NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

Discriminating Interceptor Technology Program (DITP)
Steering Mirror Component Specification

NCST-S-DT302 **28 February 2000**

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RECORD OF CHANGES

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1.0 INTRODUCTION

This component specification describes the Naval Research Laboratory's (NRL) requirements for the steering mirror components being used on the Discriminating Interceptor Technology Program (DITP).

1.1 Description. The Fast Steering Mirror (FSM) shall provide the means to scan the IR Passive Sensor Subsystem (PSS) and LADAR 0.6 x 0.6 degree fields of view (FOV) over the telescope 0.9 x 0.9 degree field of regard (FOR). The specification is based on a common optics telescope with a magnification of 5x.

1.2 Item Description. The FSM shall be comprised of two components: the mirror assembly and a servo control circuit card assembly. From external sources, the servo control circuit card assembly accepts position offset and position error commands and converts these commands into currents to drive the FSM in azimuth and elevation angles about the mirror normal at the optical center. The servo control circuit card assembly accepts mirror position sensor output and thermistor output from the mirror assembly and makes these available at the external interface. In addition to these basic operational signals, a set of diagnostic signals shall available at the external interface.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents. The following documents of the exact issue shown form a part of this document to the extent specified in Section 3.0. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered the superseding requirement.

2.1.1 Specifications, Standards, and Handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the Department of Defense Index of Specifications and Standards (DoDISS).

Number	Title	Tailoring Guidelines	Internet URL	Para Reference
MIL-C-48497	Durability Requirements for Single or Multilayer Interference Coatings	Guidelines Only	http://ditp.pxi.com	3.1.8.1, 3.1.8.2, 3.1.8.3, 3.1.8.4
MIL-O-13830A	General Specification Governing the Manufacture, Assembly, and Inspection of Optical Components for Fire Control Instruments	Guidelines Only	—	3.1.9
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)	Guidelines Only	http://ditp.pxi.com	3.7.1.2
MIL-STD-7179	Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems	Guidelines Only	http://ditp.pxi.com	3.7.1.4
MIL-HDBK-1568	Material and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems	Guidelines Only	http://ditp.pxi.com	3.7.1.4

2.1.2 Other Government Publications. Documents beginning with the control number “NCST” are program documents controlled by the NRL. Documents beginning with NRP are controlled by the National Aeronautics and Space Administration and may be obtained via their Internet Uniform Resource Locator (URL) address or as directed by the contracting office.

Number	Title	Tailoring Guidelines	Internet URL	Para Reference
NCST-D-DT004	DITP Environmental Requirements Document	—	http://ditp.pxi.com	3.6.1, 3.6.2
NRP-1124	Outgassing Data for Selecting Spacecraft Materials	—	http://misspiggy.gs-fc.nasa.gov/og/	3.7.1.3.2

2.1.3 Other Government Documents, Drawings, and Publications. The following other government documents, drawings, and publications form a part of this document to the extent specified herein.

Number	Title	Tailoring Guidelines	Internet URL	Para Reference
DoD Cataloging Handbook H4/H8	Commercial and Government Entity (CAGE) Cataloging Handbook	—	—	—
DoDISS	Department of Defense Index of Specifications and Standards	—	—	—
DoD Directive 5230.24	Distribution Statements on Technical Documents	—	—	—

(Copies of Cataloging Handbooks H4/H8 are available form the Commander, Defense Logistics Center, Battle Creek, MI 49017-3084. Copies of the DoDISS are available on a yearly subscription basis in either hard copy from the Government Printing Office for hard copy or in 1/2-inch magnetic tape available from the DoD Single Stock Point, Standardization Documents Order Desk, Bldg. 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094. Applications for copies of the DoD Directive 5230.24 should be addressed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402-0001.)

2.2 Order of Precedence. In the event of a conflict between the text of this specification and the reference cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 REQUIREMENTS

3.1 Optical Requirements.

3.1.1 Incident Optical Power. The Fast Steering Mirror (FSM) shall be capable of withstanding a peak incident laser flux of 750 millijoule/cm^2 pulse at a wavelength of 532 nm. The incident flux is in the form of a pulse train consisting of pulses of 1.0 nsec duration at a pulse repetition rate of 100 pulses per second. The average power is 25 watts in a $1cm^2$ beam centered on the mirror. The rest of the clear aperture is used for the receive beam.

