events files.	Self-derived	Demonstration	
L4WSDC-034	As a goal the WSDC shall complete the ingesting of level 0 science data within 3 days from its receipt at the WSDC.	L3MOS-274	Demonstration	
L4WSDC-035	The WSDC shall ingest and validate the level 0 science data for readability and completeness of content.	L3MOS-276	Demonstration	
L4WSDC-036	After successful read of the level 0 science data the WSDC shall notify the MOS so that any temporary storage related to this dataset can be released for overwriting.	L3MOS-282	Demonstration	
	2.2.2 Pipelines			
L4WSDC-	The WSDC Pipelines subsytsem shall convert raw WISE	Self-derived	Design	

ID	Requirement	Traceability	Verification Method	Notes
037	science and engineering data into calibrated images and extracted source lists from which the preliminary and final WISE data products will be derived.			
L4WSDC-038	The WISE science data processing shall be designed to meet image and catalog quality requirements for data taken as close as 15 deg. to the moon, assuming adequate stray light performance of the flight system, assuming that all other elements of the WISE system satisfy their performance requirements.	L3MOS-270	Analysis Inspection	
L4WSDC-039	Within 3 days from receipt of a given data set at the WSDC all data shall be processed through the first stage of the pipeline, performing processing on images from individual orbits. The results of this processing step shall be updated Quality Analysis Web-pages and a set of pre-processed data for internal evaluation.	L3MOS-284	Demonstration	
L4WSDC-040	Within 6 days (goal) from receipt of a given dataset the data of the individual orbits with the dataset shall be co-added using the in-scan overlaps. The results of this processing step shall be preliminary source extractions and image data, which are loaded into the WISE extracted source working database (WDB) allowing access by the WISE Science Team for external quality assessment.	L3MOS-286	Demonstration	
L4WSDC-041	Within 15 days (goal) from receipt of all the science and ancillary data for a given orbit, the WSDC shall generate science data products that combine (stack) its images with those from orbits (>18) taken earlier to make use of cross-scan redundancy and new source extractions	L3MOS-288	Demonstration	
L4WSDC-042	The WSDS Pipeline processing shall remove the instrumental signature from Level 0 image frames.	Self-derived	Demonstration	
L4WSDC-043	The WSDS Pipeline processing shall detect sources down to a threshold of at least five times the image noise from the calibrated image frames, and the combined Atlas Images.	L1PP-14	Demonstration	

ID	Requirement	Traceability	Verification Method	Notes
L4WSDC-044	The WSDS Pipeline processing shall merge source detections in the four WISE bands into a single source catalog entry.	Self-derived	Demonstration	
L4WSDC-045	The WSDS Pipeline processing shall measure the brightness of sources detected on the calibrated WISE images relative to the brightness of calibration stars measured on-orbit.	Self-derived	Demonstration	
L4WSDC-046	The WSDS Pipeline processing shall reconstruct the J2000 equatorial positions of sources detected on the calibrated WISE images relative to the positions of objects in the 2MASS All-Sky Point Source Catalog that are detected in the WISE science images.	L1PP-13, L3MOS-370	Demonstration	
L4WSDC-047	The WSDS Pipeline processing shall combine multiple image frames covering each point on the sky to form the Atlas Images, and construct coverage maps that encode the number of image frames contributing to each pixel of the Atlas Images.	L1PP-8, L3MOS-366	Demonstration	
L4WSDC-048	The WSDC shall identify spurious extractions of image artifacts and transient events in the source lists for the purpose of eliminating them from the WISE Source Catalog.	L1PP-10	Demonstration	
L4WSDC-049	WSDS Pipeline shall be robust to data missing from one or more bands.	Self-derived	Demonstration	
	2.2.3 Archive			
L4WSDC-050	The WSDC shall create a copy of the level 0 science data in a medium appropriate for permanent long-term storage.	L3MOS-278	Demonstration	
L4WSDC-051	The WSDC shall make the WISE catalog and image products available to the community via the internet through appropriate web-based tools.	L3MOS-383	Demonstration	
L4WSDC-052	As a goal, the WSDC will maintain the data products in a way that distribution of the complete WISE Source Catalog to users via portable media would be possible.	L3MOS-385	Inspection	
L4WSDC-053	The WSDC shall make the Image Atlas and Catalog products accessible to the astronomical community in	L3MOS-387	Inspection	

ID	Requirement	Traceability	Verification Method	Notes
	collaboration with the NASA/IPAC Infrared Science Archive (IRSA) to ensure long-term availability beyond the end WISE missions operations and data processing phase, and to insure interoperability with other NASA mission archives.			
L4WSDC-054	The WSDC shall maintain a complete copy of the WISE science data set and software source code at a secure off-site location during the WISE mission to ensure survivability in case of major catastrophe.	L3MOS-389	Inspection	
L4WSDC-055	After the WISE mission, a copy of the Level 0 science data shall be delivered to the National Space Science Data Center (NSSDC) for permanent archive.	L3MOS-396	Inspection	To be arranged by Letter of Agreement between IPAC and NSSDC
L4WSDC-056	The WSDC shall maintain an archive of metadata derived from data processing for the individual science images for the duration of the project for the purpose of analysis and support of image access tools.	Self-derived	Demonstration	
L4WSDC-057	The WSDC shall provide an online repository for operations products for the life of the project.	L3MOS-146,	Demonstration	Operations products do not include science data
L4WSDC-058	The MOS shall capture and archive the following data sets received or created by the EOS during the mission: (a) all telemetry data received on the ground, (b) all commands sent to the spacecraft, (c) all sequence products, (d) all data processing logs.	L3MOS-403	Demonstration	
L4WSDC-059	Sample WISE images shall be made available for outreach purposes within 1 month of start of normal operations.	L3MOS-416	Demonstration	This is assumed to mean single-epoch images.
	2.2.3.1 Data Access			
L4WSDC-	The WSDC archive shall provide a web-based interface to	Demonstration	Demonstration	

