System Performance Specification
for
Cryogenic Transmission Electron Microscope
Image Acquisition and Analysis Toolkit

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CSC592
Spring 2005

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Document Revision History

Release Date	Revision	Notes
16 May 2005	20050226T1-1	Final draft release for CSC592.
01 Mar 2005	20050226T1-0	Draft release for class review.

1 SCOPE

This document provides the System Performance Specification for the Cryogenic Transmission Electron Microscope Image Acquisition and Analysis Toolkit (CTEM-IAAT). This document provides a single source of the detailed specifications and acceptance criteria for the system.

1.1 Identification

The 'system' addressed in this document is the CTEM-IAAT which is to be used to provide assistance in the acquisition and analysis of images from a cryogenic transmission electron microscope (CTEM). This document addresses the first implementation of the system. This version of the system shall be known as version 1.0. Unless specifically called out as "In-Active", all requirements within this specification shall be applicable to version 1.0 of the system.

1.2 System Overview

CTEM has the possibility of opening up a new methodology for measuring macromolecular biologic objects. It has previously has been applied to blood samples[4][5] in order to analyze the sizes and shapes of lipids. The CTEM images are acquired via a transmission electron microscope (TEM) that is used with a "cold station". The liquid samples are placed in a thin film of "holey" or "lacey" carbon such that a very thin layer of the sample fluid is left in each of the holes in the carbon film. By quickly cooling the samples in ethane and then transferring the cooled samples into liquid nitrogen, the sample liquid is frozen but is not crystallized. Thus, the elements of the sample liquid can be imaged via the TEM.

The cryogenic nature of the process, however, means that the acquisition of the images is different than the normal TEM process. Imaging and analysis of the frozen liquid samples is made difficult by two issues. First, the TEM beam can warm the frozen sample liquid, thus making the material unstable for imaging. Limiting exposure energy is crucial to prevent melting of the sample. This makes the acquisition of multiple images difficult since added exposure frames can melt the sample liquid. Second, multiple perspective angles are currently required to allow for the size and shape analysis through 3-D reconstruction of the images at a range of exposure angles.

Thus, the CTEM-IAAT must provide support for both the acquisition process as well as the analysis of the set of images that is limited in number due to the potential melting issues. The system provides this support in the form of a software package that can possibly interface with the TEM and can provide off-line analysis of the limited number of frames.

1.3 Document Overview

The system performance specification and acceptance criteria are documented following the guidelines of ISO-12207 [1] and MIL-STD-498 [2] (from which ISO-12207 originated). This section provides an overview of the system and this document. Section 2 provides a list of general and application-specific reference documents. Section 3 provides the detailed requirements for the system. Section 4 provides an acronym list and general notes as applicable.

This document is to be used in conjunction with several other documents as necessary. This document, the SPS, provides the top-level requirements to be met by the system. An Acceptance Test Procedure shall be used to ensure compliance with the requirements as required by contractual obligations. Various manuals for training and operations may also be provided as needed. These documents shall be deemed as suitable for distribution to customers. The requirements in this document are also carried forward into documentation as necessary for internal development and maintenance of the underlying hardware and software. These documents shall be deemed as non-distributable documents and shall remain internal to the development staff.

The requirements are listed by sub-system. The fully qualified requirement number includes the sub-section in which it is contained. The requirement numbers are tied to the sub-system level thus they are numbered from 1 to N for each sub-section of the requirements section. This is done to allow for additions within a sub-system without affecting other sub-systems. Once a requirement has been active, it cannot be deleted, only its status may be changed to *deleted* to preserve numbering.