3.1.2 Spectral coverage. The FSM mirror shall operate at the LADAR wavelength of 532 nm and in the PSS wavebands of 8 to 10 microns. The FSM is used at a nominal angle of incidence of 45^o.

3.1.3 Clear Aperture. The optical clear aperture shall be elliptical with major axis of 8.43 cm and minor axis of 5.98 cm. These dimensions do not include mirror oversizing for manufacturability. The FSM is to be used at a nominal 45 degree angle of incidence with respect to the plane containing the mirror normal and the major axis of the mirror ellipse.

3.1.4 Surface Figure. The FSM mirror shall have a surface figure of 0.025 waves rms at a wavelength of 532 nm. This surface figure applies under worst case operating conditions in the flight environment. The surface figure specification shall be maintained for at least 150 seconds at full power.

3.1.5 Reflectance. The reflectance of the FSM mirror shall be greater than 99% at 532 nm and greater than 98% (emissivity less than 0.02) at the PSS wavelength of 8 to 10 microns. The reflectance requirement applies to any polarization state.

3.1.6 Surface Roughness. The FSM mirror roughness shall be less than 30 Angstroms-rms.

3.1.7 Cleanability. The FSM optical surface shall be designed to be cleanable.

3.1.8 Coating Reliability Testing.

3.1.8.1 Abrasion Resistance. The mirror optical coating shall show no signs of deterioration such as streaks or scratches following Moderate Abrasion testing per MIL-C-48497 or the vendor's commercial equivalent test.

3.1.8.2 Adhesion. The mirror optical coating shall show no signs of coating removal following adhesion testing per MIL-C-48497 or the vendor's commercial equivalent test.

3.1.8.3 Temperature. The mirror optical coating shall show no signs of flaking, peeling, cracking, or blistering following temperature cycling in accordance with MIL-C-48497 or the vendor's commercial equivalent test.

3.1.8.4 Humidity. The mirror optical coating shall show no signs of flaking peeling, cracking, or blistering following the humidity test prescribed in MIL-C-48497 or the vendor's commercial equivalent test.

3.1.8.5 Lifetime. The mirror optical coating shall be designed to withstand storage and use in a typical laboratory environment (22^oC, 20-50% relative humidity) for a period exceeding 5 years.

3.1.9 Surface Quality. The mirror surface quality shall be 10-50 scratch-dig per MIL-O-13830 or the vendor's commercial equivalent inspection.

3.2 Pointing Agility Requirements.

3.2.1 Travel Range. The maximum range of accurate operation shall be greater than 3.5 degrees in each axis in mechanical coordinates.

3.2.2 Operational Modes. The FSM shall have three modes: electronically caged standby, base referenced pointing, and non-operating for storage and transportation.

3.2.3 Servo Performance. The FSM shall perform a 3.5 milliradian slew to settle within 10.5 microradians in less than 30 msec (10 msec desirable). Slew controller sampling frequency must be less than 1000 Hz.

3.2.4 Positioning Accuracy.

3.2.4.1 Linearity. The linearity shall be better than 0.2% of full scale (0.12 milliradian for 3.5^o full scale).

3.2.4.2 Positioning Accuracy. The position repeatability shall be < 1.0 microradian relative to the mirror frame.

3.2.4.3 Long Term Position Repeatability. The position repeatability over any 150 second operating period during which excursions over the full mirror travel range and over the operating temperature range occur shall be less than 10 microradian absolute after any combination of excursions.

3.2.4.4 Position Reporting Accuracy.

3.2.4.4.1 Resolution. The resolution of the position readout shall be better than 0.5 microradian.

3.2.4.4.2 Repeatability. The repeatability of the position readout shall be better than 0.5 microradian.

3.2.4.4.3 Linearity. The linearity of the position readout shall be better than 0.2% of full scale (0.12 milliradian for 3.5^{o} full scale).

3.2.4.5 Jitter and Stability. Residual jitter in the base referenced pointing mode shall be less than 400 nanoradian rms.

3.3 Electrical Requirements.

3.3.1 Supply Voltages. The FSM shall operate from a $\pm$ 15 to $\pm$ 24 VDC $\pm$ 5% power source with ripple less than 100 millivolts. The FSM servo electronics will also have available a "quiet supply" of $\pm$ 15 VDC, 3 watt, 5 mV ripple.