ID	Requirement	Traceability	Verification Method	Notes
060	enable selection, display and retrieval of any or all single-epoch images and combined Atlas Images based on position or time of observation for the purpose of quality assurance, validation and analysis. The goal shall be to also allow image selection on any image metadata parameter.			
L4WSDC-061	The WSDC archive shall provide a web-based interface to enable selection of sources extracted from single-epoch frames and/or combined Atlas Images based on position, flux, or combinations of any parameter maintained in the extracted source databases or Source Catalog.	Demonstration	Demonstration	
	2.2.4 Quality Assurance			
L4WSDC-062	The WSDC shall perform quality analysis of all WISE science data and make reports available on a regular basis.	L3MOS-290	Demonstration	
L4WSDC-063	The WSDC shall work with the WISE Science Team to validate that the Image Atlas and Source Catalog satisfy WISE requirements prior to their release.	Self-derived	Demonstration	
L4WSDC-064	The WSDC shall work in collaboration with the WISE Science Team to characterize and document the overall data product quality relative to the mission requirements. This documentation shall be included in the WISE data product explanatory supplement.	Self-derived	Demonstration	
	2.2.4.1 Quicklook Quality Assurance			
L4WSDC-065	A sample of 3% of the science imaging data returned to the ground each day processed in an expedited way to produce a Quicklook report that monitors the routine performance of the flight system as can be determined from the science data, and identifies problems that may require prompt action by WISE Science or Mission Operations.	L3MOS-261	Demonstration	
L4WSDC-066	The WSDC shall provide a monitor of the synchronization between the flight-system and scan mirror rates to achieve	L3MOS-340	Demonstration	

ID	Requirement	Traceability	Verification Method	Notes
	and maintain required image quality as part of Quicklook QA.			
	2.3 Operations			
L4WSDC-067	The WSDC shall as a goal design its normal mission operations processes based on a 40-hour workweek.	L3MOS-108	Inspection	
L4WSDC-068	All WSDC processes shall include at least 20% operational margin (meaning 20% of the time allocated to do a process shall be margin).	L3MOS-115, Self-derived. Operational margin is defined as time in the process to ensure its completion even if problems are encountered during the execution of the process.	Inspection Demonstration	
L4WSDC-069	The WSDC shall conduct a training program for its operations staff, including at least one formal Operational Readiness Test to certify the readiness of the WSDC operations teams to successfully execute IOC, mission critical events and science survey mission.	L3MOS-133	Demonstration	
L4WSDC-070	The WSDC shall design the Ground Data System with 50% margin in the following areas: CPU utilization, storage space, and LAN loading (for data queries, etc).	L3MOS-140	Inspection	
L4WSDC-071	Mean Time Between Failures (MTBF) for the science data processing MOS elements shall be greater than 1 week, and Mean Time To Restore (MTTR) shall be less than 1 day.	L1PP-6, L3MOS-399	Demonstration	
	2.4 Standards and Practices			
L4WSDC-072	The WSDC software development and configuration management shall follow IPAC standards as applicable.	Self-derived	Inspection	
L4WSDC-073	The WSDC software documentation shall follow IPAC standards as applicable.	L3MOS-100	Inspection	
L4WSDC-	The WSDC shall document all subsystem design	Self-derived	Inspection	

ID	Requirement	Traceability	Verification Method	Notes
074	specifications and interfaces.			
L4WSDC-075	The WSDC shall use standard SI engineering units for engineering data.	L3MOS-126	Inspection	
L4WSDC-076	All MOS/WSDC interfaces shall be implemented according to the descriptions in the WISE MOS ICD.	L3MOS-401	Demonstration	
L4WSDC-077	All data products and operations reporting shall contain Coordinated Universal Time (UTC) time-tagging with an absolute knowledge of +/-0.6 seconds.	L3MOS-121	Analysis Inspection Demonstration	
L4WSDC-078	The WISE science data products shall use the International Celestial Reference System (ICRS) to describe the positions and motions of celestial bodies. WISE astrometry shall be mapped into the ICRS using the 2MASS All-Sky Point Source Catalog as the primary astrometric reference.	L1PP-13, L3MOS-123,	Inspection	
L4WSDC-079	WISE shall as a goal implement a "test as you fly; fly as you test" philosophy throughout its V&V activities. "Test as you fly" shall be interpreted to mean: 1) operational hardware, software, operations procedures, command sequences and support equipment shall be used to the maximum extent possible consistent with time and budget resources and safety requirements 2) flight hardware, software, operations procedures and command sequences shall be used in the manner in which they are intended to be used for flight 3) flight hardware, software, operations procedures, command sequences and support equipment shall be exercised over a broad range of possible flight scenarios and situations not only just the baseline scenarios.	L3MOS-128	Inspection	

3 ACRONYM LIST

BATC – Ball Aerospace and Technologies Corporation
CPU – Central processing unit
ICD – Interface Control Document
IPAC – Infrared Processing and Analysis Center, California Institute of Technology
IRSA – Infrared Science Archive at IPAC
JWST – James Webb Space Telescope
LAN – Local area network
MOS – Mission Operations System
MTBF – Mean time between failures
MTTR – Mean time to recovery
NASA – National Aeronautics and Space Administration
NSSDC – National Space Science Data Center
QA – Quality assurance
SDL – Space Dynamics Laboratory, Utah State University
UCLA – University of California Los Angeles
UTC – Coordinated Universal Time
V&V – Verification and validation
WSDC – WISE Science Data Center (IPAC)
WSDS – WISE Science Data System