Each requirement is defined in the following format:

Requirement Sub.Section-#: Requirement Name or Title	
Requirement:	Generalized statement of this requirement
Specifics:	Specialized information regarding this requirement for the specified application. • Parameters that are To Be Determined are listed as __TBD__.
Acceptance:	The criteria that shall be used to determine acceptance of this component. These criteria will be coalesced into an overall ATP to be executed upon delivery and installation of the system. Acceptance of a requirement will be in the form of one of the following methods: • Inspection – the requirement will be accepted based upon results of the inspection and review of the system or documentation • Demonstration – the requirement will be accepted based upon operational demonstration of the capability with no prejudice towards the performance of the capability • Testing – the requirement will be accepted by running the system to collect data and the resultant analysis of the data to verify the performance
Status:	Active or In-Active. Active requirements are to be met by the system for the specified use and shall be subject to the acceptance criteria. In-Active requirements shall not be subject to the acceptance criteria. In-Active requirements are shown in gray regions.
Options:	Available options for this component.
Option Acceptance:	The criteria that shall be used to determine acceptance of this optional component. These criteria will be coalesced into an overall ATP to be executed upon delivery and installation of the system.
Option Status:	Active or In-Active. (Same as above).
Notes:	These are general notices and issues regarding the component. Notes shall not be considered part of the formal requirements.

2 REFERENCED DOCUMENTS

This section provides a list of reference documents for the system.

2.1 General System Documents

1. "Industry Implementation of International Standard ISO/IEC 12207:1995 (Standard for Information Technology Software life cycle processes)" IEEE/EIA 12207.0-1996, March 1998
2. Software Development and Documentation, MIL-STD-498, 5 December 1994
3. Data Item Description (DID) for the System/Subsystem Specification (SSS), DI-IPSC-81431, 5 December 1994.

2.2 Application-Specific Documents

4. Rik van Antwerpen and John C. Gilkey, "Cryo-electron microscopy reveals human low density lipoprotein substructure", Journal of Lipid Research Volume 35, 1994 pp:2223-2231
5. Rik van Antwerpen, Michael La Belle, Edita Navratilova, and Ronald M. Krauss, "Structural hetrogenity of apoB-containing lipoproteins visualized using cryo-electron microscopy", Journal of Lipid Research Volume 40, 1999 pp:1827-1836.

3 REQUIREMENTS

This section defines the requirements of the system. The system requirements are defined in 4 sub-sections: states and modes, interfaces, capabilities, and miscellaneous. The final subsection defines the precedence of order to be followed by the requirements in this section.

3.1 State and Mode Requirements

This section lists the states and modes that shall be provided by the system.

3.1.1 System States

The system shall have two states of operation: acquisition and analysis.

3.1.1.1 Acquisition State

Requirement 3.1.1.1-1: Acquisition State	
Requirement:	The system shall provide an acquisition state in which acquisition of images is allowed.
Specifics:	The acquisition state shall be defined as the capability of the system to acquire images.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the capability to acquire images.
Status:	Active
Notes:	The system allows the TEM to be used to collect images and allows the user to do further processing on the images. In the acquisition state, the system is used to assist in the acquisition and associated processing of images. The analysis state allows for detailed processing of the collected images.

3.1.1.2 Analysis State

Requirement 3.1.1.2-1: Analysis State	
Requirement:	The system shall provide an analysis state in which analysis of previously collected images is allowed.
Specifics:	The analysis state shall be defined as the capability of the system to analyze images.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the capability to analyze images.
Status:	Active
Notes:	The system allows the TEM to be used to collect images and allows the user to do further processing on the images. In the acquisition state, the system is used to assist in the acquisition and associated processing of images. The analysis state allows for detailed processing of the collected images.

3.1.2 System Modes

The system shall have three modes of operation: calibration, assist, and processing.

3.1.2.1 Calibration Mode

Requirement 3.1.2.1-1: Calibration Mode	
Requirement:	The system shall provide a calibration mode of operation while in the acquisition state.
Specifics:	Calibration mode allows the system to acquire and process images as necessary in order to allow for proper image acquisition. This may includes things such as accounting for sensor dark current and electron beam non-uniformity.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the capability to perform a calibration of the TEM.
Status:	Active
Notes:	Dark current correction measures the background noise of the sensor when there is no input from the electron beam. This background noise is then subtracted from all images in order to remove any sensor bias. This may be performed by the TEM camera system. Electron beam non-uniformity correction measures the output of the electron beam when there is no target present on the system. If the e-beam is not uniform then a correction factor can be determined such that the images can be corrected to account for the non-uniformity of the e-beam.