3.3.2 Power Consumption. Servo power consumption shall be less than 73 watts peak (includes 3 watts allocated to the "quiet supply").

3.3.3 Cable Length. The FSM shall be capable of meeting all specifications when the mirror assembly and the servo control electronics circuit card assembly are separated by up to two meters.

3.3.4 Analog Signals. Commands to the FSM servo controller and position monitor output shall be $\pm$ 10 V, 1.0 ma (max) analog.

3.3.5 Thermal Sensor Interface. Thermal sensors shall be 10 kohm (nominal) thermistors.

3.4 Thermal Requirements.

3.4.1 Mirror. The mirror operating temperature range shall be 23 ^{o}C $\pm$ 2 ^{o}C.

3.4.2 Position Sensor Demodulating Electronics. If mounted separately from the FSM assembly, the operating temperature range of the position sensor demodulating electronics shall be 23 ^{o}C $\pm$ 2 ^{o}C.

3.4.3 Thermistors. Precision thermistors shall be provided to sense critical temperatures of the FSM. For example, if a position sensor demodulator hybrid circuit is used in the design, then the temperature of the hybrid shall be sensed. This data will be used to correct the position versus voltage characteristics of the mirror in real time.

3.4.4 FSM Servo Electronics. FSM servo electronics operating temperature range shall be 0 ^{o}C to 50 ^{o}C.

3.4.5 Non-Operating Temperature Range. The non-operating temperature range shall be –10 ^{o}C to +70 ^{o}C.

3.5 Physical Constraints.

3.5.1 Size.

3.5.1.1 Steering Mirror Assembly. The beam steering mirror shall fit within an envelope 7.0" wide x 6.5" high x 3.5" deep.

3.5.1.2 Servo Electronics. The mirror servo electronics shall occupy no more than two electronics packages, each with a 3" x 5" footprint on the deck (ACS Module) and 5" high. That is, 150 cubic inches total split into two 75 cubic inch volumes.

3.5.2 Weight. There is no maximum weight requirement for the FSM.

3.6 Quality Requirements.

3.6.1 Environmental Test Program. The FSM assembly and the FSM electronics shall be subjected to an environmental test program to verify suitability of the hardware to perform satisfactorily under all DITP test conditions including flight test on a Black Brandt missile. The test program environment is specified in the *Environmental Requirements Document (ERD), NCST-D-DT004*. The FSM and the FSM electronics are regarded as components for the purpose of environmental testing. The non-operating temperature environmental extremes apply to both the FSM assembly and the electronics. However, the operating temperatures of the FSM assembly and the servo electronics are different from each other as described in section 3.4. All thermal testing shall be done under vacuum conditions.

3.6.2 Test Plan. Figure 3-1 defines the test sequence to be used for acceptance testing of the FSM. The test levels are provided in the *Environmental Requirements Document (ERD), NCST-D-DT004*. Figure 3-2 defines a typical thermal cycle. Vacuum tests shall be done at pressures below 10^{-5} torr. The FSM and the servo electronics will be subjected to the non-operating temperature range. The FSM shall be powered up over the entire range, but is not expected to meet performance requirements beyond the specified operational temperature range.

3.6.2.1 Linearity Testing. High precision linearity testing is to be used as the ultimate indicator of good FSM health. The test is to be performed at five discrete temperatures over the operating temperature range. The minimum acceptable measurement resolution shall be 0.04% of full scale (25 microradians for 3.5 degrees full scale). As shown in Figure 3-1, the linearity test shall be performed at the start and at the completion of acceptance testing.

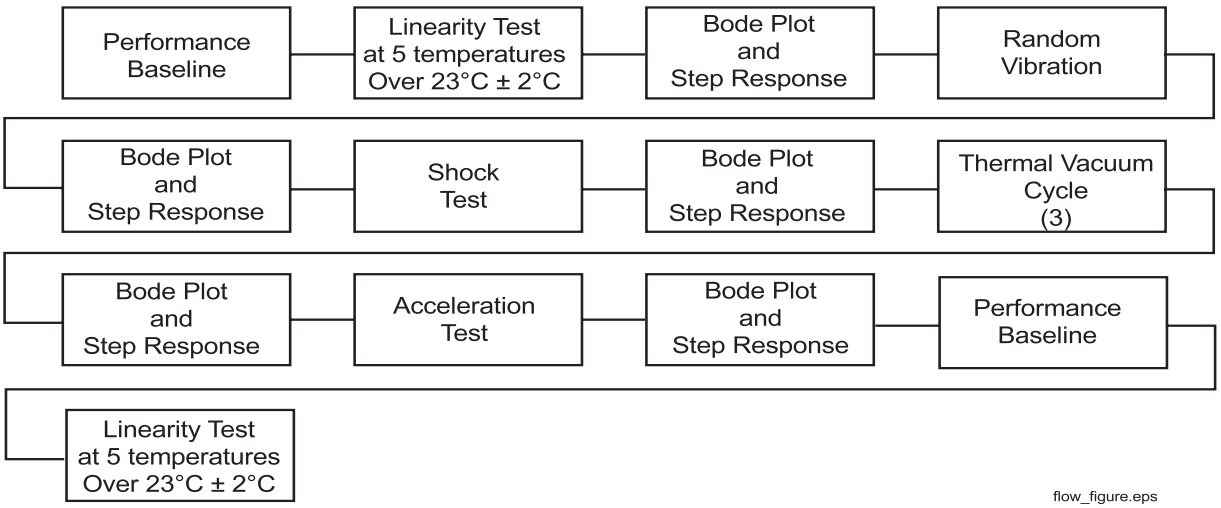

Figure 3-1. Test Sequence

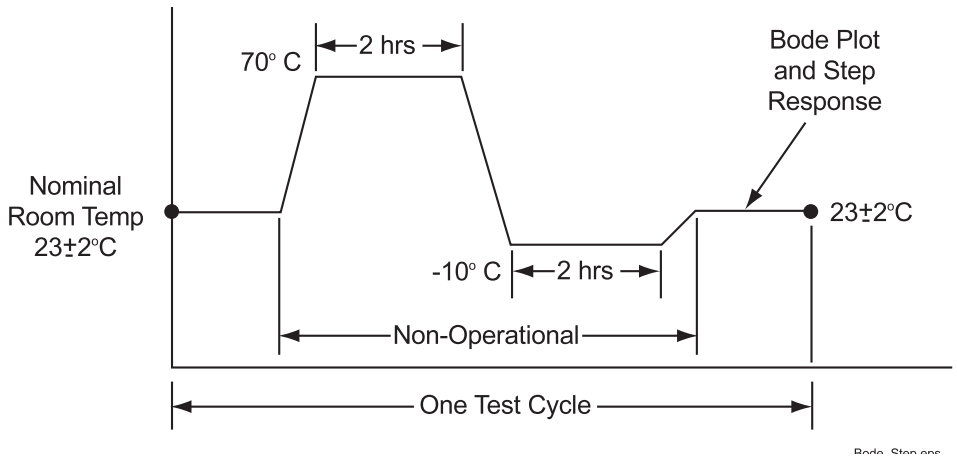

Figure 3-2. Thermal Vacuum Cycle

3.7 Design and Construction.

3.7.1 Parts, Materials, and Processes.

3.7.1.1 EEE Parts Program. A formal Electrical, Electronic, and Electromagnetic (EEE) parts program shall not be required.

3.7.1.2 Electrostatic Discharge (ESD) Sensitive Parts. All electrical components utilizing electrostatic discharge sensitive parts shall provide adequate protection to preclude part failure resulting from handling, shipment, or storage in accordance with the guidelines of MIL-STD-1686 (or equivalent).

3.7.1.3 Materials. Any materials that fail to meet the following criteria shall be identified to the NRL.

3.7.1.3.1 Prohibited Materials. The following materials shall not be used unless approved by the NRL:

- Teflon insulation subject to “cold-flow”
- Nylon
- Polycarbonates
- Polyvinyl Chloride (PVC)
- Silicone grease with zinc oxide filler
- Cadmium
- Zinc
- Non-fused tin-electroplated parts

3.7.1.3.2 Material Selection for Outgassing. Materials shall be selected for low out-gassing characteristics using only materials exhibiting a Total Mass Loss (TML) of 1.0% or less and Volatile Condensable Material (VCM) values of 0.1% or less per NASA Reference Publication 1124 (NRP-1124).