3.1.2.2 Assist Mode

Requirement 3.1.2.2-1: Assist Mode	
Requirement:	The system shall provide an assist mode of operation while in the acquisition state.
Specifics:	Assist mode provides assistance to the operator during acquisition of images. Such assistance may include selection of e-beam settings to maximize contrast or to select ROIs with candidate objects of interest.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the capability to provide assistance to the operator during acquisition of images.
Status:	Active
Notes:	N/A

3.1.2.3 Processing Mode

Requirement 3.1.2.3-1: Processing Mode	
Requirement:	The system shall provide a processing mode of operation while in the analysis state.
Specifics:	Processing mode provides the analysis of the images acquired by the TEM.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the capability to process images.
Status:	Active
Notes:	N/A

3.2 Interface Requirements

Three items describe the external interfaces to the system. Details of the input and output data are provided in the applicable subsection pertaining to supported TEMs, Cameras, and operator interfaces.

3.2.1 Supported TEM Systems

This section lists the TEM systems that are supported by this system.

3.2.1.1 JEOL-1200EX

Requirement 3.2.1.1-1: Inputs from JEOL-1200EX	
Requirement:	The system shall support the JEOL-1200EX TEM.
Specifics:	This system supports acquisition if images through the combination of the JEOL-1200EX TEM system.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	N/A

Requirement 3.2.1.1-2: Outputs to JEOL-1200EX	
Requirement:	The system shall support the JEOL-1200EX TEM.
Specifics:	This system supports acquisition if images through the combination of the JEOL-1200EX TEM system.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	N/A

3.2.2 Supported Camera Systems

This section lists the camera systems that are supported by this system.

3.2.2.1 TVIPS F224

Requirement 3.2.2.1-1: Inputs from TVIPS F224	
Requirement:	The system shall receive inputs from the TVIPS F224 camera system.
Specifics:	This system supports acquisition of images through the combination of the JEOL-1200EX TEM when fitted with the TVIPS F224 camera system.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	The JEOL-1200EX TEM is currently the only TEM with which the TVIPS F224 camera is supported. Other TEMs may be added in the future so implementation should not preclude this.

Requirement 3.2.2.1-2: Outputs to TVIPS F224	
Requirement:	The system shall provide outputs to the TVIPS F224 camera system.
Specifics:	This system supports acquisition of images through the combination of the JEOL-1200EX TEM when fitted with the TVIPS F224 camera system.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	The JEOL-1200EX TEM is currently the only TEM with which the TVIPS F224 camera is supported. Other TEMs may be added in the future so implementation should not preclude this.

3.2.3 Operator Interfaces

This section lists the operator interfaces that shall be provided by the system.

3.2.3.1 Operator Inputs

Requirement 3.2.3.1-1: Operator Image Family Inputs	
Requirement:	The system shall accept image family inputs from the operator.
Specifics:	The system shall accept the following image family selection information from the operator: • Quit – exits the program. The MS-DOS window may need to receive a <CR> to close. • Reset Images – causes the images to be reset to the initial state. This is used in case processing has changed images and it is desired to restore them. • Process Analysis Image – causes the internal memory to use the self-generated analysis image for all processing. • Process Maya Image – causes the internal memory to use an image that was generated by Maya for all processing. While functional, this code is currently set up to use a copy of the analysis images. A compile time option can be changed to read in the Maya images once they are ready for use. • Process Blood Image – causes the internal memory to use a previously captured image of blood. This image does not match the expected statistics or magnification but is provided for demonstration purposes. • Color – leads to a sub-menu to set the background color. A setting other than black may be desired since some of the processing can lead to a black image.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	N/A

Requirement 3.2.3.1-2: Operator Display Control Inputs	
Requirement:	The system shall accept display control inputs from the operator.
Specifics:	The system shall accept the following information from the operator to determine which image is to be displayed: • Quit – exits the program. • Reset Images – causes the images to be reset to the initial state. • Toggle show Max Point – causes a red crosshair to be displayed at the location with the maximum value. • Show Base Image – displays the decimated version of the base image for the current family. This is the image with no processing applied. • Show FFT of Base Image – displays the decimated version of the FFT of the base image. • Show Template Image – displays the decimated version of the template image. This is the image that is used for the FFT correlation processing. This image is split so that it is centered at a virtual 0,0 point. A similar image that is not split, which cannot be viewed, is used for the correlation processing. • Show FFT of Template Image – displays the decimated version of the FFT of the template image. • Show Results Image – displays the most recent results. The results are based upon the processing that has been selected in the right hand window. • Show FFT of Results Image – displays the decimated version of the FFT of the current results image.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	N/A

Requirement 3.2.3.1-3: Operator Processing Control Inputs	
Requirement:	The system shall accept display control inputs from the operator.
Specifics:	The system shall accept the following information from the operator to determine which image is to be displayed: • Quit – exits the program. • Reset Images – causes the images to be reset to the initial state. • Toggle show Max Point – causes a red crosshair to be displayed at the location with the maximum value. • Process ROI w/ CORRELATION – causes the current base image to be processed with true correlation but only in the selected ROI. • Process ROI w/ FFT CORRELATION – causes the current base image to be processed with a correlation via multiplication of FFTs followed by an inverse FFT but only in the selected ROI. • Process Combined Image w/ CORRELATION – causes the decimated version of the current base image to be processed with true correlation. • Process Entire Image w/ CORRELATION – causes the entire current base image to be processed with true correlation. • Process Entire Image w/ FFT CORRELATION – causes the entire current base image to be processed with a correlation via multiplication of FFTs followed by an inverse FFT. • Process Combined Image w/ Template Series and CORRELATION – causes the decimated version of the current base image to be processed with true correlation against a series of templates. The ranges of these templates are compile-time options. • Process Entire Image w/ Template Series and FFT CORRELATION – causes the current base image to be processed with a correlation via multiplication of FFTs followed by an inverse FFT against a series of templates. The ranges of these templates are compile-time options. • Process ROI-centered 1Kx1K of Image w/ FFT CORRELATION – causes a 1Kx1Kpixel region of the current base image to be zero padded to 2Kx2K and processed with a correlation via multiplication of FFTs followed by an inverse FFT.
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	N/A

Requirement 3.2.3.1-4: Operator Cursor Inputs	
Requirement:	The system shall accept display cursor inputs from the operator.
Specifics:	The system shall accept the following inputs from the operator via the computer cursor: • ROI Center point • Cursor readout point
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	The information to be presented to the operator is derived from the operator inputs.

3.2.3.2 Operator Outputs

Requirement 3.2.3.2-1: Operator Screen Outputs	
Requirement:	The system shall provide screen outputs to the operator.
Specifics:	The system shall provide the following outputs to the operator via the computer screen: • Operational Status (the currently executing step of the process) • Error Messages • Cursor Readouts • Images
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	The information to be presented to the operator is derived from the operator inputs.

Requirement 3.2.3.2-2: Operator File Outputs	
Requirement:	The system shall provide file outputs to the operator.
Specifics:	The system shall provide the following outputs to the operator via the files: • Statistics from correlation runs • Statistics from combined correlation runs • Statistics from FFT correlation runs
Acceptance:	The system shall be deemed to meet this requirement by demonstrating the existence of the listed interfaces.
Status:	Active
Notes:	The information to be presented to the operator is derived from the operator inputs.

Capability Requirements

The system capability requirements are divided by the modes listed in Section 3.1.

3.2.4 Calibration Capabilities

This section defines the requirements for the calibration mode.