3.7.1.3.3 Report Silicone Use. All use of silicone shall be identified to the NRL.

3.7.1.3.4 Corrosion Resistance. Metallic materials shall be inherently corrosion resistant or shall be corrosion inhibited.

3.7.1.3.5 Galvanic Couples. Base metals intended for intermetallic contact and that form galvanic couples shall be plated with metals that reduce the potential difference of the couple or shall be suitably insulated by a non-conducting finish.

3.7.1.3.6 Magnesium Alloys. Magnesium alloys shall not be used for electrical bonding or grounding.

3.7.1.4 Protective Coatings and Finishes. Protective methods and materials for cleaning, surface treatment, and application of finishes and protective coatings shall conform to MIL-STD-7179 and MIL-HDBK-1568 (or equivalent).

3.8 Documentation.

3.8.1 Drawings. Drawings in vendor format shall be provided.

3.8.2 Hardware Test Plans. System and subsystem test plans shall be provided for hardware. These plans will identify what tests will be performed, the overall objectives of each test, and the chronological sequence of testing.

3.8.3 Hardware Test Procedures. Test procedures documented to the level that allows testing of the system by DITP engineers and scientists shall be provided for planned tests.

4.0 VERIFICATION REQUIREMENTS

4.1 Verification Cross Reference. Table 4-1 cross references verification methods to the appropriate specification requirements from Section 3.0. The supplier shall identify in a test plan the verification method to be used for each item in the checklist and shall use established supplier practices and procedures to document results.

The supplier shall perform the verification requirements called out by this specification for the steering mirror. NRL shall be invited to observe all tests. The supplier's quality assurance (QA) program shall provide control and assurance of quality within the supplier's organization. Specifically, the supplier's QA program shall ensure the adequacy of the product design and development, the effectiveness of procurement and receiving inspection procedures, and the quality level of manufacturing and assembly operations.

4.1.1 Verification by Analysis. Analysis shall be accomplished using analytical techniques in lieu of or to supplement test data to verify requirement compliance. Analytical techniques include but are not limited to modeling and simulation, statistical evaluation, reliability analysis, worst case analysis, radiation analysis, and systems engineering analysis.

4.1.2 Verification by Inspection. Inspection is a non-destructive verification method consisting of reviewing applicable documents, drawings, engineering data, specifications and/or assembly procedures or examination of hardware to determine quantitative and qualitative properties.

4.1.3 Verification by Demonstration. Demonstration is a verification method which involves a readily observable function or operation under actual or simulated use conditions to determine compliance with requirements. Demonstration shall consist of functional checks and tests to confirm compliance with requirements.

4.1.4 Verification by Test. Various types of testing are defined in the following paragraphs. Criteria and procedures for the monitoring of critical parameters during testing shall be developed.

a. Performance Test: This test sequence demonstrates and quantifies the specified electrical and mechanical performance parameters of the unit or system. These tests shall be made according to formal test procedures. A record shall be made of all data necessary to determine complete operational and performance characteristics.

b. Functional Test: This test sequence verifies the end-to-end operation of the unit or system without necessarily testing all of the internal functions. A functional test is performed by applying the proper power and signals to the input terminals and then verifying that the output is within nominal specification parameters. Functional tests shall be performed before, during, and after environmental exposures as part of the component and system test sequences. These tests shall be made according to formal test procedures. A record shall be made of all data necessary to determine complete operational and performance characteristics.

c. Component Test: This test sequence consists of the required formal tests conducted to demonstrate the acceptability of an item for delivery and flight. Component tests are intended to act as product assurance screens to detect latent deficiencies in workmanship, material, and quality.

d. System Test: This test sequence consists of the required formal tests conducted to demonstrate the acceptability of a system for delivery and flight.