3.2.4.1 Dark State Correction

Requirement 3.2.4.1-1: Dark State Image Acquisition	
Requirement:	The system shall provide for acquisition of a dark state image.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by demonstration of the capability to acquire the required dark state image.
Status:	Active
Notes:	N/A

Requirement 3.2.4.1-2: Dark State Defective Pixels	
Requirement:	The system shall analyze the dark state image for defective pixels.
Specifics:	The system shall provide the ability to look at each pixel in the dark state image and determine which pixels are outside the bounds of expected behavior. Hyperactive and hypoactive pixels will be marked for further correction in the normalization process.
Acceptance:	The system shall be deemed to meet this requirement by demonstration of the capability to analyze the dark state image for defective pixels.
Status:	Active
Notes:	N/A

Requirement 3.2.4.1-3: Dark State Subtractive Image	
Requirement:	The system shall provide a dark state subtractive image.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by demonstration of the capability to provide the required dark state image.
Status:	Active
Notes:	N/A

3.2.4.2 Bright State Correction

Requirement 3.2.4.2-1: Bright State Image Acquisition	
Requirement:	The system shall provide for acquisition of a bright state image.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by demonstration of the capability to acquire the required bright state image.
Status:	Active
Notes:	N/A

Requirement 3.2.4.2-2: Bright State Defective Pixels	
Requirement:	The system shall analyze the bright state image for defective pixels.
Specifics:	The system shall provide the ability to look at each pixel in the bright state image and determine which pixels are outside the bounds of expected behavior. Hyperactive and hypoactive pixels will be marked for further correction in the normalization process.
Acceptance:	The system shall be deemed to meet this requirement by demonstration of the capability to analyze the bright state image for defective pixels.
Status:	Active
Notes:	N/A

Requirement 3.2.4.2-3: Bright State Subtractive Image	
Requirement:	The system shall provide a bright state mulplicative image.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by demonstration of the capability to provide the required bright state image.
Status:	Active
Notes:	N/A

3.2.5 Assist Capabilities

This section defines the requirements for the assist mode.

3.2.5.1 Maximize Contrast

Requirement 3.2.5.1-1: Maximize Contrast …	
Requirement:	The system shall provide __TBD__.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	

3.2.5.2 Select ROI

Requirement 3.2.5.2-1: Select ROI …	
Requirement:	The system shall provide __TBD__.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	

3.2.6 Processing Capabilities

This section defines the requirements for the processing mode.

3.2.6.1 Geometric Correlation Processing

Requirement 3.2.6.1-1: Correlation Processing	
Requirement:	The system shall provide the ability to perform correlation processing between the input image and geometric models.
Specifics:	This processing will perform “manual” correlation between a template image and the image being analyzed. It is recognized that this will be very computationally intensive but this capability will be provided as a baseline for other methods.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	*This performance specification includes a definition of the processing to be performed. Normally, an SPS would only contain limits of performance (e.g. how well a matching must function). In this case, an exception is taken since exact correlation is required to demonstrate the overall functionality (as compared to decimated correlation and correlation via FFT/multiply/IFFT).*

Requirement 3.2.6.1-2: Decimated Correlation Processing	
Requirement:	The system shall provide the ability to perform correlation processing between a decimated version of the input image and decimated versions of the geometric models.
Specifics:	This processing will perform "manual" correlation between a decimated version of the template image and a decimated version of the image being analyzed. The system will support decimation values of 4to1.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	*This performance specification includes a definition of the processing to be performed. Normally, an SPS would only contain limits of performance (e.g. how well a matching must function). In this case, an exception is taken since decimated correlation is required to demonstrate the overall functionality (as compared to exact correlation and correlation via FFT/multiply/IFFT).*

Requirement 3.2.6.1-3: FFT Correlation Processing	
Requirement:	The system shall provide the ability to perform correlation processing between the input image and geometric models using FFT processing.
Specifics:	This processing will perform correlation between a template image and the image being analyzed. This processing will use an FFT of the images, a complex multiply, and an inverse FFT to compute the correlation.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	*This performance specification includes a definition of the processing to be performed. Normally, an SPS would only contain limits of performance (e.g. how well a matching must function). In this case, an exception is taken since correlation via FFTs is required to demonstrate the overall functionality (as compared to exact correlation and decimated correlation).*

3.2.6.2 Other processing…

Requirement 3.2.6.2-1: Other Processing…	
Requirement:	The system shall provide __TBD__.
Specifics:	
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	

3.3 Miscellaneous Requirements

This section provides miscellaneous system requirements. This section is tailored after the MIL_STD_498 system requirements specification format as defined in references [2-3].

3.3.1 Data Requirements

This section lists the data requirements to be met by this system

3.3.1.1 User Data Requirements

Requirement 3.3.1.1-1: User Database Formats	
Requirement:	The system shall record all data that must be accessed by the end user in a standard format.
Specifics:	The system shall record all data that must be accessed by the end user in a comma separated variable (.CSV) format.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

Requirement 3.3.1.1-2: User Image Formats	
Requirement:	The system shall record all images that must be accessed by the end user in a standard format.
Specifics:	The system shall record all images that must be accessed by the end user in the __TBD__ format.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

Requirement 3.3.1.1-3: User Picture Formats	
Requirement:	The system shall record all pictures (e.g. defect maps) that must be accessed by the end user in a standard format.
Specifics:	The system shall record all pictures that must be accessed by the end user in the __TBD__ format.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

Requirement 3.3.1.1-4: User Report Formats	
Requirement:	The system shall record all reports that must be accessed by the end user in a standard format.
Specifics:	The system shall record all reports that must be accessed by the end user in the text (.TXT) format.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.1.2 Internal Data Requirements

Requirement 3.3.1.2-1: Internal Data Formats	
Requirement:	Internal data formats shall be selected to assist in development and debugging as applicable.
Specifics:	Internal data formats will be dictated by the development environment so that development and debugging efforts will be minimized. For example, if LabVIEW is used then the IMAQ package should be used for image processing so that its features do not have to be reinvented.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.2 Safety Requirements

This section lists the safety requirements to be met by this system.

3.3.2.1 Electrical Safety

Requirement 3.3.2.1-1: TEM Electrical Emergency Stop	
Requirement:	The system shall provide an emergency stop control that, when activated and if allowed by the underlying TEM, removes electrical power from items that could cause harm to the operator, the system, or the sample under test.
Specifics:	The system emergency stop will be a control that the operator can select if needed to send any allowed appropriate signals to cut off power to the system. Applicable controls and signals will be listed in the interface section. This requirement just covers the overall capability.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This requirement is provided so that the final system will not cover up any existing E-STOP capability on this display in the base system.

Requirement 3.3.2.1-2: Camera Electrical Emergency Stop	
Requirement:	The system shall provide an emergency stop control that, when activated and if allowed by the underlying camera, removes electrical power from items that could cause harm to the operator, the system, or the sample under test.
Specifics:	The system emergency stop will be a control that the operator can select if needed to send any allowed appropriate signals to cut off power to the system. Applicable controls and signals will be listed in the interface section. This requirement just covers the overall capability.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This requirement is provided so that the final system will not cover up any existing E-STOP capability on this display in the base system.

3.3.2.2 Mechanical Safety

Requirement 3.3.2.2-1: TEM Mechanical Emergency Stop	
Requirement:	The system shall provide an emergency stop control that, when activated and if allowed by the underlying TEM, removes electrical power from mechanical items that could cause harm to the operator, the system, or the sample under test.
Specifics:	The system emergency stop will be a control that the operator can select if needed to send any allowed appropriate signals to cut off power to the system. Applicable controls and signals will be listed in the interface section. This requirement just covers the overall capability.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This requirement is provided so that the final system will not cover up any existing E-STOP capability on this display in the base system.

Requirement 3.3.2.2-2: Camera Mechanical Emergency Stop	
Requirement:	The system shall provide an emergency stop control that, when activated and if allowed by the underlying camera, removes electrical power from mechanical items that could cause harm to the operator, the system, or the sample under test.
Specifics:	The system emergency stop will be a control that the operator can select if needed to send any allowed appropriate signals to cut off power to the system. Applicable controls and signals will be listed in the interface section. This requirement just covers the overall capability.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This requirement is provided so that the final system will not cover up any existing E-STOP capability on this display in the base system.