Table 4-1. Verification Matrix

Section No.	Title	Not Applicable	Analysis	Inspection	Demonstration	Test	Responsible Organization
3.0	REQUIREMENTS						
3.1	Optical Requirements						
3.1.1	Incident Optical Power					X	Vendor
3.1.2	Spectral coverage	X					
3.1.3	Clear Aperture			X			Vendor
3.1.4	Surface Figure					X	Vendor
3.1.5	Reflectance					X	Vendor
3.1.6	Surface Roughness					X	Vendor
3.1.7	Cleanability					X	Vendor
3.1.8	Coating Reliability Testing						
3.1.8.1	Abrasion Resistance					X	Vendor
3.1.8.2	Adhesion					X	Vendor
3.1.8.3	Temperature					X	Vendor
3.1.8.4	Humidity					X	Vendor
3.1.8.5	Lifetime		X				Vendor
3.1.9	Surface Quality			X			Vendor
3.2	Pointing Agility Requirements						
3.2.1	Travel Range					X	Vendor
3.2.2	Operational Modes				X		Vendor
3.2.3	Servo Performance					X	Vendor
3.2.4	Positioning Accuracy						
3.2.4.1	Linearity					X	Vendor
3.2.4.2	Positioning Accuracy					X	Vendor
3.2.4.3	Long Term Position Repeatability					X	Vendor
3.2.4.4	Position Reporting Accuracy						
3.2.4.4.1	Resolution					X	Vendor
3.2.4.4.2	Repeatability					X	Vendor
3.2.4.4.3	Linearity					X	Vendor
3.2.4.5	Jitter and Stability					X	Vendor

Table 4-1. Verification Matrix (Continued)

Section No.	Title	Not Applicable	Analysis	Inspection	Demonstration	Test	Responsible Organization
3.3	Electrical Requirements						
3.3.1	Supply Voltages			X			Vendor
3.3.2	Power Consumption					X	Vendor
3.3.3	Cable Length					X	Vendor
3.3.4	Analog Signals			X			Vendor
3.3.5	Thermal Sensor Interface					X	Vendor
3.4	Thermal Requirements						
3.4.1	Mirror		X				Vendor
3.4.2	Position Sensor Demodulating Electronics		X				Vendor
3.4.3	Thermistors			X			Vendor
3.4.4	FSM Servo Electronics		X				Vendor
3.4.5	Non-Operating Temperature Range		X				Vendor
3.5	Physical Constraints						
3.5.1	Size						
3.5.1.1	Steering Mirror Assembly			X			Vendor
3.5.1.2	Servo Electronics			X			Vendor
3.5.2	Weight	X					
3.6	Quality Requirements						
3.6.1	Environmental Test Program	X					
3.6.2	Test Plan	X					
3.6.2.1	Linearity Testing	X					
3.7	Design and Construction						
3.7.1	Parts, Materials, and Processes						
3.7.1.1	EEE Parts Program	X					
3.7.1.2	Electrostatic Discharge (ESD) Sensitive Parts		X				Vendor
3.7.1.3	Materials			X			Vendor
3.7.1.3.1	Prohibited Materials			X			Vendor
3.7.1.3.2	Material Selection for Outgassing			X			Vendor
3.7.1.3.3	Report Silicone Use			X			Vendor

Table 4-1. Verification Matrix (Continued)

Section No.	Title	Not Applicable	Analysis	Inspection	Demonstration	Test	Responsible Organization
3.7.1.3.4	Corrosion Resistance			X			Vendor
3.7.1.3.5	Galvanic Couples			X			Vendor
3.7.1.3.6	Magnesium Alloys			X			Vendor
3.7.1.4	Protective Coatings and Finishes			X			Vendor
3.8	Documentation						
3.8.1	Drawings	X					
3.8.2	Hardware Test Plans	X					
3.8.3	Hardware Test Procedures	X					

5.0 ACRONYMS AND ABBREVIATIONS

Acronym	Definition
ASME	American Society of Mechanical Engineers
BMDO	Ballistic Missile Defense Organization
°C	Degrees Centigrade
cm^2	Square centimeters
DITP	Discriminating Interceptor Technology Program
DoDISS	Department of Defense Index of Specification and Standards
EEE	Electrical, Electronic, and Electromechanical
ESD	Electrostatic Discharge
ERD	Environmental Requirements Document
FOR	Field of Regard
FOV	Field of View
FSM	Fast Steering Mirror
Hz	Hertz
IEEE	Institute of Electrical and Electronic Engineers
IFOV	Instantaneous Field of View
in^2	Square inches
IPC	Institute of Interconnecting and Packaging Electronic Circuits
IR	Infrared
LADAR	Light Amplification for Detection and Ranging
NRL	Naval Research Laboratory
NRP	NASA Reference Publication
PSS	Passive Sensor Subsystem
rms	Root Mean Square
TML	Total Mass Loss
VCM	Volatile Condensable Material