3.3.3 Security and Privacy Requirements

This section lists the security and privacy requirements to be met by this system.

3.3.3.1 Security

Requirement 3.3.3.1-1: Operating System Security	
Requirement:	The system shall not provide any additional security above and beyond that which the underlying operating system and third-party software tools provide.
Specifics:	The system shall not provide any additional security above and beyond that which the underlying operating system and third-party software tools provide.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

Requirement 3.3.3.1-2: Software Security	
Requirement:	The system shall not provide any additional security above and beyond that which the underlying operating system and third-party software tools provide to provide additional security of the system.
Specifics:	The system shall not provide any additional security above and beyond that which the underlying operating system and third-party software tools provide to provide additional security of the system.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.3.2 Privacy

Requirement 3.3.3.2-1: Data Privacy	
Requirement:	The system shall not provide any additional data privacy above and beyond that which the underlying operating system and third-party software tools provide.
Specifics:	The system shall not provide any additional data privacy above and beyond that which the underlying operating system and third-party software tools provide.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.4 System Environment Requirements

This section lists the environmental requirements to be met by this system.

3.3.4.1 Operational

Requirement 3.3.4.1-1: Computer Room Features	
Requirement:	The system shall operate in whatever room is suitable for the TEM or any external computer on which the system can operate.
Specifics:	The system shall operate in whatever room is suitable for the TEM or any external computer on which the system can operate.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the associated items.
Status:	Active
Notes:	N/A

3.3.4.2 Storage and Shipping

Requirement 3.3.4.2-1: Packaging	
Requirement:	The system shall be packaged on a CD.
Specifics:	The system shall be packaged on a CD.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the associated items.
Status:	Active
Notes:	N/A

Requirement 3.3.4.2-2: Shipping	
Requirement:	The system shall ship on a CD.
Specifics:	The system shall ship on a CD.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the associated items.
Status:	Active
Notes:	N/A

Requirement 3.3.4.2-3: Storage	
Requirement:	The system shall have no limits on its storage environment other than as may be applicable to the CD media used for packing and shipping.
Specifics:	The system shall have no limits on its storage environment other than as may be applicable to the CD media used for packing and shipping.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the associated items.
Status:	Active
Notes:	N/A

3.3.5 Computer Resource Requirements

This section describes the computer resource requirements for the system.

3.3.5.1 Computer Hardware Requirements

Requirement 3.3.5.1-1: Processor Family	
Requirement:	The system shall be able to be executed on iX86 family of processors.
Specifics:	The system shall be able to be executed on iX86 family of processors.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	Other processors may be capable of execution of the system software but the system will be qualified on processor(s) from Intel.

Requirement 3.3.5.1-2: Video Display Dimensions	
Requirement:	The system shall operate in a standard video display device.
Specifics:	The system shall operate in a video display device capable of displaying up to 1280x1024 pixels with up to 24-bit color map.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.5.2 Computer Hardware Resource Utilization Requirements

Requirement 3.3.5.2-1: Processor Resources	
Requirement:	The system shall execute on a single processing element (node) of the overall computer system.
Specifics:	The system shall execute on a single processing element (node) of the overall computer system. Its design, however, shall allow for easy modification in order to support a multi-threaded implementation.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	N/A

3.3.5.3 Computer Software Requirements

Requirement 3.3.5.3-1: Operating System	
Requirement:	The system shall be able to be executed under the MS-Windows 2000 or XP operating system.
Specifics:	The system shall be able to be executed under the MS-Windows 2000 or XP operating system.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This is a goal not a hard requirement.

Requirement 3.3.5.3-2: Portability	
Requirement:	The system will be implemented so as to minimize the effort required for porting to platforms other than the development host.
Specifics:	The system will be implemented so as to minimize the effort required for porting to platforms other than the development host. The LabVIEW graphical programming language and TestStand test script executive, both from National Instruments, will be used for the majority of the software in the system. Thus, any new target host must be supported by NI for these products.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This is a goal not a hard requirement.

3.3.5.4 Computer Communications Requirements

Requirement 3.3.5.4-1: Communications	
Requirement:	The system will provide standard hardware interfaces and software interfaces in order to simplify the interchange of data between computers.
Specifics:	The system will provide standard hardware interfaces and software interfaces in order to simplify the interchange of data between computers. All output files from the system that must be read by another computer will be stored in a multi-machine compatible format such as MS-Access.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	This is a goal not a hard requirement.

3.3.6 Software Constraints

This section provides the software constraints for the system.

3.3.6.1 Quality Factors

Requirement 3.3.6.1-1: Software Quality	
Requirement:	The system shall provide a qualification procedure.
Specifics:	The system shall provide a qualification procedure that will ensure correct functionality of the base system in all states and modes.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	N/A

3.3.6.2 Implementation Requirements

Requirement 3.3.6.2-1: Software Implementation	
Requirement:	The system shall be implemented in the LabVIEW, C/C++, and/or Java as deemed applicable by the development team.
Specifics:	The system shall be implemented in the LabVIEW, C/C++, and/or Java as deemed applicable by the development team.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.7 Logistics-related Requirements

This section provides the logistics constraints for the system.

3.3.7.1 Physical Requirements

Requirement 3.3.7.1-1: Physical Dimensions	
Requirement:	The system shall operate in a standard video display device.
Specifics:	The system shall operate in a video display device capable of displaying up to 1280x1024 pixels with up to 24-bit color map.
Acceptance:	The system shall be deemed to meet this requirement by inspection.
Status:	Active
Notes:	N/A

3.3.7.2 Maintenance

Requirement 3.3.7.2-1: Maintenance	
Requirement:	The system shall be built such that qualified maintenance personnel may perform system upgrades in the field.
Specifics:	The system shall be built such that qualified maintenance personnel may perform system upgrades in the field.
Acceptance:	The system shall be deemed to meet this requirement by demonstration.
Status:	Active
Notes:	N/A

3.3.7.3 Training

Requirement 3.3.7.3-1: Calibration Mode Training	
Requirement:	The system shall include training for the operators who use the software for calibration of image acquisition.
Specifics:	The system shall include training for the operators who use the software for calibration of image acquisition.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the provided training materials.
Status:	Active
Notes:	N/A

Requirement 3.3.7.3-2: Assist Mode Training	
Requirement:	The system shall include training for the operators who use the software for acquisition of images.
Specifics:	The system shall include training for the operators who use the software for acquisition of images.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the provided training materials.
Status:	Active
Notes:	N/A

Requirement 3.3.7.3-3: Processing Mode Training	
Requirement:	The system shall include training for the operators who use the software for processing of images.
Specifics:	The system shall include training for the operators who use the software for processing of images.
Acceptance:	The system shall be deemed to meet this requirement by inspection of the provided training materials.
Status:	Active
Notes:	N/A

3.4 Precedence and Criticality of Requirements

All requirements levied on the system in this document have the same precedence and criticality with the single exception of safety. All requirements that relate to the safety of the personnel who come in contact with this system shall take precedence over all other requirements.

4 NOTES

This section provides an acronym list and general notes for this document.

4.1 Acronym List

Table 4-1. Acronym List

Acronym	Description
ATP	Acceptance Test Procedure
CTEM	Cryogenic Transmission Electron Microscope
DOF	Depth Of Focus
DUT	Device Under Test
DUTIF	Device Under Test Inter-Face
EO	Electro-Optical
FOV	Field Of View
NA	Not Applicable
NI	National Instruments
SPS	System Performance Specification
TEM	Transmission Electron Microscope
ROI	Region Of Interest
__TBD__	To Be Determined
V-SYNC	Vertical Synchronization

4.2 General Notes

__TBD__